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PROGRAM AND ABSTRACTS

Part Two:

Abstracts

79th Annual ESA Meeting

Science and Public Policy

Knoxville, Tennessee

7–11 August 1994

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ACKER, STEVEN A. Oregon State University, Corvallis, OR 97331. Long-term changes in wood volume growth and development of old-growth forest characteristics in maturing Douglas-fir stands in the Pacific Northwest.

Societal demands for conservation of biological diversity and extraction of wood products are forcing reexamination of forest management in the Pacific Northwest. Of particular interest are methods to speed the development of late-seral forest structure and enhance accumulation of wood volume in younger forest stands. To provide benchmarks from natural forests for these management objectives, I analyzed 18 permanent forest study plots established in young Douglas-fir stands (45-85 years old at establishment), and periodically measured for as long as 80 years. The plots are scattered through western Oregon and Washington. Volume growth rates declined gradually; similarity to old-growth structural characteristics increased rapidly at first and more slowly later. These natural stands displayed a variety of time trends in wood volume growth and development of old-growth features, presumably due to differences in inherent site characteristics and stand histories. The general patterns from these plots, and inherent site-to-site variation, will need to be taken into account to evaluate new approaches to forest management.

ADAMS, ELDRIDGE S. University of Rochester, Rochester, NY, 14627, USA. Territory size and shape in crowded populations: A new model tested with the fire ant Solenopsis invicta.

In crowded populations, interactions with neighbors are a key determinant of territory size and shape. A model of territory boundary formation is described in which each resident exerts pressure against its neighbors as a result of aggressive behaviors. Boundaries are formed along lines where the pressure applied by adjacent residents is equal. A computer algorithm is described which solves for boundary positions that satisfy this condition. The model has been tested for territories of the fire ant, Solenopsis invicta. Observed and predicted territories were significantly correlated in area and in shape (length/width ratio) over a wide range of sizes. The nests of many colonies were not at the geometric center of their territories. For these colonies, the model produced highly accurate predictions of the direction in which the nest was off center and weaker, but significant, predictions of the distance of deviation.

ADKISON, GREGORY P. University of Kentucky, Lexington, KY, 40506, USA. Forest herb community and population patterns along an environmental gradient in Kentucky, USA.

A gradient analysis of forest herbs in two watersheds in the mixed mesophytic forest of the Cumberland Plateau identified a dominant compositional gradient that was strongly correlated with moisture and topography. In addition density was positively related to moisture, and cover was related to density by a classic 'constant yield' function. From the broader community patterns I isolated a closely related group of species (genus *Viola*) that varied in their distribution across the gradient. Two of the species appeared to be specialists restricted to moist sites, and two other species were generalists occurring throughout the entire range of the gradient. Individual size of the generalist species either increased then leveled off or increased then slightly decreased with moisture. These community and population patterns suggest potential roles for both tolerance to dry conditions and competitive ability in moist sites in controlling the distribution of forest herbs in this system.

AGUIAR, MARTIN [12],WILLIAM K. LAUENROTH[1] and DEBRA P. COFFIN[1]. Colorado State University, Fort Collins CO 80521, USA; [2]University of Buenos Aires, Buenos Aires, Argentina. Experimental addition of water and nitrogen and competition between dominant grasses in the shortgrass steppe.

Bouteloua gracilis and *Buchloë dactyloides* are dominant and subdominant species, respectively, throughout a region which includes sites with large differences in water and nitrogen availability. We conducted a field experiment to evaluate the effects of water and nitrogen availabilities on intra- and interspecific competition. Our garden experiment included both species planted in an honeycomb design. Nitrogen addition increased (40%) plant biomass accumulation ($p = 0.07$) but did not interact with type of competition. Water incresed (52%) plant biomass accumulation ($p < 0.05$) and also interacted with type of competition. It increased the negative effect of both, intraspecific competition on *B.gracilis* and interspecific competition on *B. dactyloides* ($p < 0.05$). Our results agree with observations of the relative dominance of these species in the shortgrass steppe.

AKÇAKAYA, H. REŞİT, MICHAEL A. MCCARTHY and JENNIE L. PEARCE. Applied Biomathematics, Setauket, NY 11733-1345, USA, and University of Melbourne, Parkville, Victoria 3052, Australia. **Linking Landscape Data with Population Viability Analysis: Management Options for the Helmeted Honeyeater.**

A population viability analysis (PVA) model is developed to link spatial data on the habitat requirements of a species to a metapopulation model for extinction risk assessment, viability analysis, reserve design and wildlife management. The use of the model is demonstrated by an application to the spatial dynamics of the Helmeted Honeyeater (*Lichenostomus melanops*

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cassidix), an endangered species endemic to Victoria, Australia. Spatial data on the habitat requirements of the helmeted honeyeater is organized by a GIS, and a patch-recognition algorithm is used to define the structure of habitat patches where subpopulations may survive. The patch structure is then combined with demographic data to build a metapopulation model, incorporating a ceiling-type density dependence, stage structure within each of four populations, environmental and demographic stochasticity, spatial correlation and dispersal among patches, and catastrophes (fire). The PVA model is used to analyze the effectiveness of translocating individuals to a new habitat patch as a conservation strategy for the helmeted honeyeater, by estimating the risk of extinction under various translocation scenarios.

AKEY, WILLIAM C., ROBERT F. NORRIS, MARCEL REJMANEK and CLYDE L. ELMORE. Section of Plant Biology, University of California, Davis, CA 95616, USA. The impact of plant aggregation on interspecific competition.

Current models relating crop yield to weed density assume a regular or uniform spacing of plants. However, when weed distribution is patchy these models may overestimate yield losses. We examined the influence of spatial distribution of barnyardgrass (Echinochloa crus-galli) on interspecific competition with tomato (Lycopersicon esculentum) under field conditions. A factorial experiment with 19 different proportions and/or total densities of barnyardgrass and tomato, and three spatial arrangements of barnyardgrass was analyzed using the linear reciprocal yield model. Barnyardgrass plants were arranged regularly, randomly or in clumps. Tomato was planted in a regular pattern. The ratios of regression coefficients representing the intensity of interspecific and intraspecific competition in reciprocal yield equations for tomato were 1.64, 1.47, and 0.73, respectively, when barnyardgrass was planted in regular, random or clumped arrangements. At a commercial planting density, tomato yield losses ranged from 10 to 35% for the clumped arrangement and from 20 to 50% for the regular and random arrangements, for equivalent barnyardgrass densities. Our results confirm that competition experiments using uniform spacing of weeds may seriously overestimate crop yield losses compared to when weeds occur in clumps.

ALBAUGH, TIMOTHY J. and H. LEE ALLEN. North Carolina State University, Raleigh, NC. Nutrient and moisture availability impacts on leaf area production and growth of Pinus taeda L.

Our objective was to quantify the impact of moisture and nutrient availability on leaf area and biomass production of loblolly pine. Understanding these relationships will improve our ability to predict impacts of different climate scenarios on pine productivity. Loblolly pine were treated with a 2x2 factorial combination of moisture and nutrient regimes in four replications. Improved nutrition increased leaf area (100%) and biomass (60%) in the year after treatment. In the second year, nutrition increased leaf area and biomass production 60%. With improved moisture availability, additional leaf area and biomass production on the better nutrition sites was possible. Improved moisture availability alone had no impact on leaf area but increased biomass 20%. The apparent improvement in growth efficiency is due to timing of foliage and volume growth and naturally occurring moisture. Foliage production occurs in spring when moisture is available while volume growth occurs in summer when moisture may not be available in untreated plots.

ALDINGER, SUZANNE and C. SWIFT. Whittier College, Whittier, CA 90602. The photosynthesis-nitrogen relationship in sycamore, Platanus racemosa, a deciduous tree in Southern California.

Sycamores are a deciduous tree species restricted to drainages in Southern California. The trees loose their leaves prior to the wet season and flush new leaves toward the end of the wet season. The purpose of this study was to attempt to identify the effect of light availability on leaf carbon budgets. Net daily photosynthetic carbon gain and nitrogen content of leaves of different ages were monitored on sycamore individuals throughout the year. Older leaves did not experience reduced amounts of light and did not suffer lower net daily photosynthesis as a result. Nitrogen use efficiency was similar for different aged leaves. Light compensation points suggest that leaves are not able to maintain a net carbon gain in the winter when light availability decreases. This study suggests that the deciduous habit in California is an adaptation to lower light availability.

ALEMAYEHU, MAKONNEN, GOBENA HULUKA, P.K. BISWAS and DOUGLAS R. HILEMAN. Tuskegee University, Tuskegee, AL 36088, USA. Morphological and physiological responses of loblolly pine (*Pinus taeda* L.) seedlings to elevated carbon dioxide.

Seedlings of loblolly pine were planted in June 1993 in the ground in open-top chambers and exposed to three levels of carbon dioxide (0, 150 and 300 μmol mol^{-1} above ambient) in an experiment designed to last at least 2 years. Morphological measurements (plant height, stem diameter, number of branches and number of flushes) were made monthly, beginning at the time of planting. Gas exchange determinations were made monthly from July until November 1993 using the Li-Cor LI 6200 portable photosynthesis system. Stem diameter, plant height and the number of flushes were significantly greater at the highest CO_2 treatment starting in July, August and October, respectively. There was no consistent effect of CO_2 on the number of

branches. In the first month of gas exchange measurements (July), CO_2 enrichment had no significant effect on net photosynthetic rates, but led to decreased transpiration rates. In all succeeding months, net leaf photosynthetic rates increased with increasing CO_2, while transpiration rates were not affected. As of November, there is no evidence of a downward regulation of the CO_2 enrichment effect on photosynthesis.

ALLISON, TABER D., DAVID R. FOSTER, AND NATALIE DRAKE. Harvard Forest, P.O. Box 68, Petersham, MA, 01366, USA. Regional vegetation response to deforestation in central New England.

The post-settlement period of New England has been marked by deforestation, intensive farming, and natural reforestation. We used multivariate analysis of pollen percentage diagrams from several lakes in north-central Massachusetts to assess the impact of land-use history during this period on forest composition and rates of vegetation change at the sub-regional (single lake) and regional level (all lakes combined). Our analyses support the following hypotheses: 1) at the sub-regional level, forests during the height of land clearance are most dissimilar to presettlement forests. Modern forest composition has converged toward pre-settlement composition, but modern forests remain distinct. 2) Regional variation in modern forest composition has diminished because the past disturbance of massive deforestation has obscured the effect of regional environmental variation. Some differentiation in forest composition has persisted due to regional variation in intensity and type of land-use activity.

ALLEN, M. E., A. Y. DRUK, and E. I. FRIEDMANN. Florida State University, Tallahassee, FL., 32306, USA.
Cyanobacteria: Important Primary Producers in Extreme Arid Deserts.

Extreme arid regions of the Gobi desert, Mongolia, are covered by desert pavement (formed of many small stones on the surface of and half imbedded in soil). Hypolithic cyanobacteria (Chroococcidiopsis, Aphanocapsa, Nostoc, Scytonema, and Phormidium) colonize white (translucent) quartz stones of the desert pavement at the stone-soil interface, and in the most extreme arid regions, these cyanobacteria are the sole primary producers. Where more water is available, Iljinia regelii (Anthophyta: Chenopodiaceae) is also present. Cyanobacterial biomass is proportional to the abundance of white stones and ranges (on average) from 0.01 to 0.76 g dry organic matter/m^2. Where it is present, the average biomass of Iljinia regelii is 0.6 g dry organic matter/m^2 (Kazantseva, T. I. In: Deserts of Transaltai Gobi, Moscow, 1986) and thus comparable to cyanobacterial biomass. However, the two sources of biomass differ in distribution. A 1000m^2 area contains (on average) 13 Iljinia plants whereas the average number of colonized stones ranges from 15 x 10^3 to 240 x 10^3. Therefore, cyanobacterial biomass is distributed more evenly than that of Iljinia and has a much greater effect on soil formation and binding. It is likely that, in other deserts of the world with desert pavements, cyanobacteria play a similarly important ecological role.

ALLEN, READ, JACQUELINE HOCKETT, NICHOLAS LEE, BRUCE TRACEY, PHILIPPE PIERRE-LOUIS, and VIRGINIA M. CARD. Macalester College, St. Paul MN 55105. Winter limnology of Brownie Lake, a small meromictic lake in Minneapolis, Minnesota.

Brownie Lake is a small (7 ha) relatively deep (13m) eutrophic (secchi 3-8m) meromictic lake in the Minneapolis Chain of Lakes. The phytoplankton is dominated by diatoms as a result of iron limitation of blue-green algae (Swain 1986). Onset of meromixis has been dated to canal construction in 1914, which lowered the lake level and decreased the surface area to depth ratio of the already well-sheltered lake (Swain 1986). Monitering of the seasonal physical, chemical and biological limnology of Brownie Lake was begun in November 1993. Experimental manipulation of the lake revealed that the winter community is affected by light and nutrient availability, water movement and water temperature. The development of the spring diatom bloom began under the ice in late winter, triggered by increasing light levels. Autumn diatoms were mostly *Asterionella formosa*. Spring diatoms were mostly *Fragilaria crotonensis*.

ALLMON, WARREN D., PAUL J. MORRIS and MICHAEL L. McKINNEY. Paleontological Research Institution, Ithaca, NY, 14850, USA and Dept. of Geological Sciences and Graduate Program in Ecology, University of Tennessee, Knoxville, TN, 37996, USA. An intermediate disturbance model of maximal speciation: predictions and tests.

The common observation that species diversity is maximal when environmental disturbance is of intermediate intensity or frequency is usually explained by reference to theories of *maintenance* of diversity; e.g. , number of species in a community is high because disturbance is intense or frequent enough to suppress predators or dominant competitors but not so intense or frequent that many species cannot maintain viable populations. On an evolutionary timescale, the role of disturbance in affecting species diversity must be examined in the context of theories of *origin* of diversity, i.e., speciation. Allopatric speciation is necessarily divisible into three stages (isolate formation, isolate persistence, and isolate differentiation). Consideration of the interplay of these stages with environmental disturbance at ecological timescales suggests that moderate levels of disturbance would be expected to cause vicariance, i.e., isolate formation, while higher levels of disturbance would be expected to lead to decreased probability of persistence of these isolates. Thus maximal speciation, over evolutionary time, would be expected to occur at intermediate levels of environmental disturbance. Anecdotal evidence from both Recent communities and fossil sequences, as well as simple computer models, support this interpretation.

ALROY, JOHN. University of Chicago, Chicago, IL, 60637, USA. Long-term equilibrium in North American mammalian diversity.

The diversity of North American mammals in the Cenozoic (65 Ma - present) is studied using a database of 2300 taxonomically standardized faunal lists including 1100 genera. An objective time scale is defined using a multivariate ordination method that synthesizes the lists, stratigraphic data, and 100 absolute dates. Diversity curves are computed directly from the ordination. An extremely rapid diversification did occur immediately after the Cretaceous-Tertiary mass extinction event, but apparently low diversity levels in the middle Cenozoic result from undersampling rather than extinction. Although the raw Cenozoic diversity pattern is indistinguishable from a Markovian random walk, correcting for the number of lists and geographic units in each time interval produces a relatively stable curve with a mean of 110 genera. Less than 1% of 10,000 random walks based on the observed step-size distribution have so little variance. Further bootstrapping tests combining logistic and Markovian dynamics fail to reject the hypothesis that equilibrium diversity is constant through time. Other tests show that there are as few as two "pulsed" extinction events in the entire Cenozoic. These results conflict strongly with claims that continent-wide diversity has failed to reach equilbrium or that it is controlled by productivity, rainfall, seasonality, temperature, trophic diversity, and/or inter-continental migration rates, all of which change dramatically through the Cenozoic. Land area is one of the only relatively constant factors. Mammalian diversity may evidence a powerfully homeostatic system that is being dismantled by human activities.

ALSTAD, DON. University of Minnesota, St. Paul, MN 55108, USA. Within- and between-plant differentiation of scale insects and the conundrum of local adaptation.

Populations of black pineleaf scale insects, *Nuculaspis californica*, are spatially structured, with genetically differentiated subunits on adjacent host trees and different limbs within trees. This pattern in neutral genetic markers could result from drift, or from mating preferences that evolve in response to locally varying selection pressures and multiple-niche polymorphism. I will review the theoretical requirements and empirical evidence for both hypotheses to explain why I can no longer accept the adaptationist view that first attracted me to this system, 20 years ago.

ALWARD, RICHARD. Colorado State University. Fort Collins CO 80523 USA. *Bouteloua gracilis* growth rates and herbivory damage rates similarly influenced by edaphic and competitive environments.

I conducted field experiments to assess whether the competitive and edaphic conditions that modify blue grama (*Bouteloua gracilis*: Poaceae) responses to defoliation also affect the intensity of grasshopper herbivory on blue grama. I transplanted marked blue grama seedlings into plots on two topographic positions along a dune slope with or without blue grama or sand dropseed neighbors. Repeated measures analyses revealed significant treatment effects upon both seedling growth rates and both the rates and intensities of defoliation. Plants with neighbors grew slowly regardless of neighbor identity or topographic position. Plants without neighbors in the valley grew twice as fast as similar plants on the ridge. Plants without neighbors and plants in the valley had a greater number of leaves damaged but a smaller proportion of leaves damaged than did plants with neighbors or on the ridge. Thus, defoliation intensities were lightest under the same conditions that promoted rapid seedling growth. Blue grama seedlings in the valley may escape severe defoliation by rapidly growing through the most vulnerable stages.

ANAND, MADHUR, and LASZLO ORLOCI. Department of Plant Sciences, The University of Western Ontario, London, Canada. N6A 5B7. Is vegetation recovery an orderly, directional process? : test of a Markov model.

Is vegetation recovery an orderly, directional process? My objective is to answer this question based on time series data from permanent plots on abandoned agricultural land in the Carolinian Zone of southwestern Ontario. I reason that to show regularity, it is sufficient to show that some mathematical model fits the data, within the bounds of statistical acceptability. I determined the transition probabilities in the early phase of recovery dynamics and tested the significance of Markovity in random simulation. From the results I concluded that the stationary Markov chain is a realistic model for vegetation recovery on the study site.

ANDERSON, M. REBECCA, ERICA A. CORBETT, GAIL A. CORBETT, KARL J. ROBERTS, TIMOTHY M. KELLEY, AND ROGER C. ANDERSON. Illinois State University, Normal, IL, 62901, USA. Influence of white-tail deer (Odocoileus virginianus) browsing on prairie forbs in Illinois.

At Goose Lake Prairie State Park, Grundy County, IL, deer selectively browse prairie plants and display seasonal preferences in their browsing patterns. Selective browsing on forbs negatively effects the reproductive success of some of these species. In a deer exclosure and an adjacent control plot, there was no significant ($p<0.05$) difference in the number of stems of Amorpha canescens between the two areas (means $\pm$ SE = 3.1 ± 1.0 vs. $3.7\pm1.7/m^2$ for the exclosure and the control, respectively). The number of browsed stems was significantly greater in the control area than in the exclosure (2.1 ± 1.1 vs. $0.0/m^2$). Flowering stems were not encountered on the control plot. Flowering stems in the exclosure ($1.6\pm0.5/m^2$) represented slightly more than 50% of the stems. Similar effects on reproductive success of prairie forbs was seen for Baptisia leucantha and Phlox pilosa. Deer browsing may reduce the floristic diversity of prairies by reducing the competitive abilities of prairie forbs and limiting their reproductive success.

ANDERSON, ROGER C., BARBARA D. HETRICK, AND GAIL T. WILSON. Illinois State University, Normal, IL, 61790, and Kansas State University, Manhattan, KS, 66506, USA. Mycorrhizal dependence of Andropogon gerardii and Schizachyrium scoparium in two prairie soils.

Growth and mycorrhizal colonization of roots of Andropogon gerardii and Schizachyrium scoparium were compared in soil collected from Konza Prairie Research Natural Area (KPRNA), Riley County, KS and from Sand Ridge State Forest (SRSF), Mason County, IL. Plants of both species were grown in the two soils and were inoculated with Glomus etunicatum spores originally collected from KPRNA or colonized root pieces from S. scoparium plants collected from SRSF. Glomus etunicatum inoculum resulted in significantly ($p<0.05$) greater root colonization and biomass of both plant species in steamed KPRNA soil than did root piece inoculum. There was no benefit from inoculation in nonsterile soil which contained indigenous mycorrhizal fungi. In SRSF soil, there was no response to inoculation with mycorrhizal fungi from either source. The lack of mycorrhizal response in SRSF soil is attributed to the greater plant-available P level of this soil compared to the KPRNA soil (5 vs. 40 ug/g).

ANDREWS, ROBIN M. and BARBARA R. ROSE. Virginia Polytechnic Institute and State University, Blacksburg, VA 24061, USA and 37861 Glenmoor Drive, Fremont, CA 94536, USA. Evolution of viviparity: costs of egg retention for the lizard Sceloporus virgatus.

Extended egg retention is presumably an intermediate step in the evolution of viviparity in squamates. The presumptive selective benefit of extended egg retention is that embryonic development in utero is faster than embryonic development in nests. We tested this assumption by contrasting the embryonic development of S. virgatus eggs laid at the normal time and eggs retained for an additional 13, 20, and 30 d under conditions simulating thermal environments in utero and of nests. Embryonic development was retarded by egg retention; embryos from retained eggs were smaller and less differentiated than control eggs. Egg retention also lengthened the incubation period from 57 d for eggs laid at the normal time to 65, 66, and 71 d for eggs retained 13, 20, and 30 d, respectively. As a consequence, hatchlings from retained eggs would have less time to grow prior to winter than hatchlings from eggs laid at the normal time; possible costs of egg retention are reduced survival or delayed sexual maturation or both.

ANDREWS, SUSAN S., CAROL A. HOFFMAN, and C. RONALD CARROLL. University of Georgia, Athens, GA, 30602, USA. The effects of wild and cultivated cucurbit root extracts on soil bacteria.

Through laboratory and field experiments we assessed the growth effects of root extracts from domesticated Cucurbita maxima and wild C. andreana on two soil microorganisms: a generalist, Pseudomonas fluorescens and a specialist pathogen, P. lachrymans. Objectives were to determine the effects of cucurbitacin B on the two bacteria and to detect extract differences between the wild type squash and the cultivated squash. Field experiments added cropping and fertilizer treatments. Roots were harvested, extracted in water, and filter sterilized. Concentrated cucurbitacin B was also assayed. Bacterial growth was estimated in inoculated extract subsamples using a Milton Roy Spectrophotometer 301. Total carbon and nitrogen and cucurbitacin B levels were quantified by combustion gas chromatography and thin layer chromatography or HPLC. Results using concentrated cucurbitacin B strongly indicate growth stimulation of both microorganisms. Differences in bacterial growth between plant species, cropping strategies, and fertilizers types were also observed.

ARMENTANO, TOM. Everglades National Park, Homestead, FL 33034, USA. Ecological aspects of conservation constraints in the Everglades region.

The everglades region of south Florida is subject too managed and unmanaged human influences of many kinds. Large scale, landscape-level conservation and restoration plans are underway despite limited testing of ecologically based concepts needed to develop scientifically based plans. Current scientific understanding indicates that a number of ecological and landscape features constrain the application of ecological concepts developed for the applied to temperate regions: a subtropical, savanna climate, low elevation and coastal location with a unique substrate, oligotrophy, the particular spatial distribution of ecosystems and spatial boundaries, and biogeography (in relation to southeastern United States and Caribbean regions). To be effective, conservation actions like prescribed fire programs, hydrological restoration, and exotic species control must recognize conservation constraints and develop ecological concepts specific to subtropical ecosystems.

ARNONE, J. A. III, J. G. ZALLER, C. KORNER, C. ZIEGLER, and H. ZANDT. Depts. of Botany & Zoology, University of Basel, CH-4056 Basel, Switzerland. Insect herbivory in model tropical plant communities after 1.5 years exposure to elevated CO_2

Insect herbivores have been observed to practice compensatory feeding when provided leaves from plants grown under elevated atmospheric CO_2. This has been attributed to reductions in leaf quality (e.g. increased C:N ratio) occurring at high CO_2. However, no data are available on feeding patterns in plant communities exposed to high CO_2, where insects can choose among species and canopy layers. We introduced 100 Spodoptera eridania larvae to each of four identically-planted communities of moist tropical species (80 plants,

7 spp.) after 1.5 years exposure to either ambient (340 $\mu l\ l^{-1}$) or elevated (610 $\mu l\ l^{-1}$) CO_2. Species representing contrasting life forms were installed in 6.7 m^2 closed ecosystems, each with a common soil. Larvae actively fed in all communities, but the total amount of leaf area and leaf biomass consumed was similar at both CO_2 levels. Elevated CO_2 did alter herbivore plant-species preference. For example, 62.8% of the total leaf area consumed was represented by Cecropia peltata in communities exposed to ambient CO_2, versus 44.1% under elevated CO_2. Our results indicate that compensatory feeding may not occur in natural plant communities in a CO_2-rich world.

ARNOTT, DIANE L. and MICHAEL J. VANNI. Miami University, Oxford, OH, 45056, USA. Nutrient excretion by the zebra mussel, Dreissena polymorpha, and possible effects on the Lake Erie food web.

The zebra mussel, Dreissena polymorpha, invaded the Laurentian Great Lakes in the 1980's and the population has exploded. Our research has focused on the ecological impact of the zebra mussel in the western basin of Lake Erie via nutrient cycling. In the summer of 1993 we measured mussel excretion in order to determine if there was an effect of season or mussel size on N, P and N:P excretion rates. We found no size or month effect on N excretion rate. Mussel size and month had a significant ($P<.05$) effect on P excretion rate, with small mussels (<12mm) excreting P at a higher rate per gram body weight than medium (12-18mm) or large (>18mm) mussels. P excretion in June was significantly lower than P excretion in July, August, and September. We also found a significant ($P<.05$) effect of mussel size on the N:P excretion ratio; small mussels excrete at a lower N:P than medium or large mussels. Overall, zebra mussels excrete at a low N:P ratio; this may result in lake conditions favoring blue-green algae. Such a change in algal species composition may have diverse food web effects, resulting in reduced energy flow to pelagic species and reduced sport fish populations.

ASCANIO, RHODA M. and MARY V. PRICE. University of California, Riverside, CA, 92521, USA. Habitat utilization in Dipodomys stephensi and D. agilis ; implications for interspecific competition.

In western Riverside county CA., the federally endangered heteromyid rodent, Dipodomys stephensi, is largely confined to grassland, while the non-threatened Dipodomys agilis is common in adjacent coastal sage scrub. Although congeneric heteromyid rodents of similar size generally utilize distinct habitats, our results illustrate that these species utilized both habitats foraging for seed. Stable populations of both species existed at all 3 sites studied, and individuals of both species were regularly captured at the same location. Radio tracking data also supported this observed overlap in habitat use on a daily basis. Removal and behavioral studies indicated both species were opportunistic in searching for and acquiring seeds. We conclude that these two species have a high probability of encountering one another on a regular basis, and are likely to influence the habitat affinity of each other. Therefore, since individuals of these species can occupy the same space, and forage for the same seeds, they are likely competitors.

ASHER, JERRY, E., Bureau of Land Management, Portland, OR, 97208, USA. **Alien plant invasions: Increasing impacts to the integrity of rangeland ecosystem health.**

The objectives of this paper are to raise the awareness level about the proliferation and impacts of noxious weeds on western rangelands and to recommend solutions, including research. Far more than anything else, biodiversity and ecosystem health depend on well functioning native plant communities. The single greatest threat to these native communities, and to the restoration of less than healthy communities, is the rapid expansion of noxious weeds. On BLM lands alone, noxious weeds exist on approximately 7,000,000 acres of both disturbed and relatively undisturbed areas, and this infestation is spreading at approximatley 2300 acres per day - an "explosion in slow motion". Similar conditions exist on other rangelands. Consultations with all western university weed science departments and many other weed experts show that there is uniform agreement about the exponential weed spread. Increased "Integrated Weed Management" is needed including substantial research to determine life cycle requirements of the most serious weeds.

AUERBACH, MICHAEL, EDWARD F. CONNOR, and SUSAN MOPPER. University of North Dakota, Grand Forks, ND 58202, USA, University of Virginia, Charlottesville, VA 22903, USA, and University of Southwestern Louisiana, Lafayette, LA 70504, USA. Population dynamics of latent and irruptive leaf miners.

Insects with leaf-mining larvae occur in four orders and attack a wide variety of herbaceous and woody plants. While most species appear latent, always occurring at low densities and causing little damage to host plants, some species are irruptive with densities varying greatly between generations or among populations. For those irruptive species who have received considerable study, variation in timing of spring leaf production or autumn leaf fall appear to be major sources of unpredictable mortality. When budburst of *Populus* is synchronized with emergence of *Phyllonorycter* adults, or when a large fraction of the last larval cohort complete development in *Cameraria* on *Quercus* and *Phyllonorycter* on *Malus*, survival is high and population densities can increase radically over one generation. Population declines appear to arise largely because of phenological asynchrony between insect and host plant, and because of mortality from intraspecific competition. While avian predators have a density-dependent impact on irruptive *Phyllonorycter* on *Betula* in Scandinavia, the impact of parasitoids on irruptive leaf miners, both spatially and temporally, is density-independent or inversely density-dependent.

AUSTIN, KELLY A. Weyerhaeuser Company, Tacoma, WA, 98477. Vegetation inventories on managed forests in western Washington.

Base-line inventories of vegetation and wildlife are important for resource managers on private forests of the Pacific Northwest to develop strategies for ecosystem management. Composition, abundance, and structure of understory vegetation including density, size, and decomposition stage of downed woody debris and snags associated with upland managed stands were inventoried in two Weyerhaeuser tree farms (Snoqualmie, White River) located in the western Cascades, western Washington. The survey areas were stratified according to a survey matrix composed of elevation (0-16,500 m), age class (1- 400 years), regeneration history (e.g., natural regeneration or planted), and aspect. Forest stands were surveyed over the entire range of available combinations during summer of 1993. Preliminary results indicate that over 170 species in Snoqualmie and 245 species in White River were inventoried, including trees, shrubs, forbs, ferns, graminoids, mosses, liverworts, and lichens. Log density ranged from 0-38 / ha (mean 14 / ha) and snag density ranged from 0-17 / ha (mean 4 / ha). Further inventories will focus on uplands as well as wetlands and riparian areas. This information from managed stands will be used with samples from comparable non-managed forests to identify and interpret effects of initial stand conditions, site environment, management history, and stand age on forest composition, structure and plant species diversity.

AXT, JOSEPHINE R. and MARK R. WALBRIDGE. George Mason University, Fairfax, VA, 22030, USA.
Phosphorus removal capacity of forested wetland soils in Virginia's Piedmont and Coastal Plain regions.

We examined the ability of soils in six non-tidal palustrine forested wetlands, evenly divided between Virginia's Piedmont and Coastal Plain, to remove phosphorus (P) from surface and groundwater. The effect of landscape position on P sorption capacity was compared by sampling adjacent streambank and upland soils. Wetland soils had significantly higher P sorption capacities than both streambank and upland soils, which were not significantly different from each other. In all landscape positions, initial trends indicate that P sorption at the surface (0-15 cm) is less than subsurface P sorption (15-100 cm). Changes in P sorption capacity within and among sites are addressed by comparing relevant soil characteristics, such as oxalate-extractable Al and Fe, exchangeable Ca, organic matter content and soil texture. As Virginia strives to reduce the amount of nonpoint source P entering the Chesapeake Bay while continuing to encourage a developing business climate, the apparent ability of wetland soils to improve water quality by removing more P than contiguous streambank and upland soils may play an important part in longterm wetland conservation.

AYAL YORAM. Mitrani Center for Desert Ecology, Blaustein Institute for Desert research, Ben-Gurion University of the Negev, Midreshet Ben-Gurion, Israel 84993. **WHAT FORMS A PATCH FOR A FORAGER: AN EXAMPLE FROM INSECT PARASITOIDS**

The patch is a central concept in optimal foraging theory (OFT) but patches are rarely defined explicitly. OFT includes two aspects about how a forager relates to a patch; *evaluation* takes place as the forager enters a patch and decides whether to stay or leave, and a *foraging 'rule'* determines how long the forager will stay in the patch once it decides to stay in the patch. Most parasitoids are attracted to their hosts' food-plant whether or not it is infested. They then inspect the plant for host cues, i.e. kairomones, as a cue for patch evaluation; the amount of kairomones in a patch determines whether they will leave or stay (e.g. Waage 1978,1979, Ayal 1987). Using the world wide system of the cabbage aphid *Brevicoryne brassicae* and its parasitic wasp *Diaeretiella rapae* I will show how kairomones are also used for setting the foraging rule i.e. they determine how many hosts a parasitoid infects in each aggregation within the plant and on the plant as a whole. I will also show that evaluation takes place of the entire food-plant of the aphid, the wild mustard *Sinapis alba* . I will than argue that for most predatory insects and parasitoids of herbivorous insects, their victim's food-plant forms a patch. When the rate of parasitism is examined on the plant scale, density dependence of parasitism is often found.

BABBITT, KIMBERLY J. and FRANK JORDAN. University of Florida, Gainesville, FL, 32611, USA.
Effects of habitat drying, density, and food on metamorphosis in southern leopard frogs, Rana sphenocephala

Tadpoles living in ephemeral environments are expected to show phenotypic plasticity in developmental rate. We examined the effects of drying (constant vs. 16 week drying), tadpole density (4 vs. 8), and per capita food levels (0.15x vs. 0.075x weight) on metamorphosis in southern leopard frogs in a 2x2x2 factorial randomized block design with 6 replicates. Tadpoles on the high food treatment metamorphosed earlier, weighed more, and had longer SVLs than those on low food. Tadpoles on the drying treatment were smaller, weighed less, and metamorphosed earlier than those on the constant treatment. Drying did not effect age at metamorphosis of tadpoles fed high food, but tadpoles fed low food metamorphosed earlier on the drying treatment. Density had no significant effects. These results suggest that tadpoles can accelerate development in drying conditions, even when drying is gradual.

BAILEY, BARBARA A. North Carolina State University, Raleigh, NC 27695, USA. Local Lyapunov Exponents: Predictability depends on where you are.

The dominant Lyapunov exponent of a dynamical system measures the average rate at which nearby trajectories of a system diverge. Even though a positive exponent provides evidence for

chaotic dynamics and unpredictability, there may be predictability of the time series over some finite time periods. We will present an application using yearly average global temperature data simulated from a general circulation model of the earth. A feed forward neural network is used to estimate the nonlinear autoregressive process and calculate the Lyapunov exponents. The dominant exponent (in units of inverse years) is found to be 0.2 > 0, showing the system to be chaotic. The examination of finite time or local Lyapunov exponents indicates there to be both negative and positive exponents showing there to be places in the time series that may be more predictable than others over a 5 year ahead prediction period. An examination of the fluctuations of the local Lyapunov exponents about the average exponent may provide important information in understanding complex biological systems.

BAILEY, ROBERT C. Department of Zoology, The University of Western Ontario, London, ONT., CANADA. N6A 5B7. Multi-scale habitat and community structure of artificial substrates in a Yukon stream: predicting a brick's future.

Multiple, short-term colonization experiments were carried out to test whether small spatial (cms), medium spatial (meters), or short temporal (days) scale variation in habitat structure could best predict the structure of colonizing macroinvertebrate communities on bricks in a stream. In a 60m stretch of a small (width 4-5m, summer discharge 500L/s) stream near Whitehorse, Yukon, I deployed 20 bricks (4*10*20cm) for 43 days. The bricks were distributed as 10 pairs at locations in the stream with variable depth (e.g. Day 2: 11-35cm) and current velocity (e.g. Day 2: 0 to 85cm/s). Over the experimental period, nine measurements of depth and current velocity were made directly beside the upstream edge of each brick. I made three harvests of macroinvertebrates (Days 8, 22, and 42), immediately replacing bricks at the same points following harvest. Preliminary results showed that medium spatial scale (i.e. among-pairs) habitat structure best predicted the ultimate macroinvertebrate community structure on the bricks.

BAKER-BROSH, KATHLEEN, ROBERT K. PEET, and PETER S. WHITE, University of North Carolina, Chapel Hill, NC 27599-3280 USA. Selection for heterozygosity during stand development in *Pinus taeda*.

Intraspecific competition induces density-dependent mortality in loblolly pine (*Pinus taeda*) during the thinning stage of forest stand development. We hypothesize that differences in heterozygosity partially account for differences in growth rates of seedlings experiencing intense competition. We established experimental loblolly seedling plots to determine whether seedling growth rates are correlated with heterozygosity. We found a significant correlation between number of heterozygous loci and early growth rate in dense stands of seedlings. Variance in height was significantly greater in the dense plots than in sparse plots. These findings suggest that heterozygosity contributes to competitive success and is consequently selected for during the thinning phase of stand development.

BAKER, STEVEN C., ELOISE B. CARTER, HOMER F. SHARP, JR. AND THEODOSIA R. WADE. Oxford College of Emory University, Oxford, GA 30267, USA. Improvement of ecology education by sharing knowledge and field experiences with K-12 teachers.

The Oxford Institute for Environmental Education was developed to introduce the fundamental concepts necessary to understand ecological systems and to provide field and laboratory experiences for K-12 teachers. The two week program includes an introduction to ecology and the investigation of terrestrial and aquatic ecosystems using appropriate sampling techniques. Participants prepare a reference collection of aquatic invertebrates and common woody plants and evaluate their schoolyard for development and use as an outdoor classroom. The development of K-12 activities was not our strength but rather we have relied on our knowledge and experience in teaching and research to improve ecology education.

BALDWIN, ANDREW H., WILLIAM J. PLATT, KARI L. GATHEN, JEANNINE M. LESSMANN, and THOMAS J. RAUCH. Louisiana State University, Baton Rouge, LA, 70809, USA. Hurricane damage and regeneration in mangrove forests of southeast Florida USA.

In March 1993 hurricane damage was surveyed at two sites in lower intertidal regions of mangrove forests along Biscayne Bay, FL that were hit by Hurricane Andrew 24 August 1992. The three species of mangroves present, Avicennia germinans, Laguncularia racemosa, and Rhizophora mangle, were found to differ in their susceptibility to hurricane-related damage and mortality and in their mechanisms of regeneration following the hurricane. Higher mortality was observed in R. mangle (85.1%) than in A. germinans (65.0%) or L. racemosa (59.5%). However, R. mangle sustained proportionally less severe structural damage than A. germinans and L. racemosa. Reestablishment of R. mangle is occurring primarily from seedlings present at the time of the hurricane, while A. germinans and L. racemosa are resprouting epicormically. Similar patterns of regeneration also appear to have occurred at two sites surveyed on Key Largo and in Everglades National Park impacted by Hurricane Betsy in 1965.

BALL, J. TIMOTHY[1,2] JOHN B. PICONE[1] PETER D. ROSS[1] GREGORY N. ROSS[1] DALE W. JOHNSON[1,3]. [1] Biological Sciences Center, Desert Research Institute, Reno NV 89506 USA [2] Department of Biochemistry and [3] Department of Environmental and Resource Sciences University of Nevada, Reno, Reno, Nevada USA. Insights on carbon budgets for Ponderosa pine systems growing at three levels of CO2 and of nitrogen from leaf to whole open-top chamber flux measurements.

At any scale of integration carbon accumulation in the biosphere is a small difference between large input and output terms and is proportional to resource levels. This can result in the impression that growth and carbon accumulation have little to do with either the input or output rates. Our measurements show that rising concentrations of CO_2 in the atmosphere results in biospheric influx and efflux of carbon increasing and the proportionality between carbon left and nitrogen in the system changing. A gap exists between the carbon balance inferred from gas-exchange and measured changes in pool sizes. The rhizosphere is the likely harbor for much of this "missing carbon." These measurements were made on ponderosa pine saplings growing near Placerville, California USA. The chambers are set at ambient, 525 ppm, 700 ppm CO_2. Soil nitrogen levels are at the background level, plus 10 g/m^{-2} or plus 20 g/m^{-2} .

BARBOSA, PEDRO and PAUL GROSS. University of Maryland, College Park, MD, 20742, USA. Patterns of Parasitism Among Arboreal Lepidoptera Species: Vast Discrepancies in Close Proximity.

Lepidoptera larvae on Salix nigra and Acer negundo were collected from each of four sites in Maryland from 1991 to 1993. Larvae were reared in the laboratory to determine the composition of the parasitoid community attacking co-occurring externally feeding caterpillars. The study resulted in the collection of over 40 species of Lepidoptera and their parasitoids. Patterns of parasitoid abundance and diversity are discussed in relation to current concepts including hypotheses on enemy free space and apparent competition. Results suggest several patterns that are counterintuitive to current thinking. For example, levels of parasitism were generally low and there was little sharing of parasitoids by co-occurring herbivore species on the same tree.

BARDEN, LAWRENCE S. Univ. North Carolina at Charlotte, Charlotte, NC, 28223, USA. Recovery of Schweinitz's sunflower *Helianthus schweinitzii*, a federally-listed endangered species, after early- and mid-growing season controlled burns in piedmont North Carolina.

Recently, controlled burning during the growing season to kill woody competitors of perennial herbaceous plants has received increased emphasis despite the immediate damage to endangered herbaceous species. A controlled burn in North Carolina in early April 1993 top-killed newly sprouted (2-5 cm) Schweinitz's sunflower. In October 1993 average height was reduced 44% compared to 1992, but the number of stems per plant increased 200%, with an average of 27 flower heads per plant. In contrast, a controlled burn in mid-growing season (August 1992) top-killed nearly mature plants (avg height 72 cm) which resprouted but reached only 10 cm height by October, with none flowering. One year later (October 1993) survival was less than 80%, survivors were only 40% as tall as pre-fire plants, there was no increase in the number of stems, and only 30% of plants produced flowers. Negative effects of mid-growing season burns may be temporary but should be considered by managers of endangered species.

BARKASCI, MARY-JO K., ERICA HWANG, RESHMA C. KATIRA, LEMUEL NEWTON, ENRIQUE POMALES-CRESPO, and YOUNG D. CHOI. Bionetics Corp., Kennedy Space Center, FL 32899, Florida A&M Univ./SLSTP, Tallahassee, FL 32307, and Purdue Univ. Calumet, Hammond, IN 46323, USA. Analysis of Florida scrub jay habitat after a prescribed fire at the Kennedy Space Center.

Oak (*Quercus* spp.)-dominated scrub vegetation is habitat for Florida scrub jay (*Aphelocoma coerulescens coerulescens*), a threatened species as listed by the federal Endangered Species Act. In 1993 summer, we investigated the suitability of an oak-saw palmetto (*Serenoa repens*) habitat that was burned in 1992 located at the Kennedy Space Center. The DCA (Detrended Correspondence Analysis) segregated our 40 sample plots into four groups: Type A (45% oak cover, 15% open space, 9% pine canopy, 237m from forest, and 114cm shrub height), Type B (28%, 8%, 6%, 315m, and 70cm), Type C (15%, 2%, 5%, 309m, and 81cm), and Type D (8%, 27%, 5% 341m, and 122cm). According to our Habitat Suitability Index (HSI), Type A (HSI 0.85) was most suitable followed by Types B (0.37), C (0.24), and D (0) as such habitat.

BARNES, PAUL W., STEPHAN D. FLINT and MARTYN M. CALDWELL. Southwest Texas State University, San Marcos, TX, 78666, USA and Utah State University, Logan, UT, 84322, USA. Early-season effects of solar UV-B enhancement on plant canopy structure, simulated photosynthesis and competition.

Mixed-species stands of wheat (Triticum aestivum) and wild oat (Avena fatua) were exposed to enhanced solar UV-B radiation simulating a 20% reduction in column ozone to assess the timing and seasonal development of the UV-B-induced alterations in competitive balance between these species. Results from

two years of field studies revealed that UV-B enhancement did not significantly affect the magnitude or timing of seedling emergence or the combined-species LAI of 4-week old mixtures (near 2 for both years). The UV-B did, however, significantly increase (5-9%) the relative proportion of the mixture LAI contributed by wheat which then resulted in a 6-8% increase in its calculated relative light interception and canopy carbon gain. These findings, and others, indicate that the effects of enhanced UV-B on competitive balance are realized very early during canopy development and suggest that UV-B-induced alterations in seedling growth may have persistent and significant consequences for light competition later in the growing season.

BARRETT, GARY W., SUSAN R. BREWER, and MARY BENINGER-TRUAX. Miami University, Oxford, OH , 45056, USA.
Biological and chemical mechanisms of ecosystem recovery following long-term nutrient enrichment: a case study in restoration ecology.

This study was conducted at the Miami University Ecology Research Center, Oxford, Butler County, Ohio, USA. Biological and chemical (seed bank disturbance and/or liming) mechanisms of old-field ecosystem restoration were examined during 1991 - 1993 following eleven years (1978-1988) of nutrient enrichment (commercial fertilizer or sewage sludge). Plant species richness and composition of the old fields differed significantly between nutrient-enriched and control plots, as well as between former fertilizer and sludge treatments during the initial years of restoration, attributed to contrasting types of nutrients applied and to species life history response to treatment differences. Former fertilizer- and sludge-treated plots, dominated by summer annuals during 1991 and 1992, were dominated by perennials during 1993, indicating that the composition and trajectory of secondary succession now approached structural values observed in control plots. Annual net primary productivity also decreased in former nutrient-enriched plots to control levels by the fifth year of restoration. Long-term enrichment appeared to affect old-field structure and function more than short-term liming and/or tilling manipulations. Results suggest that it is possible to restore old-field communities to control levels during the fifth year following restoration practices.

BART, HENRY L., JR. Tulane University Museum of Natural History, Belle Chasse, LA 70037, USA. Influence of local habitat complexity and basin/province-scale species richness on local stream fish diversity in the southeastern United States

Data on fish diversity (richness and heterogeneity) and habitat complexity were gathered for 41 sites on small streams representing upland and lowland physiographic provinces in 13 southeastern drainage basins. Fish species richness at the scale of provinces within drainages was estimated from literature sources. Data on local fish diversity were regressed on data for local habitat heterogeneity and basin/province-scale species richness to determine which of these latter two factors was the most important predictor of local fish diversity. In lowland streams, the only significant influence of local species richness was richness at the basin/province level. Relationships between local fish diversity and local habitat complexity were weak and nonsignificant. In upland streams, local species richness was strongly related to richness at the basin/province scale, but species heterogeneity was strongly dependent on substrate complexity. The results suggest that species richness at the basin/province level is a more important than local habitat conditions as a determinant of local species richness, whereas, local habitat conditions are important determinants of local species abundance relationships. The differences noted between physiographic provinces may reflect greater environmental disturbance in lowland streams as compared to upland streams.

BARTHELL, JOHN F.*, JOHN M. RANDALL*, ROBBIN W. THORP*, and ADRIAN M. WENNER**. *University of California, Davis, CA 95616, USA and **University of California, Santa Barbara, CA 93106, USA. **Invader-assisted invasion: pollination of yellow star-thistle by feral honey bees in island and mainland ecosystems.**

Mutualistic invasion by two or more introduced species is a relatively unexplored phenomenon. The relationship between flowering weed species and introduced pollinators in western North America represents an ideal venue for studying this invasion mechanism. By manipulating pollinator densities at flowers of the introduced weed yellow star-thistle (Centaurea solstitialis), we estimated the percent seed set feral honey bees (Apis mellifera) contribute to star-thistle populations in each of two ecosystems: Santa Cruz Island and the Central Valley of California. This was accomplished with nylon bags of varying mesh sizes that excluded different pollinator groups. In both study locales, honey bee foraging produced significantly greater numbers of viable seeds per flower head than when their foraging was excluded. This effect was more pronounced on the mainland where, overall, approximately 50% seed set resulted from honey bees. Historically, then, the invasion of yellow star-thistle into western North America was probably assisted by feral honey bee populations, particularly in regions where native bee densities were low.

BARTON, ANDREW M. and SCOTT K. GLEESON. University of Kentucky, Lexington, KY, 40506, USA.
Physiological responses of tree seedlings across a moisture gradient in eastern Kentucky.

We measured net photosynthesis (A), leaf conductance (g), and leaf water potential (LWP) of seedlings of five oak species and red maple across a topographic gradient on the Cumberland Plateau. Although soil moisture (and temperature) declined from north to south aspects, soil moisture never reached very low levels, and physiology was generally not correlated with topography or sampling date. In fact, most of the variation in response was due to diurnal patterns. For all species, LWP, g, and A were high in the morning, but declined until about 1500 hrs, probably because of transpirational loss. From 1500-1900, LWP rebounded, but A and g continued to decrease. Species varied in their overall and diurnal pattern. Compared to the oaks, red maple exhibited very low A and g and very high LWP. Red oak, the most mesophytic oak species, also exhibited "conservative" physiological responses compared to the other oaks. In contrast to the other species, in red oak and red maple, A increased over the day on mesic sites but decreased on xeric sites.

BASINGER, MARK A. and BETH A. MIDDLETON. Southern IL University, Carbondale, IL 62901, USA. Plant species distribution and environment in baldcypress wetlands in the Cache River region in southern IL.

The floristic structure of permanently flooded cypress swamps differed from that of seasonally wet/dry swamps in the Cache River region. The environment of these two swamp types is related to water chemistry factors. Plant species richness was calculated by recording species encountered along a 300-meter line transect and canopy coverage in two random 50.3 meter circular plots along each transect. Four random transects were studied at each site. At each site, 10 water chemistry factors were tested. Agglomerative cluster analysis was used to determine structure of the sites based on species presence and canopy coverage data. Stepwise discriminant analysis was used to correlate water chemistry factors with community structure derived in the cluster analyses. From a total of 254 taxa found in the 13 cypress swamps, 24 taxa were found to be important in their community structure and alkalinity, chloride, conductivity, dissolved oxygen, total phosphate, and water temperature were correlated with species richness ($p = 0.05$). Soil and water pH, total dissolved solids and soil temperature were not correlated with species richness.

BASSET, ALBERTO. Università di Cagliari, 09126 Cagliari, ITALIA. Conceptual analysis of body size related competitive coexistence.

Coexisting competitors should differ in body size and partition resources accordingly. Many cases seem, however, difficult to explain through size-related resource partitioning. Here, I attempt to investigate whether body size-related constraints at individual level on home-range resource harvesting could conceptually lead to coexistence between interspecific competitors of different sizes utilizing a single limiting resource. Considering a four dimensional space, consisting of two spatial dimensions, describing the larger competitor home-range, resource availability and time, it has been possible to conceive a distance in size at which spatio-temporal constraints on home-range harvesting, trophic optimization and relativity of resource availability associate to body size, could allow competitive coexistence independently on the niche overlap between individuals. It also implicates that guild structure seems likely to be based on a hierarchy of inclusive home-ranges.

BASSIRIRAD, HORMOZ, DAVID C. TREMMEL, JAMES F. REYNOLDS and ROSS A. VIRGINIA. Duke University, Durham, NC 27708, USA and Dartmouth College, Hanover, NH 70919, USA. Temporal differences in resource capture between two desert shrubs following a simulated rainfall event.

An experiment was conducted in June 1993 at the Jornada LTER site in the Chihuahua desert to compare the rapidity with which comparable sized plants of creosotebush (Larrea tridentata) and mesquite (Prosopis glandolusa) acquire water, CO_2 and N following a simulated rainfall event. Plants growing in a roughly 50 m^2 area were labeled with 8 equally distant patches of $20mM\ ^{15}NH_4{}^{15}NO_3$ (98 atom %) applied to the soil at 20cm from the center of the plant at soil depths of 10 or 20 cm. Treatment plants received 3.5 cm of rain, while no supplemental water was added to controls. At various times after watering, leaf xylem water potential (Ψ_x), net assimilation rate A_{net}) and leaf $\delta^{15}N$ were evaluated. A_{net} and Ψ_x exhibited significant recovery in watered Larrea within 3d but no recovery was observed in Prosopis, even 6d after watering. Larrea had a more rapid capacity for N uptake following the rain. Leaf $\delta^{15}N$ was 5x in watered Larrea within 2d while leaf $\delta^{15}N$ was not significantly different between the control and watered Prosopis. Physiological plasticity exhibited by these potential competitors may have significant implications for the vegetation dynamics.

BASSOW, S.L. and F.A. BAZZAZ. Harvard University, Cambridge, MA, 02138, USA. Forest carbon cycles and elevated CO_2: What can experiments on seedlings tell us?

To understand how elevated CO_2 may affect forests, we must link controlled environment experiments and field studies. We must also address ontogenetic differences in CO_2 response. Our previous results show correspondence between species- and height-specific leaf-level gas exchange and ecosystem-level CO_2 exchange, measured by eddy-correlation. We postulate that forest carbon exchange can be modeled as gas exchange of a population of leaf modules. But are all leaves alike? We grew seedlings of 4 tree species in pots placed on platforms at the top (20 m) and mid-point (12 m) of Canopy Access Towers, corresponding to canopy heights of the dominant trees (red oak, red maple, white and yellow birch). We grew a similar set of seedlings in the glasshouse with light levels, temperature and wind simulating 2 canopy heights, at ambient and elevated CO_2. Photosynthetic light response curves, leaf chlorophyll and N, leaf-air temperature differentials, leaf $\delta^{13}C$ and N-photosynthesis relationships were compared. For red maple and the birches, P_{max} was higher for canopy-top than sub-canopy foliage, and was consistent for ontogenetic stages. The "glasshouse effect" was minimal. Elevated CO_2 doubled the seedlings photosynthetic rate. Ontogenetic differences in oak were pronounced: mature tree P_{max} was three-fold that of all seedlings. Thus the model of leaves as modules is most useful for scaling leaf-level photosynthesis of early successional, indeterminate species, and should be used cautiously for late successional species.

BATES, JOHN M., SHANNON J. HACKETT, and JOEL CRACRAFT. American Museum of Natural History, New York, NY, 10024, USA. Patterns and timing of avian diversification in the Neotropics.

Avian areas of endemism in South America have been well-documented. Although birds are among the better studied groups of Neotropical organisms, there have been few studies of the relationships of populations and species of birds and little rigorous analysis of relationships among areas of endemism. We employ a cladistic biogeographic approach to determining relationships among Amazonian areas of endemism, based on the current distributions of species. These data demonstrate that a single hypothesis of area relationships is unlikely, and many currently-

recognized South American areas of endemism are composites of species with different historical time-frames and patterns of divergence. Traditional explanations for the origin of Amazonian biodiversity have postulated isolation during late Pleistocene climatic cycles (the "refuge theory"). Genetic data, including allozymes and mitochondrial DNA sequences suggest that some avian species, and thus their areas of endemism, are much older.

BATISTA, WILLIAM B. and WILLIAM J. PLATT. Louisiana State University, Dept. of Botany, Baton Rouge, LA 70803, USA. Old-growth condition in Coastal Plain mesic Hardwood Forests.

If a paradigm of old growth is to serve as a reference for forest conservation it has to be related to the natural dynamics of the particular ecosystem. In the past, mesic, mixed evergreen-deciduous forests, dominated by Fagus grandifolia, Magnolia grandiflora and Pinus spp., have been proposed as the climax of the southern Coastal Plain. However, frequent but non-devastating disturbances, associated with hurricanes, would prevent these forests from ever being at a steady state. They exhibit a large proportion of gaps, high tree density, canopy trees of moderate size, and low density of snags. Tree recruitment, growth and death occur in pulses that produce fluctuations in relative species composition. Two alternative models of the dynamics of these forests have been recently proposed that take into account frequent allogenic disturbance. In the first model, an autogenic succession is frequently reinitiated (or prompted forward) by allogenic disturbance, determining cyclical change of the forest. According to the second, these forests change driven by individual species responses to allogenic disturbance, and thus they are neither successional nor climaxic. The appropriate definition of old growth would depend on which model is more realistic.

BATZLI, GEORGE O., STEVEN J. HARPER, AND KIRK LIN. University of Illinois, Urbana,IL, 61801, USA. Population dynamics of voles: an experimental test of a multiple-factor model.

The use of factorial, replicated field experiments is essential for rigorous testing of multi-factorial hypotheses about the mechanisms of population dynamics. This paper reports the main results from the simultaneous manipulation of predation, food quality, and interspecific competition on populations of prairie voles (Microtus ochrogaster). Results from previous work indicated that the effect of meadow voles (Microtus pennsylvanicus) should be to increase per capita dispersal from prairie vole populations. Because the effect of meadow voles on dispersal of prairie voles is thought to be caused by aggressive encounters between species, because predation reduces movement of voles, and because high quality food reduces aggressiveness of voles, we expected to detect factor interactions in our experiment, and we did. The effect of meadow voles on dispersal was less in populations of prairie voles that were exposed to predators or provided with high quality food.

BAZZAZ, F. A. Harvard University, Cambridge, MA 02138, USA. Competition and resource interactions in forests.

Because forests play a major role in the global carbon cycle, it is crucial to understand their future response to global change. Most of the studies on forest trees have been conducted on individually grown plants. In order to predict changes in composition of forests and their response to long term global change, the response must be examined under competitive conditions. Under these conditions competitive interactions can produce very different patterns than when individuals are grown separately. Temperate forest enhancement of growth by elevated CO_2 was lower for plants grown in stands than for plants grown as individuals. Competition in a high CO_2 environment also caused a reduction in variance in size hierarchy. Allocation to roots and shoots was different in stands than in individuals. Growth in a high CO_2 environment hastened competition for light. Size inequality in competition is related to differences among individuals in resource capture e.g. N, P, and PAR. In a tropical assemblage elevated CO_2 had small effects. However, there was a marked effect of elevated CO_2 upon species composition in competition. Competition for nutrients allowed *Piper*, with its high proportional allocation, to root early in the season to gain the initial competitive advantage. But when the canopy closed, competition for light became more important in determining competitive success. *Senna*, because of its relatively greater biomass allocation to stems and high photosynthetic rate, was able to overtop the other species and dominate the assemblage.

BECK, MICHAEL W. Department of Biological Science, Florida State University, Tallahassee, FL, 32306-2043, USA. Size-specific shelter limitation in stone crabs: a test of the demographic bottleneck hypothesis.

Habitat structural complexity can facilitate species persistence by providing refuges and the availability of refuges may control the size of many populations. The size and abundance of refuges is particularly important, because population regulating factors may operate strongly on only one size class or ontogenetic stage within a population, creating a demographic bottleneck. I test the demographic bottleneck hypothesis in stone crabs, Menippe mercenaria X adina, by first supplementing shelter with 5 different sizes of PVC pipe in St. Joseph Bay, Florida to determine the size class most likely to be shelter limited. In comparison to natural densities of crabs, the supplemental shelters particularly attracted large (>70 mm CW) gravid females and molting individuals, suggesting that shelter may affect both fecundity and growth. Tethering experiments show that the strong affinity of large females for shelter is not explained by their risk of predation. However, females tethered with shelter were able to produce egg masses twice as fast females without shelter. The evidence suggests the merits of the demographic bottleneck hypothesis; habitat structural complexity may affect both the size of populations and the size of individuals within the population.

BEISNER, B.E., E. MCCAULEY and F.J. WRONA*. University of Calgary, Calgary, AB., T2N 1N4, CANADA and *National Hydrology Research Institute, Saskatoon, SK, S7N 3H5, CANADA. Stability of laboratory mesocosms - effects of temperature and food chain length.

Investigations of the dynamics of populations in simple communities can provide information about the effects of temperature, predators and community complexity on population stability. Food chain theory was used to make predictions regarding the effect of food chain length and temperature increases on population stability and equilibrium biomass. A test of these predictions was conducted using 700L mesocosms maintained at 18°C and 25°C. Treatments included 2-level (phytoplankton and Daphnia pulex) and 3-level (phytoplankton, D. pulex and flatworm predator) systems within simple aquatic communities. Population dynamics of all trophic levels were monitored twice weekly for five months. Results indicate a regulatory effect of D. pulex on phytoplankton biomass that is released in the presence of the carnivore. The increase in temperature led to a destabilization of Daphnia-algal dynamics and the Daphnia-carnivore dynamics.

BEISWENGER, JANE M. The University of Wyoming, Laramie, WY, 82071, USA. Ecology Education in Wyoming.

The Wyoming team for Ecology Education identified five goals: to identify all Wyoming ecologists, to support the effort of a newly formed Wyoming Association of Environmental Education, to assist in developing an environmental education curriculum for Wyoming teachers that is underway, to assess the possibility for involving Wyoming ecologists and teachers in a statewide project, and to hold a workshop at the State Interdisciplinary Conference. Our primary concern in all cases was to establish working relationships between ecologists and teachers. Fifty of 132 ecologists with which we have corresponded have indicated an interest in our efforts. We held a workshop where we discussed our goals and demonstrated an interactive exercise where both a teacher's and ecologist's expertise would be valuable. We are working now to form teams of ecologists and teachers that will work together to develop activities for the students in their local schools. We have been frustrated by barriers of misunderstanding, complacency and territoriality but we have been encouraged in many ways as well. Time, perseverance, and a great deal of patience seem to be the keys to progress.

BEISWENGER, RONALD E. The University of Wyoming, Laramie, WY, 82071, USA. A task force approach to resolving conflicts associated with endangered species protection.

The endangered Wyoming toad (Bufo hemiophrys baxteri) is close to extinction with one known natural population in the Laramie Basin of southeastern Wyoming. In May, 1993, the Environmental Protection Agency (EPA) proposed restrictions on the use of 43 pesticides in the 970 square mile area that constitutes potential habitat for the toad. Because of strong local opposition to these restrictions, a Task Force of governmental, academic, agricultural and environmental interests was established to develop alternatives to the proposed restrictions. The Task Force developed a plan to protect the toad while minimizing the burden on those who benefit from pesticide use. In December, 1993, the Governor of Wyoming approved the plan and forwarded it to the EPA. The Task Force approach is viewed as an experiment in resolving controversial endangered species issues. An assessment of the Task Force plan indicates that it provides a reasonable level of protection for the existing toad population, but ignores other important ecological and social values. The goals and actions of the Task Force were more limited than those of the Pacific Northwest timber conference and other recent endangered species agreements. Interviews of Task Force members reveal that there is some interest in exploring broader approaches to managing the wetland and aquatic ecosystems in the Laramie Basin.

BELK, MARK C. Brigham Young University, Provo, UT, 84602, USA. Effects of presence of predators on age at maturity in bluegill sunfish, Lepomis macrochirus: a phenotypic response.

Non-experimental studies suggested that differences in age at maturity among populations of bluegill sunfish (Lepomis macrochirus) were not genetically based, but rather were a phenotypic response to the presence of predators. I conducted a factorial experiment to determine if the presence of largemouth bass affected age at maturity in bluegill sunfish. Juvenile bluegills from two different populations were placed in one of three treatments: 1) control, no contact with predator, 2) visual treatment, only visual contact with predator, 3) same water treatment, visual contact and presence in same water as predator. Refuge use and growth were monitored during the experiment and reproductive activity was evaluated when bluegills reached age one. Bluegills in the same water treatment showed significantly increased refuge use and decreased growth. Significantly fewer bluegills from one population in the "same water" treatment were reproductive at age one and their gonadal/somatic index was significantly lower than bluegills in the other two treatments. The population that responded to the presence of predators had a history of high predation levels for the past 30-40 years. The other population came from a pond where only bluegills are present. This study suggests that predators can influence prey population dynamics by altering age at maturity.

BELNAP, JAYNE. National Biological Survey, Moab, UT, 84532, USA. Effects of soil surface disturbances on Colorado Plateau cold-desert grassland and shrub communities.

Cold-desert communities have low levels of soil surface disturbance when compared to other ecosystems. Native ungulates, burrowing mammals and soil fauna are limited in number. Plant death results in little soil disturbance. Current and historic uses have resulted in large

disturbances to soil surfaces, drastically altering nutrient cycles and plant community structure. Nitrogenase activity in cryptobiotic soil crusts, an important source of nitrogen, has been severely impacted. Carbon fixation has declined. Soils have been compacted and highly eroded. Surface albedos have increased, affecting local climate. Soil bacterial, fungal and nematode populations have been reduced, and natural relative abundances altered. Grasslands have been converted to shrublands, resulting in decreased and highly localized fertility in soils. Macronutrient levels in plant tissue have declined in trampled areas. In shrub communities, interspace flora has shifted from perennials to annuals, and spacing of shrubs has been altered. The effect of soil disturbance in cold and hot deserts will be compared.

BELOVSKY, GARY E. and ANTHONY JOERN. Utah State University, Logan, UT, 84322, USA and University of Nebraska, Lincoln, NE, 68588, USA. Grasshopper population dynamics: alternative domains of regulation in time and space.

We have studied population dynamics of grasshoppers at two rangeland sites (Palouse Prairie in Montana and Sandhill Prairie in Nebraska) for more than 15 years. Using identical experimental manipulations at both sites, we explain how abiotic-induced density-independent mortality, natural enemies and competition for food resources interact to limit populations in different habitats and in different years in the same habitat. From these experiments, a population perspective based on Ricker Models indicates that a population's density can be attracted to domains regulated by: 1) only natural enemies, 2) only food availability, or 3) either natural enemies or food depending upon the density of emerging nymphs. A population might shift between these alternative domains of attraction in different years as environmental conditions vary annually. This population perspective enables us to stipulate conditions for the juxtaposition of populations in different habitats that would create unique landscape effects such as a population's escape from a domain defined by natural enemies, if its habitat was isolated, to a domain defined by food resources when it is adjacent to other populations in different habitats. Our population perspective is not solely based upon the models, but can be experimentally demonstrated via empirical measurements of the Ricker Model and population responses to experimental manipulations.

BENKE, ARTHUR C. AND DAVID L. STITES. University of Alabama, Tuscaloosa, AL, 35487, USA. Production dynamics of the exotic bivalve, Corbicula fluminea, in a Coastal Plain blackwater river.

Corbicula fluminea, the Asiatic clam, has spread to at least 33 states of the USA and is found in both lentic and lotic habitats. We quantified its growth and production dynamics in the Ogeechee River of the SE Coastal Plain. Life span was at least 3 years, density averaged about 200/m^2 and biomass ranged between 1 and 4 g dry mass (DM)/m^2 over a period of 42 months. Growth rates, determined from clams reared in situ, were highest in late spring and were inversely related to individual size. Annual production, ranged from 0.18 g DM/m^2 at a main-channel site to 7.6 g DM/m^2 in a backwater, and averaged 1.8 and 1.2 g DM/m^2 for the entire river for two consecutive years. Mean daily production was highest in spring (>8 mg DM/m^2) and fell to zero in mid-winter when growth ceased. Annual production/biomass values were about 7-8 for first-year individuals, 1.0 for the second year, 0.3 for the third, and ranged from 0.55 to 1.78 overall, depending on year and site. Various population parameters indicated that this blackwater river was a stressful environment for Corbicula, probably caused by low alkalinity (<30 mg/L as $CaCO_3$). Unlike its influence in many systems, Corbicula appears to play a minor role in the trophic dynamics of the Ogeechee. In less than a decade after its invasion of the river, the population appeared relatively stable over a 4-yr period.

BENNINGTON, CYNTHIA C. West Virginia University, Morgantown, WV, 26506-6057, USA. Ecotypic differentiation and phenotypic selection in Impatiens pallida.

Reciprocal transplant experiments have been used to describe ecotypic differentiation, and to infer the role of natural selection when there is evidence for home site advantage. The demonstration of a home site advantage, however, does not reveal which plant characters are responsible for conferring increased fitness on populations planted in their native site. To concurrently quantify the magnitude of genetic differentiation and the action of natural selection, two phenotypically-distinct populations of Impatiens pallida found in a floodplain and hillside environment were reciprocally transplanted. There was a clear home site advantage for both populations with respect to total seed production (fitness). In addition, genetic differentiation between populations was observed for several life history traits. For example, plants which originated from the hillside population produced flower buds earlier than plants from the floodplain population regardless of the site into which they were planted. Selection favored early flower production for hillside plants planted on the hillside, but there was no selection on date of flower production for floodplain plants in their native site. The results of this experiment demonstrate that some of the observed phenotypic differentiation between these two populations is due to genetic differentiation and that this is a consequence of differential selection pressures in the two sites.

BERKOWITZ, ALAN R., STEWARD T.A. PICKETT and STUART E.G. FINDLAY. Institute of Ecosystem Studies, Millbrook, NY, 12545, USA. Beyond hands-on: engaging undergraduates in the broader contexts of ecological research.

Success in science depends on understanding the context of research, as well as the substance and procedures of a particular discipline. The Institute of Ecosystem Studies' summer Research Experiences for Undergraduates program seeks to go beyond hands-on research by helping students reflect on it and explore its social, societal and personal contexts. Students conduct independent research projects under the direction of a mentor scientist and receive explicit training in the research process. In addition, students are involved in

activities to broaden their perspectives on the various contexts and applications of science: a full-day Forum on Opportunities in Ecology, case studies, group discussions and near-peer teaching. Our six years of experience suggest that immersion in a rich research community and consideration of broader contexts of research are extremely helpful to aspiring scientists.

BERLOW, ERIC L. Oregon State University, Corvallis, OR, 97331-2914, USA. Temporal and spatial variation in indirect interactions and the nonlinear effects of predators: An experimental evaluation.

Both indirect interactions between species and nonlinear effects of density pose significant challenges to achieving greater predictability in ecology. I experimentally evaluated how the outcome of indirect interactions varied with three different predator densities in a 'simple' marine rocky intertidal interaction web consisting of one predator (whelks) and two sessile prey that compete for space (barnacles and mussels). All combinations of the presence/absence of the three species were manipulated in a replicated factorial design . Three densities of whelks were used to evaluate whether the outcome of indirect interactions varied with the relative strength of predation and whether the effects of predators were linear. Two and a half years of 'press' manipulations show that the indirect effects varied not only with the density of predators but also between years of differing recruitment intensity. The effects of predators on barnacle and mussel covers varied non-linearly with the density of the predators enclosed, and these nonlinearities also varied between years. A general pattern emerged in which the net effects of low predator densities varied more over time and space than the effects associated with high predator densities.

BERRY, KRISTIN H., MICHAEL N. WEINSTEIN, GARY C. WHITE, and FREDERICK B. TURNER. National Biological Survey, Riverside, CA, 92507, USA; El Morro Institute, Solvang, CA, 93463, USA; Colorado State University, Ft. Collins, CO, 80523, USA; and University of California, Los Angeles, CA, 90024, USA. A new life table and population models for the desert tortoise (Gopherus agassizii) in the eastern Mojave Desert, California.

Using data spanning 13 years (1977-1990), we developed new growth and survivorship models and a new life table for tortoise populations in the eastern Mojave Desert. Growth was examined for males and females using 1467 pairs of records. Key determinants of growth rate were size and sex of tortoises and general availability of food and water. Survival rates, measured by the SURVIV program, varied considerably from year to year, e.g., 26.2-92.3% for 1-yr old tortoises. The new life table predicted that the initial cohort would fail to replace itself and the population is likely to decline at a rate of 2.9%/yr. Rainfall and food availability profoundly affect survival rates of juveniles and thereby success of the cohort.

BEYERS, JAN L., GINGER C. PENA and WILLIAM O. WIRTZ II. USDA Forest Service, Pacific Southwest Research Station, Forest Fire Laboratory, Riverside, CA, 92507, and Department of Biology, Pomona College, Claremont, CA, 91711, USA. Coastal sage scrub in relation to fire history and use by the California Gnatcatcher.

Coastal sage scrub is a fire-dominated vegetation type rapidly disappearing to development in southern California; it is home to the California Gnatcatcher, a small songbird federally listed as threatened. We examined plant cover and vegetation structure at two coastal and two inland sage scrub sites in plots differing in fire history and use by California Gnatcatchers. Shrub cover in plots occupied by gnatcatchers was at least twice as great as in unoccupied areas; shrubs were taller as well. Artemisia californica dominated the coastal plots used by gnatcatchers, but at one inland site Salvia mellifera was the most common species. Recently burned plots were not used by gnatcatchers except on an occasional basis. Previous work suggests that 5 to 7 years recovery from fire are required before gnatcatchers will reoccupy an area. However, an inland site burned 12 years earlier had less than 10% shrub cover and no gnatcatchers; annual grasses and Brassica sp. dominated the site. Implications for fire management and postfire site treatment in gnatcatcher habitat reserves are discussed.

BIGGER, DAVID and LAUREL R. FOX. University of California at Santa Cruz, Santa Cruz, CA 95064, USA. Intrinsic properties of individuals from outbreak and non-outbreak populations of an herbivorous pest.

Populations of insects persist at different densities. Among herbivorous insects, there is genetic variation in key life history traits, such as population growth rate and host use patterns. Attempts to find associations between life history traits and the tendency of forest insect herbivores to have large fluctuations in population density have yielded contradictory trends. We explore host use patterns of an agricultural pest, the diamondback moth, Plutella xylostella (Plutellidae). Throughout the moth's distribution, populations persist at high or at low densities for long periods of time. We compared key life history traits and oviposition preferences among several of these populations. We found that diamondback moth populations that persist at high densities tended to be more generalized in oviposition preference while offspring performance was inconsistent.

BILBROUGH, CAROL J. and MARTYN M. CALDWELL. Utah State University, Logan, UT, 84322, USA. Exploitation of seasonally variable N pulses by six Great Basin plant species.

We investigated the exploitation of temporally variable N pulses by 6 Great Basin species of 3 growth forms (woody shrub, annual grass and perennial grass) that were established in irrigated,

monoculture sand-filled field plots. Four-day N pulses were applied in early, mid or late spring. Control plots received the same amount of N in a continuous supply. All species responded to pulsed N with higher growth rates and biomass than to continuous N supply. However, the timing and number of pulses resulting in the greatest responses varied among species. The grasses benefitted most from early and mid spring pulses, while shrub responses were greatest for the mid and late spring pulses. Only two species responded equally to pulses at two different times; the other species exhibited a maximum response to only one pulse. The interaction between timing of N availability and species-specific traits may affect plant competition and coexistence.

BISHOP, JON A. and W. SCOTT ARMBRUSTER. Institute of Arctic Biology, University of Alaska Fairbanks, Fairbanks, Alaska, 99775-0180, USA. The effect of body size on passive radiative heat gain, diel foraging activity, and phenology in a bee community of interior Alaska.

We investigated the influence of body size on three aspects of thermal biology and ecology of bees in interior Alaska: 1) radiative heat gain 2) structure of diel foraging activity 3) structure of phenological patterns. We compared operative environmental temperature (T_e) of bees from 10 mg to 500 mg to determine whether size affects the thermal regime a bee experiences. T_e integrates ambient temperature (T_a), radiative heat gain, and convective heat loss, and is estimated by measuring the temperature of a dead bee in the field environment. T_e for very small bees is very similar to T_a even in the direct sun suggesting that solar radiation is contributing little to their thermal balance. T_e of large bees can be 17°C greater than T_a. This shows that different size bees are experiencing different thermal regimes in the same micro-habitat. We recorded bee activity on Hedysarum boreale (Fabaceae) for 15 minutes of each hour. Activity peaks for small bees were at higher T_e than for large bees. Thus, larger bees began foraging earlier in the morning. Body size of solitary bees increases through the season in sharp contrast to the pattern observed in Isreal by Shmida and Dukas (1989). This suggests that thermal limits on foraging activity are structuring the diel foraging patterns but not the phenological patterns of the Alaska bee community.

BILL, C. JASON and P. A. HARCOMBE. Rice University, Houston, TX 77251 USA. Hurricane effects on a Fagus/Magnolia forest in the context of twelve years of forest monitoring.

Disturbance due to hurricanes has been considered by many to strongly influence the structure and dynamics of mesic forests of the Gulf Coastal Plain. At Wier Woods, a well developed mesic forest in the Big Thicket Area of Texas, measurements of all live stems > 4.5 cm dbh started in 1980 and were repeated in 1985, 1987, 1989, and 1992. In 1986, Hurricane Bonnie passed over Wier Woods causing substantial tree mortality and opened several canopy gaps. Percent mortality was highest in the largest dbh classes and, trends in percent mortality for individual species can be explained by the species size class structure, except for Quercus nigra, which had been rapidly declining in standing basal area. Even though Bonnie caused heavy damage there was only a slight decrease in basal area from 1985 to 1987. Ingrowth into the 4.5 cm dbh size class was accelerated by the hurricane. Ilex opaca was by far the most common recruit to tree size (> 4.5 cm dbh), followed by Magnolia grandiflora. Ilex opaca has been rapidly increasing in numbers since 1980, where the rate of Magnolia grandiflora ingrowth only increased substantially after 1985.

BIONDI, FRANCO and DONALD D. MYERS. University of Arizona, Tucson, AZ 85721, USA. Long-term spatial dependence of tree size and increment in an old-growth forest ecosystem.

Spatial stochastic models were fitted to stem diameter (DBH), basal area (BA), and basal area increment (BAI) at 10-year intervals from 1920 to 1990 to test for trends in spatial interactions among trees. The study area was an old-growth, naturally-seeded stand of southwestern ponderosa pine (Pinus ponderosa Dougl. ex Laws. var. scopulorum) where total basal area and tree density have increased since the early 1900s. Despite increased crowding, stem size (DBH, BA) maintained the same type of spatial dependence from 1920 to 1990. Stem size was spatially autocorrelated over distances no greater than 30 m, a measure of average patch diameter. Tree density increased by increasing the number of pine groups rather than their horizontal dimension. Spatial dependence of stem size was always much greater than that of stem increment (BAI). Increased tree crowding corresponded to lower average, variance, and spatial dependence of individual growth rates. In 1980-90, BAI varied regardless of mutual tree position. Since growth variation was less related to inter-tree distance at higher tree densities, density-dependent limitation of tree growth did not necessarily correspond to distance-dependent growth rates. These results deserve consideration when predicting, estimating, and/or simulating tree performance.

BISHOP, LESLIE. Earlham College, Richmond, IN, 47374, USA. Colonization rate and habitat choice in an assemblage of web-building spiders in a Puerto Rican rain forest.

In this study, I examine the factors affecting habitat colonization in the rain forest in the Luquillo Mountains of Puerto Rico by web-building spiders and the relationship among spider species in the new assemblage. I constructed 3-dimensional structures (hypergrids) by suspending strings vertically and horizontally among four poles to create a cube. During a six month period, I monitored spider colonization on these structures and recorded colonization rates and nearest neighbor distances among species. By the end of the sampling period, 10-12 species had colonized the $(2m)^3$ grids, with up to 180 individuals per hypergrid. To test the hypothesis that colonization rate and species assembly are dependent upon habitat complexity, in a randomized complete block design, I increased complexity in treatments by varying the number of strings and by varying the distance between strings. There was a significant difference among treatment types, with spiders more readily

colonizing the most complex structures (i.e. most attachment sites). In a second hypothesis I tested if the prior presence of silk affects successful colonization by other spiders. Thus, treatments with silk on the strings prior to colonization were compared to treatments without silk. There was a significant difference among treatments with or without silk in both colonization rate and species richness.

BLACK, R. ALAN. Washington State University, Pullman, WA, 99164, USA. Variation in whole tree water use among ramet individuals and between hybrids of Populus in response to environment.

Sap flows for three ramet individuals of three Populus hybrids (P. trichocarpa X P. deltoides) within the same plantation were continuously monitored using a heat balance technique during the summer months of 1993. All trees transpired more water than predicted (>2X) by integrated daily calculations of potential evapotranspiration (PET). Nighttime transpiration, a general lack of stomatal control, and lateral transfers by wind may have contributed to high sap flow estimates compared to PET. Considerable variation in diurnal patterns of flow was detected between hybrids in response to watering and drought; integrated-daily water use was only weakly correlated between hybrids. Ramet individuals exhibited similar patterns of flow with variation between individuals only in the maximum rates. Daily weather patterns explained comparatively little of the variation in integrated-daily water use (<15%). While PET was relatively high, irrigation of the trees apparently uncoupled their response to environment. Trees exhibited increased flow following irrigation events but did not change daily patterns with and between waterings. Irrigation also caused a short term (<24 h) decrease in sap flow during the watering event suggesting a flooding response as the soil profile became saturated.

BLAIR, JOHN M., HAIPING SU, JACK C. SHAW and ALAN K. KNAPP. Kansas State University, Manhattan, KS, 66506, USA. Effects of topography and fire on soil processes and plant productivity in tallgrass prairie.

Konza Prairie is characterized by landscape-level variation in topography and edaphic factors, which affect soil-plant nutrient relationships. In 1993 we examined soil N dynamics and plant productivity along topoedaphic gradients across two watersheds being intensively studied as part of the Konza LTER program. We quantified (1) soil N availability at upland, mid-slope and lowland sites on watersheds with different fire frequencies (annual vs. 20 year fire intervals), (2) above-ground net primary production (NPP) and (3) soil moisture across these gradients. There was a stronger relationship between topographic position and soil moisture on the annually burned watershed, and NPP was correlated with topographic position on the annually burned watershed only. Extractable soil inorganic N also was affected by topographic position on the annually burned watershed only (highest concentrations at lowland sites), especially early in the growing season. The unburned watershed generally had higher concentrations, and greater spatial and temporal variability, of extractable N, compared to the annually burned watershed. No consistent topographic effects on extractable N were observed on the unburned watershed. These differences between watersheds conform to our understanding of the effects of fire and topography on soil processes in tallgrass prairie.

BLEW, ROGER D. and ROBERT L. EDMONDS. University of Washington, Seattle, WA, 98195, USA. Precipitation chemistry along a transect inland from the Pacific coast and stream chemistry on the Olympic Peninsula, Washington.

Chemistry of bulk precipitation (PPT) was monitored during 1989-1992 at sites 4, 13, 24 and 31 km inland from the Pacific Ocean in the Hoh River Valley and stream chemistry was monitored during 1984-1993 in 58 ha West Twin Creek Watershed, 33 km from the Pacific Ocean in the Hoh River Valley, Olympic National Park. Mean annual PPT increased from 2780 mm at 4 km to 3500 mm at all sites further inland. Mean pH of PPT ranged from 5.3 to 5.6 and stream pH averaged 7.5. Chemistry of PPT was dominated by oceanic influences with Na and Cl being the dominant ions. Stream chemistry was influenced by bedrock weathering and was dominated by Ca, HCO_3, and SO_4. Concentrations of sea-salt ions in PPT were highest nearest to the coast. There was considerable SO_4 input (12.2 kg ha^{-1} yr^{-1}) to the watershed via PPT. Highest rates of deposition of sea-salt ions occurred during the winter rainy season. In stream water, seasonal patterns of HCO_3, NO_3, SO_4, Ca, Mg, K and Na concentrations corresponded to stream discharge rates. There were large increases in NO_3 concentration in stream water during fall and early winter suggesting increased nitrification or release of accumulated NO_3 from sediments or soil.

BLOOMFIELD, JANINE, KRISTIINA A. VOGT, and DANIEL J. VOGT. Yale School of Forestry and Environmental Studies, Yale University, New Haven, CT 06511, USA. Nutrient dynamics of decomposing tropical tree foliage and fine roots in relation to secondary chemistry in the Luquillo Experimental Forest, Puerto Rico.

Decomposition of foliage and fine roots in tropical montane rain forests is typically rapid with complete mass loss often occurring within 1 year. Furthermore, frequent disturbances can lead to large inputs of plant materials to the decomposition subsystem in this ecosystem. We measured nutrient accumulation and release dynamics of decaying plant tissues from tree species in the Luquillo Experimental Forest in Puerto Rico, to determine to what extent nutrients were conserved in decaying litter and whether their dynamics varied by initial substrate quality and tissue type. Initial C/nutrient ratios were important in describing nutrient fluxes but tissue type was not predictive. For example, leaves of Dacryodes excelsa had higher C/N ratios than fine roots and had greater N immobilization, while fine roots of Prestoea montana had higher C/N ratios than leaves and had greater N immobilization. Despite fast mass loss rates, nutrients (including N, P, Ca, and Mg) were immobilized to varying extents in the decomposing litter, possibly due to the formation of insoluble complexes between nutrients and polyphenolic decay products. Increases in absolute lignin amounts in decayed litter were attributed to the formation of these complexes which may help regulate the conservation of nutrients in these tissues during decay.

BLOZAN, WILL F. USDI, NPS, Great Smoky Mountains National Park, Gatlinburg, TN 37738. Use and interpretation of core samples to substantiate delineation of old-growth forests.

In a current project to identify and delineate old-growth oak (Quercus spp.) and eastern hemlock (Tsuga canadensis (L.) Carr.) forests in the Great Smoky Mountains, field experience has established that data from core samples are an integral part of old-growth evaluation. Field characteristics such as large trees and multi-layered canopy structure have proven to be unreliable indicators of old-growth. In addition to age, interpretation of cores from dominant and sub-canopy trees reveal growth patterns such as canopy release and suppression. Correlation of dates to known or suspected human disturbance influences stand evaluation and candidacy for old-growth designation. Core sampling allows accurate documentation of visual attributes, therefore making the use of core sampling a repeatable, consistent method for stand evaluation.

BLUM, UDO, LARRY D. KING and ARCH D. WORSHAM. North Carolina State University, Raleigh, NC, 27695, USA. Effects of cover crops on weed seedling emergence in no-till plots.

Crimson clover, subterranean clover, rye, or wheat was planted in 24 m^2 plots on October 20, 1992. No cover crop plots were used as the control plots. Three management treatments, desiccation of cover crops by glyphosate on April 29 or May 10, 1993, or soil incorporation of cover crops on April 30, 1993, were applied to the plots. Morning-glory, pigweed, and prickly sida seeds were sown on the soil surface on February 2, 1993, for the glyphosate plots and on May 7, 1993, for the tilled plots. Soil temperature, soil moisture and soil pH, and seedling emergence were monitored during May to July, 1993. Emergence of morning-glory, pigweed, and prickly sida was inhibited by rye and wheat surface debris. Prickly sida emergence was also inhibited by the clover debris. Seedling emergence was not inhibited when the cover crops were incorporated into the soil. Measured soil parameters under the cover crops were very similar. Debris toxicity studies suggest that the inhibition of seedling emergence was due to the release of allelopathic compounds.

BOBASHEV GEORGIY V., STEPHEN P. ELLNER, DOUGLAS W. NYCHKA. North Carolina State University, Raleigh, NC, 27695-8203, USA. Modeling of the disease dynamics in two interacting populations of different sizes.

Dynamics of a disease such as measles in a single population is often modeled by a system of ordinary differential equations known as the SEIR model. In order to model the interaction among several population centers it is important to study how a system of several SEIR units behave. Two SEIR models were built that represent qualitatively different disease dynamics in big (pop. bigger than 10^6) and small (pop. less than 5*10^5) cities. The systems were then coupled by a forcing function cross-term. It was shown that even "weak" coupling is enough to synchronize big-small or big-big city pairs. The analysis of real data from UK cities shows that there exists a lagged relationsip between disease outbreaks. However the coupled model fails to reproduce delayed dynamics. This failure suggests that the coupled systems must be made more complex in order to describe spatial-temporal patterns in measles.

BOERNER, R.E.J. and DAVID C. LEBLANC. Ohio State University, Columbus, OH, 43210, USA and Ball State University, Muncie, IN, 47306, USA. Landscape position, substrate quality, and NO_3 additions affect N dynamics in oak forest soils.

We sampled A horizon soils from upper south and lower north slopes in oak stands at two sites in The Hoosier National Forest, Indiana which differed in bedrock (Deam Wilderness/DW: acid sandstone; Harden Ridge/HR: limy sandstone). NH_4-N pool sizes did not differ between sites (=bedrock types) or slope positions. Although NO_3-N pools did not differ between sites, they were significantly larger in soils from lower north positions than in those from upper south positions. There was no significant effect of either slope position or bedrock geology on N-mineralization in 30 day aerobic incubations done in the laboratory. The proportion of NH_4-N subsequently nitrified did differ both between sites (DW > HR) and positions (upper south > lower north). To quantify the effect of heavy nitrate deposition in precipitation on N turnover, we also incubated paired samples with the equivalent of either 5.6 or 30.0 kg/ha/yr of NO_3 in the 'precipitation' used to keep them near field capacity. Heavy NO_3 addition had no significant effect on N mineralization; however it did result in mean reductions of 49-96% in proportional nitrification. In these sites, slope position and NO_3 addition exert greater effects on soil N turnover than does bedrock type.

BOHLEN, PATRICK J., CLIVE A. EDWARDS and BENJAMIN R. STINNER. Ohio State University, Columbus, OH. 43210, and OARDC, Wooster, OH, 44691, USA. Manipulation of earthworm populations in agroecosystems with different nutrient sources.

We initiated a field experiment in 1991 in which we have manipulated earthworm populations to investigate their effects on C and N cycling processes in agroecosystems. Earthworm populations in field enclosures were decreased by electroshocking, increased by additions of field-collected worms, or left unmanipulated. These manipulations were in corn agroecosystems in which nutrients were supplied as 1) legume

cover crop 2) cow manure, or 3) NH_4NO_3 fertilizer. Initial earthworm populations at our site were high (587 m^{-2}), and the community was dominated by *Lumbricus terrestris* and *Aporrectodea tuberculata*. Earthworm numbers and biomass were lowest in the NH_4NO_3 treatment in spring and fall of 1993. Total earthworm numbers in the fall of 1993 were 304, 288 and 54 m^{-2}, in the addition, unmanipulated and reduction treatments, respectively, indicating that we were more successful at reducing than increasing earthworm populations. In the earthworm addition treatment, increases in earthworm numbers and biomass were much greater for *L. terrestris* than for *A. tuberculata*. Our earthworm manipulations have had significant effects on C and N cycling processes in all nutrient treatments.

BOLKER, BENJAMIN M., STEPHEN W. PACALA, and RICHARD K. KOBE. Princeton University, Princeton, NJ, 08544, USA. Species diversity and the community response to CO_2 fertilization.

Many existing models of carbon storage in the biosphere assume a mean species response to climate change, possibly underestimating the response of plant communities to CO_2 enrichment. We estimate the effect of species diversity on growth and carbon uptake of a transition-northern hardwood forest under conditions of doubled CO_2 using an individual-based forest model (SORTIE). We combine data on greenhouse CO_2-fertilization of seedlings of 9 common northeastern tree species with field measurements on their growth, mortality, and dispersal. The additional effect of species diversity on growth can be nearly as large as the mean CO_2 enhancement itself. Species diversity has the greatest effect when large-scale forest disturbance recurs on time scales of a century or less. These results suggest the importance of biodiversity for carbon storage by forests, and for buffering ecosystems against other anthropogenic changes. In this example, the enhancement caused by species-specific CO_2 fertilization hinges on red oak, an early successional species with a large CO_2 fertilization effect; in other plant communities, mitigation of anthropogenic change could depend on particular species, currently unidentified, responding to particular conditions.

BONSER, STEPHEN P. and RICHARD J. READER. University of Guelph, Guelph, Ontario, N1G 2W1, Canada. **Intensity of plant competition and herbivory across a productivity gradient.**

This study tested whether the intensity of herbivory and plant competition were independent of habitat productivity. A test species, *Poa compressa* L. (Gramineae), was transplanted into eight habitats whose productivity ranged from 65 to 775 g/m²/yr. Tiller production by transplants was compared with neighbors and/or herbivores present versus excluded experimentally. Excluding neighbors (or herbivores) increased tiller production significantly, especially in habitats with relatively high productivity. Our results support theories that predict plant competition and herbivory intensify with an increase in primary productivity.

BOORSE, GRAHAM C. AND STEPHEN D. DAVIS. Pepperdine University, Malibu, CA, 90263, USA. **Differential response of chaparral shrubs to below freezing temperatures.**

We compared four methods of detecting freezing injury to excised leaves of four, co-occurring species of chaparral shrubs from the Santa Monica Mountains of southern California. We determined the lethal temperature for 50% change in activity or cell death (LT_{50}) by measuring electrical conductivity (electrolyte leakage); photosynthetic fluorescent capacity (Fv/Fm); vital stain (fluorescein diacetate); and visual score of leaf color (Munsell Color Chart). In every case, the estimate of LT_{50} by the electrical conductivity method was significantly higher (less negative) than the other three methods (range from 2 to 5 °C higher). The LT_{50} among plants ranged form -5 °C for the most sensitive species (*Rhus laurina*) to -17 °C for the least sensitive species (*Rhus ovata*). These results were consistent with field observations of differential shoot dieback between these two congeneric species after a natural freeze-thaw event in the Santa Monica Mountains. Funded by NSF grants BBS-9100731 and BSR-90-07288.

BOOSE, DAVID L. University of California, Davis, CA 95616, USA. The influence of nectar production rate on pollinator visitation in a natural population of Epilobium canum, a hummingbird-pollinated shrub.

I observed the behavior of Anna's Hummingbirds (Calypte anna) visiting 17 individuals of Epilobium canum, a perennial, herbaceous shrub. At each plant, I recorded the number of visits, the duration of each visit, and the number of flowers probed per visit. I also recorded the number of flowers on each plant during each observation time, and the plant mean nectar production rate. Observations were made over multiple days, and each plant was observed for a total of 12 hours. I found significant differences among plants in all three visitation variables. The number of flowers on a plant explained most of the observed variation, but nectar production rate also had a significant effect. After accounting for flower number, higher nectar production rates were associated with longer visits and a larger number of flowers probed per visit. In later observations, higher nectar production also was associated with more visits, suggesting that pollinators may remember and favor more productive plants.

BORING, L.R. and R.J. MITCHELL. Jones Ecological Research Center, Newton, GA 317770. Fire effects on forest floor nitrogen cycling in *Pinus palustris* savannas.

Fire serves an important role regulating the structure and function of *Pinus palustris* savannas. Specifically, fire has been previously shown to strongly control N flux; however, little is known of how fuel types or season of burn influence nitrogen dynamics. The objectives of this work were to address: 1)relative N losses associated with dormant season and growing season burning practices; and 2) determine the affects of fuel types (i.e. wiregrass (*Aristida stricta*) versus old-field vegetation dominated by *Andropogon*, and fuel loadings of longleaf needles) on fire intensity and impacts on N pools and mineralization. Significant increases in NH_4^+ were observed immediately after a fire, and this was related to longleaf needle loading more than dominant grass type. Time-temperature curves will be presented for various fuel types, and related to patterns in N pools and mineralization.

BOROWICZ, VICTORIA A. and ANU KHANNA. Illinois State University, Normal, IL, 61790-4120, USA. Effects of VAM colonization and phosphorus level on infection of soybean by Phytophthora megasperma.

Several studies suggest that colonization by vesicular-arbuscular mycorrhizal (VAM) fungi may increase disease resistance of host plants. In two experiments we tested whether colonization by Glomus etunicatum and [P] of fertilizer affect infection of soybean (Glycine max) by the root pathogen Phytophthora megasperma. We tested a cultivar that is tolerant of this pathogen in the first experiment and a susceptible cultivar in the second experiment. Seedlings were assigned to high or low P fertilizer and inoculated with soil and roots of VAM- infected plants or with VAM-free filtrate. Three weeks later they were transferred to pots containing sterile V-8 agar or V-8 agar with P. megasperma mycelium. Plants were harvested five weeks later. Despite an order of magnitude difference in fertilizer [P] and significant differences in VAM colonization, neither P treatment nor VAM treatment affected infection by the pathogen or growth of the plant. Both affected foliar [P] of the susceptible cultivar. Plants from the susceptible cultivar that were challenged by the pathogen were smaller than controls. There were no VAM*PATHOGEN interactions, indicating VAM did not affect resistance of either cultivar to attack by P. megasperma.

BOSY, JENNIFER L. and RICHARD J. READER. University of Guelph, Guelph, Ontario, N1G 2W1, Canada. Multiple effects of herbaceous litter on forb seedling recruitment.

Three potentially negative effects of grass (*Poa pratensis*) litter on forb seedling recruitment were measured and compared in a greenhouse study: (1) inhibition of seed germination (ie. radicle protrusion) by leachate (L) from litter, (2) inhibition of seed germination due to change in microclimatic conditions (M), and (3) prevention of seedling emergence by restriction of shoot extension (S). The relative importance of these effects was species-dependent. For example, the ranking of negative effects was L>S>M for *Helianthus annuus*, but S>L=M for *Hypericum perforatum* and L>M>S for *Dipsacus sylvestris*. Results indicate that there are multiple mechanisms by which litter may affect seedling recruitment.

BOUCHER, JEAN-FRANÇOIS(1), ALISON D. MUNSON(1) and SUZANNE WETZEL(2) . (1)Laval University, Québec (Qc), G1K 7P4, Canada, and (2)Petawawa National Forestry Institute, Chalk River (Ont.), K0J 1J0, Canada. Water relations and nutrition of Eastern White Pine subjected to intensive silvicultural treatments.

The principal goal of the study was to evaluate the level of moisture stress caused by intensive silvicultural treatments on Eastern White Pine (Pinus strobus L.) , and to examine how water and nutrient status interact to control photosynthesis and growth. During the summer of 1993, predawn and midday water potentials were measured on four different dates, and foliage was sampled for nutrient analyses. Throughout the season, competing vegetation had a significant negative effect on water status of the trees, and this effect was most marked in control plots, with the highest level of competition. Long term water-use efficiency, as measured by carbon isotope composition of foliage, was greatest for treatments including vegetation control. Fertilization did not affect plant water status, but it improved the long term water-use efficiency of trees in scarified plots.

BOUTTON, THOMAS W., STEVEN R. ARCHER, and ANDREW J. MIDWOOD. Texas A&M University, College Station, TX, 77843, USA. $\delta^{13}C$ values of soil organic matter confirm increased tree/shrub abundance in a subtropical savanna ecosystem.

Present vegetation patterns and a 50 yr sequence of aerial photos suggest that C_3 woody plants (low $\delta^{13}C$) have increased in areas that were once C_4 grassland (high $\delta^{13}C$) in the Rio Grande Plains, southern Texas. Low-lying landscape positions are presently closed-canopy subtropical thorn woodland, while uplands have a two-phase pattern with discrete tree/shrub assemblages in a grassland matrix. To confirm increased tree/shrub abundance, $\delta^{13}C$ was determined on soil organic matter (SOM) from remnant grasslands and from upland and lowland areas now dominated by woody plants. $\delta^{13}C$ of grassland SOM was ≈ -17‰ throughout the upper 1.5 m of the profile, consistent with long-term dominance by C_4 grasses. Although $\delta^{13}C$ of litter and roots in areas currently dominated by woody plants were typical of a C_3 community (-25‰), $\delta^{13}C$ of SOM ranged from -20‰ at 0-15 cm (≈ 50% C_4 carbon) to -15‰ at 15-90 cm (≈ 85% C_4 carbon). In areas now

dominated by C_3 trees/shrubs, SOM derived from C_3 sources was found exclusively in the sand ($\delta^{13}C$= -26‰) and coarse silt ($\delta^{13}C$= -21‰) fractions, which have high turnover rates; SOM from C_4 sources was primarily in the fine and coarse clay ($\delta^{13}C \geq$ -16‰) fractions, which have slow turnover rates. These results based on $\delta^{13}C$ of SOM provide direct evidence that both upland and lowland areas now dominated by woody plants were once grassland or open savanna dominated by C_4 grasses, and confirm similar conclusions based on other techniques.

BOUWES, NICOLAAS W. and CHRIS LUECKE. Dept of Fisheries and Wildlife, Utah State University, Logan, UT, 84322-5210, USA. The effects of growth rates on larval Bonneville cisco survivorship: evidence from otolith microstructure.

Formation of year class strength in fish populations is often determined by differential survivorship at the larval stage. Increase in larval size can decrease susceptibility to predation and starvation, suggesting faster growing larvae should be selected for. Others argue, however, that larger larvae are more visible and hence are more frequently encountered by their predators. We suggest optimal growth should be dependent on the predatory regime and prey availability. These factors may have little effect on mean size at age but may decrease variability. We tested this hypotheses by examining the otolith microstructure of larval Bonneville cisco. Initial daily growth rates were compared between 1, 2, and 3 month old young-of-the-year cisco. Our analysis suggested that cisco surviving to 3 months of age are a biased subset of the initial size distribution. Year to year variability in larval survivorship may be determined by factors affecting variation in larval growth rate.

BOWDEN, RICHARD D.[1], KATHLEEN M. NEWKIRK[2], GINA RULLO[1] and CATHY M. MILLIKIN[3]. (1) Allegheny College, Meadville, PA 16335, USA; (2) The Ecosystems Center, Woods Hole MA, 02543, USA; (3) University of California-Davis, Davis, CA 95616, USA. Effects of soil moisture and temperature on fluxes of carbon dioxide and methane in laboratory-incubated temperate forest soils.

Relative effects of soil moisture and temperature on carbon dioxide (CO_2) and methane (CH_4) fluxes between soils and the atmosphere were examined in the laboratory. Forest floor and mineral soils were collected from the Harvard Forest LTER and incubated at temperatures ranging from 5°C to 25°C, and at soil moistures ranging from 20% to nearly 100% of field moisture capacity (FMC). Forest floor CO_2 effluxes were greater than mineral soil effluxes, on a per gram-soil as well as a per gram soil organic matter (OM) basis. For both soil horizons, CO_2 effluxes were greatest between 50% and 80% of FMC, with the highest rates (over 25 ugC/g soil OM/h) observed in forest floor incubated at 25°C. For CH_4, mineral soil OM showed greater uptake rates than forest floor OM. Uptake was generally highest (over 35 ngC/g soil OM/h) between 40% and 65% of FMC in the mineral soil, with drastically reduced levels of uptake at dry or wet soil conditions. Temperature displayed a minimal effect on uptake for both soil horizons. These results indicate that both temperature and moisture are important in controlling CO_2 effluxes, but that moisture alone is the strongest controller of CH_4 uptake.

BOWMAN, WILLIAM D., BRIAN THOMAS, JAMES C. SCHARDT, STEVEN K. SCHMIDT, AND EDMUND E. GROTE.. University of Colorado, Boulder, CO 80309-334. Influence of clovers on nitrogen inputs, production and community composition in alpine tundra.

The amount of symbiotic N fixation by three alpine *Trifolium* species was estimated in three communities using the ^{15}N natural abundance technique. The tissue N derived from fixation ranged from 50 to 100%, depending on species and community. This translates to spatially averaged inputs of between 135 and 340 mg N m^{-2} yr^{-1} from fixation. These nitrogen inputs are spatially heterogeneous, as a result of the clumped nature of the clover distribution. The impact of one clover species, *Trifolium dasyphyllum*, on soil N pools, species composition, and production was assessed in dry meadow communities. Extractable NO_3^--N and NH_4^+-N increased by 175 %, and aboveground biomass was 128 % greater in the clover mats relative to the surrounding tundra. The greater biomass was the result of the presence of *Trifolium*, and not due to an increase of growth of non-*Trifolium* species. However, there was an increase in the proportion of forb biomass and a decrease in the proportion of graminoid biomass in the non-*Trifolium* biomass component. There were both positive and negative species associations with *Trifolium*, indicating that both facilitative and inhibitive biotic interactions occur with this clover species in alpine tundra.

BOYCE, RICHARD L., ANDREW J. FRIEDLAND, and C. PAGE CHAMBERLAIN. Dartmouth College, Hanover, NH, 03755, USA. Changes in canopy uptake and allocation of $^{15}NH_4^+$ and $^{15}NO_3^-$ during the growing season in red spruce.

Studies at Whiteface Mtn., NY, indicate that the canopy of its high-elevation spruce-fir forest absorbs large amounts of nitrogen from atmospheric deposition. We conducted a field experiment using *Picea rubens* saplings to determine the growing season dynamics of canopy nitrogen uptake. Canopies were sprayed with either $(^{15}NH_4)_2SO_4$ or $K^{15}NO_3$ solutions at concentrations similar to fog water. Saplings were treated approximately once a week in either June, July or August and were sampled at the end of September. Foliar ^{15}N levels were highest in the June-treated saplings and were lower in the July- and August-treated trees. Foliage treated early in the growing season showed a J-shaped ^{15}N distribution; current-year foliage had the highest levels, previous-year foliage had the lowest, and older foliage was intermediate. Foliage treated late in the growing season had the lowest levels in the current-year foliage, while ^{15}N levels increased with foliar age. Our results indicate that canopy nitrogen uptake is most important early in the growing season, when absorbed nitrogen is utilized by developing foliage. Nitrogen absorbed later in the growing season appears to be stored in older foliage.

BOYLE, TERENCE P., MATTHEW J. STRAND, and NANCY J. HOEFS. National Biological Survey, Colorado State University, Fort Collins, CO, 80523, USA. Structure and longitudinal succession of the benthic macroinvertebrate community in the Namekagon and Saint Croix Rivers of Wisconsin and Minnesota.

The Saint Croix River, and its tributary the Namekagon, arise in lakes in northern Wisconsin and flow for approximately 400 km where it becomes Lake Saint Croix before it joins the upper Mississippi River. As part of a natural resource inventory, the structural and functional attributes of the benthic macroinvertebrate community were sampled at 12 stations May through September and analyzed with several statistical and numerical methods. Density, taxonomic richness, and other measures of community structure displayed a general reduction north to south; functional groups also changed associated with stream order, geomorphology, land use practices, and changes in the hydrological regime due to peaking hydropower dams. Locally the structure of the benthic macroinvertebrate community reflected the influence of major tributaries. Data analysis benthic macroinvertebrate community will be used to derive a profile of ecological health of the river and develop community level endpoints for monitoring.

BRANCH, LYN C., DIEGO VILLARREAL, JOSE L. HIERRO, and MARCELA MACHICOTE. University of Florida, Gainesville, FL, 39611, USA and Universidad Nacional de La Pampa, 6300 Santa Rosa, La Pampa, Argentina. Herbivory and landscape dynamics in semi-arid scrub of central Argentina.

Herbivores play a key role in the dynamics of landscapes through direct impacts on the composition and structure of plant communities, modification of ecosystem processes, and alteration of the spatial attributes of the landscape. We document the role of the plains vizcacha (Lagostomus maximus, Family Chinchillidae), a large colonial rodent, in landscape change in semi-arid scrub of Argentina. The effects of vizcachas on the structure and composition of plant communities were examined 1) along transects extending from the communal burrow system to the edge of the colony site (80-100 m), 2) experimentally with exclosures, and 3) for five years following local extinction of vizcachas. Our data indicate that vizcachas create large open patches with a 20-40% increase in bare soil, cause a shift in dominance in plant communities from grasses to forbs, and significantly decrease canopy stature. Local extinctions and colonizations by vizcachas result in a dynamic mosaic of patches on the landscape.

BRASHER, ANNE M. University of California at Davis, Davis, CA, 95616, USA. Life history and population structure of an amphidromous mollusc, Neritina granosa (hihiwai), endemic to Hawaiian streams.

Surveys were conducted bimonthly in Waikolu Stream on the Island of Moloka'i to determine distribution and abundance of the endemic mollusc Neritina granosa (hihiwai). N. granosa have an amphidromous life cycle. Eggs are attached to rocks in the stream, the eggs hatch and the larvae wash out to sea. After spending a larval phase as marine plankton, small (less than 5mm diameter) N. granosa return to the stream where they spend the remainder of their life. Reproduction was found to peak in the rainy months (November through January). Recruitment back to the stream continues throughout the year. Recruitment was highest during the spring (May) and lowest in January. N. granosa is primarily nocturnal, subjecting it to predation by the introduced prawn Macrobrachium lar. The greatest threat to N. granosa, however, is habitat destruction, especially dewatering of streams which reduces optimal habitat and inhibits larval dispersal and return migrations.

BREITBURG, DENISE L. The Academy of Natural Sciences, Benedict Estuarine Research Laboratory, Benedict, MD, 20612, USA. Linking ecosystem-level processes with population-level responses: the importance of variation among species in predicting effects of estuarine eutrophication.

The goal of ongoing research in the Chesapeake Bay is to determine how oxygen depletion, which is common in bottom waters of stratified coastal systems, influences trophic interactions and recruitment of estuarine fishes. In Chesapeake Bay, subpycnocline oxygen concentrations decline during summer to levels that can be physiologically stressful or lethal to animals dependent on aerobic respiration. Field sampling, laboratory behavior experiments, and mesocosm studies indicate that the effects of low oxygen vary among interacting pairs of species in a single zooplankton-fish larvae-larval predator food web. The consequence is determined by how dissolved oxygen influences each individual species' vertical distribution, capture success, and escape behavior. Predation on a single prey species increases with some predators but decreases for others. Similarly, predation by a single predator increases for some prey but decreases for others. Spatially-explicit and individual-based modeling techniques are being used to predict the net effect of the varied interactions caused by this ecosystem-level perturbation.

BREMIGAN, MARY AND ROY A. STEIN. The Ohio State University, Columbus, OH, 43210, USA. The role of zooplankton size in fish-zooplankton interactions.

Fish-zooplankton interactions, which often lead to community-wide effects, have been well-studied in north temperate lakes, but have received less attention in southeastern reservoirs, where gizzard shad (Dorosoma cepedianum) and small zooplankton taxa are commonly most abundant. We hypothesize that differences in zooplankton size underlie variability both in larval shad survival and the impact of young-of-year (YOY) shad on zooplankton abundance. In 1-m^3 bag-enclosures, survival of 40 larval shad, after 2 weeks, was four times higher with small zooplankton than with large zooplankton. From a survey of 13 reservoirs, peak larval shad densities ranged from <1 larvae·m^{-3} to >80 larvae·m^{-3}, and zooplankton size was consistently small (x<0.50 mm). At peak shad densities >10·m^{-3}, zooplankton abundance declined after

peak larval shad abundance, whereas in reservoirs with low larval shad abundance, larval shad-zooplankton dynamics were not closely linked. Though small zooplankton size may predispose systems to shad recruitment, given their small gape size, differences in zooplankton size among systems did not appear to explain the outcome of YOY shad-zooplankton interactions. Rather, factors such as initial larval shad density and zooplankton productivity likely mediate the relationship between YOY shad consumption and zooplankton abundance.

BRESHEARS, DAVID D. and FAIRLEY J. BARNES. Colorado State University, Fort Collins, CO 80523, USA, and Los Alamos National Laboratory, Los Alamos, NM 87545, USA. Spatial partitioning of water use by herbaceous and woody lifeforms in semiarid woodlands.

Current models for predicting water balance and community composition in semiarid regions distinguish soil moisture by depth but ignore expected differences in tree canopy vs. intercanopy locations. The goal of this study was to investigate relationships in semiarid woodlands between spatial heterogeneity in soil moisture and plant water status of three species (Pinus edulis, Juniperus monosperma, and Bouteloua gracilis). Soil moisture was significantly different in tree canopy vs. intercanopy locations. Plant water potential of J. monosperma and B. gracilis were both correlated with shallow soil moisture (0-15 cm). These results led to a hypothesized model predicting that multiple combinations of herbaceous and woody biomass can exist at a site and suggest horizontal differences in the soil moisture profile may be as important as those associated with depth.

BRET-HARTE, M. SYNDONIA and F. STUART CHAPIN, III. University of California, Berkeley, CA, 94720, USA. Competition for nitrogen and species effects on ecosystem processes in Alaskan tundra plants

We are using simulation models to explore how growth of co-dominant tundra plant species with different physiological characteristics could affect ecosystem processes. We wish to understand how these species can stably coexist, if competition for nitrogen is their main interaction, and how their growth will feedback to ecosystem-level C and N cycling. We hypothesized that differences in phenology would allow slower-growing species with low nutrient use to avoid competition and coexist with faster-growing species with high nutrient use. We simulated the growth of one major species from each physiognomic type, assuming that plants compete only for soil nitrogen. Preliminary results indicate that differences in phenology of growth and N uptake are more important in controlling the outcome of competition than differences in nutrient content or extent of retranslocation of nitrogen from senescing tissue. Differences in phenology permitted short-term (10-50 y) coexistence of some, but not all species in the model. We are extending the model to explore the effects of heterogeneity in nitrogen supply, and are developing simulations of feedback to soil nitrogen via plant litter.

BREWER, CAROL A. and JANE M. BEISWENGER. The University of Montana, Missoula, MT, 59812, USA and The University of Wyoming, Laramie, WY, 82071, USA. Global change and the global carbon cycle: a critical thinking exercise.

The increasing concentration of carbon dioxide in the atmosphere and its probable impact on climate is receiving considerable attention in the press. Most biology students are aware of the increase of atmospheric CO_2 and of some of its possible consequences (e.g., global warming). This activity enhances their understanding of global warming and of the carbon cycle. Students are asked to balance carbon sources and sinks using information about carbon fluxes from the scientific literature. To relate the increased CO_2 and global warming to their personal lives, we ask them to explore the impact a CO_2-induced rise in global temperature on the corn agroecosystem of the Unites States. Finally, students are asked to think about 1) human impact on this cycle; 2) how we might mitigate problems associated with increased greenhouse gases; and 3) to consider a variety of potential impacts (e.g., aesthetic, health, economic) resulting from their proposed solutions.

BREWER, J. STEPHEN AND WILLIAM J. PLATT. Brown University, Providence, RI, 02912, USA and Louisiana State University, Baton Rouge, LA, 70803, USA. Modeling clonal growth of a "pyrophilic" golden aster, *Pityopsis graminifolia*.

A spatially-structured demographic model of clonal growth responses of grass-leaf golden aster (*Pityopsis graminifolia*) to low-intensity fire is described. Results of the model revealed that widespread but short-lived increases in rates of vegetative spread following May fires corresponded to a hypothesized shift in competition from aboveground to belowground. In contrast, prolonged increases in rates of vegetative spread occurring at smaller scales (e.g. within gaps) apparently resulted from increased growth rates or larger sizes of clones in areas of low shoot density. We hypothesize that the ability of golden aster to increase proportional allocation of resources to new shoots following May fires likely represents a specific adaptation to the chronic occurrence of low-intensity growing-season fire.

BRIDGE, S.R.J. and E.A. JOHNSON. Department of Biological Sciences and Kananaskis Field Stations, University of Calgary, Calgary, AB, T2N 1N4, CANADA. Integrating fire frequency models with Geographic Information Systems.

Statistically acceptable fire frequency models using time since fire maps are iterative and require specialized statistical and graphical routines. We introduce an automated technique for studying fire frequency using Geographic Information Systems' analytical capabilities. A new statistical sub-routine works within the GIS framework to estimate fire frequency in three steps: (1) spatial and temporal partitioning of the map produces homogeneous time since fire distributions; (2) for each partition, parameters are estimated and the distribution is tested for goodness of fit to a negative exponential or Wiebull model; (3) partitions with a good fit are tested for statistical difference. The fire frequency estimates the landscape survivorship due to fire. It provides a testable model for estimating the parameters of the disturbance cycle, for detecting changes in the cycle and for predicting the proportion of landscape in old growth.

BRIGGS, CHERYL J. Imperial College, Silwood Park, Ascot, Berks. SL5 7PY. U.K. The dynamics of insect-pathogen interactions in seasonal environments.

Populations of a number of forest insect species undergo dramatic multi-year fluctuations of outbreak and decline. Virus epizootics are frequently associated with the high density phases of these cycles, and it has been suggested that the interaction with the virus may drive the cyclic dynamics. Most previous models attempting to explain cycles in forest insects make the unrealistic assumption that there are continuous overlapping generations of both the host and pathogen, however most forest insects reproduce only once per year, while their viral pathogen can potentially cycle through many rounds of infection within the year. In a model that combines discrete-time reproduction between season with continuous-time pathogen transmission within a season, we find that long-period persistent cycles driven solely by the pathogen are unlikely. The potential for recycling of the pathogen within a season, and the survival of the pathogen between seasons contribute to the persistence of the host-pathogen interaction. The model is applied to the European spruce sawfly (*Gilpinia hercyniae*) which invaded Wales in the 1970's and was subsequently driven to low densities by a nuclear polyhedrosis virus (NPV).

BROCKWAY, DALE G. and KENNETH W. OUTCALT. USDA Forest Service, Gainesville, FL 32611. Plant cover, diversity and biomass in longleaf pine wiregrass sandhills ecosystems following hexazinone application.

A longleaf pine (Pinus palustris) wiregrass (Aristida stricta) sandhills ecosystem which had been invaded by turkey oak (Quercus laevis) was treated in May 1991 with single applications of hexazinone to assess its influence on plant cover, diversity and biomass. The 1.1 broadcast treatment increased eveness and decreased species richness and diversity in the first season. Forb cover declined 47% the first season then increased 236% by the third season. The 1.1 and 2.2 kg/ha spot treatments decreased eveness and increased species richness in the first season which, continued through the third season. Forb cover increased 53% in the second and third seasons for the 1.1 kg/ha treatment. Wiregrass biomass increased 100% in the first season for the 2.2 kg/ha treatment. All treatments caused an 82-94% decline in oaks and an increase in grasses during the first season, which persisted through the third season. Hexazinone-induced oak mortality freed microsites which allowed the seasonal flourishing of forbs and progressive expansion of wiregrass. The small initial response of forbs and wiregrass to the broadcast treatment and the continuing lack of response by forbs to the 2.2 kg/ha spot treatment, indicates that the 1.1 kg/ha spot treatment may be most desirable for restoring these ecosystems.

BRODY, ALISON K. and RANDALL J. MITCHELL. Stanford University, Stanford, CA 94305, USA and University of New Mexico, Albuquerque, NM 87141, USA. The effects of floral display size on pollinator visitation and plant fitness.

Monocarpic perennials are expected to maximize fitness through "big bang" reproduction. For plants that rely on animals for pollination, the fitness of individuals producing large floral displays should be favored over those with small floral displays through increased attraction of pollinators and a concomitant increase in female (seed set) and/or male (successful pollen export) function. We tested the effects of display size on pollinator visitation rates and seed production in the monocarpic perennial, Ipomopsis aggregata (Polemoniaceae). We found that many flowered individuals are more likely to be approached first in a given foraging bout by hummingbirds. However, we did not find a disproportionate increase in the number of flowers visited on many- versus few-flowered plants. Our results suggest that the advantages of producing many flowers lie in the total number of seeds contributed to the gene pool, and to male function through pollen export. In addition, we suggest that the sequence of visitation to plants by pollinators may have important consequences for the receipt and delivery of outcross pollen.

BRONSTEIN, JUDITH L. University of Arizona, Tucson, AZ 85721, USA. Intrinsic versus extrinsic constraints and their evolutionary implications in an obligate mutualism.

How do many mutualisms persist so successfully over time, when the evolutionary interests of the partners strongly conflict? One possibility is that mutualists' fates are linked by ecological factors extrinsic to their interaction that limit the success of both partners simultaneously. I investigated intrinsic versus extrinsic constraints within the mutualism between the Florida Strangling Fig (*Ficus aurea*) and its obligate, species-specific pollinator (*Pegoscapus jimenezii*). Fig wasps pollinate fig flowers, then oviposit in some of them;

pollinator offspring feed on developing seeds. Although a tradeoff between numbers of seeds and seed-eating wasps is to be expected, significantly *positive* correlations exist in this and every other fig/pollinator mutualism studied to date. Pollinators were hand-introduced in different combinations to over 100 *F. aurea* inflorescences to elucidate possible causes of this pattern. Seed-wasp correlations were significantly positive when one pollinator was introduced, but consistently and strongly negative in multiple-pollinator figs. In light of the probable causes of these patterns, these results suggest that extrinsic limits to the mutualists' reproductive success dominate when pollinator populations are small (as they commonly are in nature), whereas intrinsic limits, and the coevolutionary conflicts that accompany them, dominate when pollinators are more abundant.

BROWN, D. GORDON and ARTHUR E. WEIS. University of California, Irvine, CA 92717, USA. Quantity vs. quality: Grazing history's direct and indirect influences upon the performance of the goldenrod leaf beetle, *Trirhabda canadensis* (Coleoptera: Chrysomelidae).

Grazing-induced variation in leaf nutritional quality can affect herbivore performance both directly and indirectly. To jointly examine these paths of influence, we established many plots using ramets from a single goldenrod (*Solidago missouriensis*) clone. *T. canadensis* grazed some plots from 1988 through 1990. We fed *T. canadensis* larvae and female adults foliage from both grazed and ungrazed plots in performance trials in 1990. We used structural equation modeling to separate direct and indirect effects of foliage quality upon insect performance. In May, foliage in grazed plots was less nutritious than that in ungrazed plots and directly reduced the growth of *T. canadensis* larvae. Decreased consumption by larvae fed foliage from grazed plots indirectly intensified this negative influence. Foliage in grazed plots fed to adult females during their performance trial was flushed in July following defoliation by larvae in May. This foliage was more nutritious than that in ungrazed plots. However, reduced emergence mass and greatly diminished total foliage consumption completely offset the direct stimulation of adult growth and swamped the positive influence of foliage quality upon egg production. This made the net effect of eating foliage from grazed plots negative. Foliage consumption explained most of the variance in larval growth and egg output of *T. canadensis*.

BROWN, JAMES H. and DOUGLAS A KELT. University of New Mexico, Albuquerque, NM 87131, USA. Diversification of body size: ecological and evolutionary mechanisms.

Some of the most pervasive patterns in nature are the statistical distributions on a logarithmic scale of body sizes among species in different taxonomic groups and ecological settings. Using examples drawn from nonvolant mammals, we first document the patterns: 1) the right-skewed distribution of clades and of entire continental faunas; 2) the nearly uniform distribution of sizes within local communities; 3) macroevolutionary reduction in the extreme sizes as the area of continents and islands decrease; 4) microevolutionry trends toward gigantism and dwarfism in insular races of small and large species, respectively; and 5) Cope's rule: the continual evolution and extinction of clades of giant mammals. Then we present a theory, based on the allometries of energetics and their fitness consequences, that offers a unifying explanation for these patterns. This theory suggests that there is an optimal body size that is a consequence of energetic and phylogenetic constraints, and that local ecological conditions, including interspecific interactions, result in the evolutionary diversification of sizes away from the optimum.

BROWN, JENNIFER F. and DEBORAH L. ELLIOTT-FISK. University of California, Davis, CA.
Interactions of Sand Movement and Vegetation in a Dune Community at Mono Lake, CA.

The sand dune ecosystems of Great Basin playas offer an ideal opportunity to study the interactions between mobile sand and the vegetation community. The composition and structure of the plant community may reflect differential tolerances of plant species to sand deposition, while the presence and physical morphology of individual plants may alter sand mobility. On the dune shoreline of Mono Lake, seasonal patterns of sand deposition and erosion were measured with stakes located on a grid that encompassed a gradient from unvegetated playa to well-vegetated parabolic dunes. The presence or absence of plants is associated with the amount of sand deposition and erosion across this study site. Characteristics such as shrub spacing, the profile area intercepted by the wind, cover, and density were incorporated into a multivariate model describing the vegetation that stabilizes sand movement in a natural dune community.

BROWN, STEVEN S., STEPHEN T. THRELKELD, AND GARY R. GASTON. University of Mississippi, University, MS 38677, USA. Interactive effects of fish and nutrients on macrobenthic communities.

A center point-enhanced 2^4 factorial design was used in the treatment of 20 small ponds with 16 possible combinations of a nutrient addition and three fish species (common carp, grass carp, and largemouth bass), and 4 additional ponds treated at 50% of the high level of each factor. Benthic core samples were collected from each pond on a monthly basis, beginning one month prior to treatment and extending four months after treatment (May-September). Water quality parameters were also analyzed at two week intervals over the same study period. The independent and interactive effects of fish and nutrient treatments on macrobenthic assemblages in ponds were assessed using measures of species richness, evenness, abundance, dominance of surface vs. subsurface feeders, and community size structure. Numerous interactive effects detected in the experiment suggest the need for more experimentation on multiple controls of benthic community structure.

BROWN, VIRGINIA B., DAVID S. SCHIMEL, and STEVEN R. ARCHER. Colorado State University, Ft. Collins, CO 80523, National Center for Atmospheric Research, Boulder, CO 80307, and Texas A&M University, College Station, TX 77843. Distributions of photosynthetic capacity, foliar nitrogen and light within a complex tree-shrub canopy.

Plant canopies of a southern Texas mesquite (Prosopis glandulosa)-shrub canopy were examined to determine patterns of photosynthetic carbon exchange capacity (Amax) relative to foliar nitrogen contents, interception of photosynthetically active radiation (PAR), and height within the canopy. Amax, leaf nitrogen, and PAR all increased with height in the canopy. Amax scaled linearly with leaf nitrogen content, and leaf nitrogen increased linearly with PAR levels within the canopy. These results in a complex canopy are similar to light, nitrogen, and Amax distributions seen in monospecific, simple canopies and predicted by canopy carbon-gain optimization models. The existence of a predictable relationship between Amax and light interception regardless of canopy structure suggests that remotely sensed vegetation indices coupled with vegetation-specific models of phenology or stress may provide robust calculations of carbon uptake on large scales.

BRUGAM, RICHARD B. and MELODY GIORGI Dept. of Biological Sciences Southern Illinois University, Edwardsville, IL 62026 Paleoenvironmental Change in the Upper Peninsula of Michigan as Indicated by Fossil Diatoms.

We analysed pollen and diatom microfossils in a core taken from Glimmerglass lake in Sylvania Wilderness area in the Upper Peninsula of Michigan. Hemlock pollen was absent at the bottom of the core but appeared at an intermediate depth level indicating the arrival of Hemlock trees in the watershed dated by other investigators at 3,000 B.P. At the same time the diatoms shifted from Fragilaria construens var. venter to a group including Aulacosira distans, A. ambigua, A. perglabra and Tabellaria fenestrata. Preliminary paleoenvironmental reconstructions show that this shift in species abundances indicates a change in water chemistry towards more acid, lower alkalinity conditions.

BRUSH, GRACE S., WILLIAM B. HILGARTNER and HUMAIRA KHAN. The Johns Hopkins University, Baltimore, MD, 21218, USA. The stratigraphic record of recent climate change in mid-Atlantic USA.

The Medieval Warm Period and Little Ice Age are recorded in sediments deposited in tributaries and marshes surrounding the Chesapeake and Delaware Bays in the mid-Atlantic region of USA, by changes in pollen and seeds of terrestrial and aquatic plants, and changes in influxes of charcoal, sediment, metals and nutrients. Fossil pollen and seeds portray a regional landscape characterized by conditions drier than present from about 1000 to 1200 AD. During the same period, high charcoal and sediment influxes indicate high fire frequency. This short dry interval was followed by an expansion of submerged aquatic plants, low marsh plants, and terrestrial plants that occupy wet habitats. Charcoal influxes are extremely low during the latter interval, which extended from about 1200 AD to 1500 AD. Plant macrofossil and pollen distributions indicate a second dry period extending from 1550 to 1650 AD, which appears similar to the earlier Medieval Warm interval.

BRUST, GERALD E. Purdue University, West Lafayette, IN, 47907, USA. Straw-mulch and natural enemies reduce Colorado potato beetle numbers and damage in potato agroecosystems.

The effects of mulching on Colorado potato beetle (*Leptinotarsa decemlineata*) populations and damage to potato are reported. Potato plots were established in 1991 and wheat-straw placed in half the treatments after potato emergence. Mulching had no significant effect on beetle migration. The numbers of second, third, and fourth instars of first-generation Colorado potato beetle, and all instars of second-generation Colorado potato beetle were significantly lower in mulch than non-mulch plots. A significant increase in numbers of soil predators began in mulch plots approximately 2-3 weeks after straw was placed in the field. Many of the soil predators climbed potato plants and fed on second and third instars of the Colorado potato beetle. Eggs and first and second instars of the Colorado potato beetle were heavily fed upon by coccinelids and chrysopids. Significantly more Colorado potato beetle eggs and larvae experienced mortality in mulch plots than non-mulch plots. Non-mulch plots suffered 2.5 times more defoliation than mulch plots. Tuber yields were 35% and 32% greater in mulch plots than in non-mulch plots in 1992 and 1993, respectively.

BRYANT, CHARLOTTE. University of Minnesota, St. Paul, MN, 55108. Spatial variability in biogeochemical processes along upland-wetland toposequences.

Nitrogen cycling, litter decomposition, and total soil and aboveground C and N were measured along 5 upland-wetland transects beginning in 1992. The wetlands cover a pH gradient from ~3.8 (Sphagnum bog) to ~7 (black ash swamp), representing five different wetland types. N-cycling, using an *in situ* soil incubation method, and litter decay were measured in each of the plant communities occurring along the water-table gradient, including the zone between upland and wetland. Abiotic factors including depth to water table, O_2 availability, soil temperature, and water chemistry were measured monthly within each plant community. Correlations between vegetation type, N-cycling, decomposition, and abiotic processes will be sought using regression analysis. Initial results show NH4+ and NO3- production declining

sharply from the upland toward central wetland communities with greatest variability among upland sites. Litter decay shows a similar trend with high mass loss occurring in the margin of the wetland as well. Of the parameters pH, O_2 and soil temperature, temperature at 20 cm was the best predictor for N-cycling rates ($P < 0.05$). However, none of these was significant for the central wetland zones. Plant and soil chemistry are forthcoming and will be examined similarly.

BRYANT, DAVID M.[1], TIMOTHY R. SEASTEDT[1] and ELISABETH A. HOLLAND[2]. [1]Institute of Arctic and Alpine Research, University of Colorado, Boulder, CO 80309, USA, [2]National Center for Atmospheric Research, Boulder, CO, 80307, USA. Nitrogen and lignin controls on decomposition in alpine tundra

Preliminary data from an ongoing 2 year study were used to explore the respective roles of nitrogen and lignin in soil organic matter dynamics. Literature surveys indicate that nitrogen cannot be limiting to decomposition when C:N ratios are < 20 (ca. >2% N). Initial high nitrogen ratios are hypothesized to subsequently reduce decomposition rates although mechanisms explaining this are largely speculative. Lignin values have a uniformly negative effect on decomposition rates in all studies investigated. The CENTURY model "microcosm" version was used to evaluate nitrogen and lignin controls over the range of temperature and precipitation values likely to be encountered in alpine tundra. Data was used to test other model predictions of litter decomposition and the relationship of nitrogen in soil organic matter dynamics.

BRYLA, DAVID R. and JOHN M. DUNIWAY. University of California, Davis, CA, 95616, USA. The effect of mycorrhizal fungi on drought recovery of infected plants.

A study was conducted to determine the extent to which and mechanisms by which mycorrhizae affect plant tolerance of drought. Safflower plants were grown in the presence or absence of mycorrhizal fungi under controlled environmental conditions. Soil phosphate levels were adjusted to yield mycorrhizal (M) and nonmycorrhizal (NM) plants comparable in size and P status. There were no differences between M and NM treatments in the total amount of soil water transpired after irrigation was withheld. However, at low soil water potentials (-2.5 to -3.5 MPa), NM plants were able to tolerate lower leaf water potentials than M plants by maintaining significantly higher leaf relative water contents. When plants were reirrigated, NM plants also increased stomatal conductance and growth significantly faster than M plants. We also found that M plants had significantly lower levels of infection and shoot P concentrations at low soil water potentials than under high water potentials. These results indicate M safflower plants are unable to acquire adequate P from the soil under drought conditions.

BUCHANAN, BRYANT W. University of Missouri, Columbia, MO, 65211, USA. The influence of reproductive resource limitation on tactic choice by male treefrogs.

Tactic choice between calling or satellite behaviors in frogs is believed to be influenced by competition resulting from differences in the availability of call sites or females. Previous studies of the squirrel treefrog, *Hyla squirella*, suggest that the expression of satellite behavior is context dependent, and is a response to changing conditions of competition among choruses. I experimentally assessed the influence of call site and female availability on the behavior of individual males by inducing chorusing behavior in male treefrogs under controlled conditions in a 5x5x2.5 m enclosure. Six groups of 40 males were exposed to experimental treatments in a repeated measures factorial design using high and low values of call site and female availability. The availability of call sites appears to be the most important factor influencing tactic choice in individual frogs. Female availability did not affect tactic choice by individual males independently of site availability. These results support a model of satellite behavior as a plastic, context-sensitive alternative to vocal advertisement under conditions of intense competition among males for sites from which to advertise to females.

BUCK, KIMBERLY A. AND LAWRENCE E. STEVENS. Northern Arizona University, Flagstaff, AZ 86011, USA. Temporal, geomorphic and flow regulation effects on Colorado River waterbird distribution in the Grand Canyon, AZ.

Completion of Glen Canyon Dam in 1963 decreased sediment transport and mean and variability of water temperature, changing the Colorado River in the Grand Canyon from a turbid, seasonally warm stream into a cold, clearwater stream. These changes resulted in a dramatic increase in waterbird (aquatic and semi-aquatic avifauna) density and diversity in the river downstream, with a greatly increased wintering concentration and new summer breeding populations. Historical data and census data since 1973 demonstrate that waterbird density and diversity increased as a result of flow regulation and undergo dramatic changes over time (MANOVA approximate $F_{6,661} = 4.756$, $p < 0.001$). Reach geomorphology and width are positively correlated with waterbird density ($F_{6,661} = 5.634$, $p < 0.001$). Turbidity, a function of tributary confluence location and distance from the dam, is negatively correlated with waterbird density ($F_{6,661} = 11.331$, $p < 0.001$). Cannonical correspondence analysis of monthly relative abundance data demonstrates that different waterbird guilds vary in response to these interacting temporal and spatial factors.

BUDY, PHAEDRA and CHRIS LUECKE. Utah State University, Department of Fisheries and Wildlife, Logan, UT 84322-5210, USA. Food dependent effects of temperature on growth on endangered sockeye salmon.

Understanding the factors that determine growth can be an important aspect of managing endangered fish populations because differential growth rates among juvenile fish can lead to varying mortality. We designed and performed a series of juvenile growth experiments at different temperature regimes in two oligotrophic lakes with different levels of productivity. The objectives of the study were to identify the combined effect of temperature and food availability on juvenile sockeye growth rates and to provide a field test for a bioenergetics based model driven by food and temperature. Results from our study indicated that zooplankton food resources, temperature, and fish density affected growth. Effects of temperature were large when food availability was high. These results will aid in management decisions concerning a potential whole lake fertilization of one of five historical rearing lakes of endangered Snake River Sockeye Salmon.

BURCH, WALTER H., R. H. JONES, R. J. MITCHELL, and P. MOU. School of Forestry, Auburn University, AL, 36849, USA. Root dynamics during forest regeneration-a minirhizotron investigation.

Vegetation composition treatments, differing mainly in life form, were established following a forest harvest near Auburn, Alabama, to assess the influence of aboveground community composition on root dynamics. Treatments were: pure loblolly pine; mixed hardwood species; mixed herbaceous species; and all combinations thereof. Root systems were sampled *in situ* using a minirhizotron video camera system equipped with an ultraviolet light source. Image analysis was used to assess root density, live root fraction, and root turnover. Root densities at all depths have steadily increased two years post-harvest. Density differences were greatest in upper horizons in year 1 and in middle horizons through year 2. Treatments containing an herbaceous component showed significantly higher root density, while root density was lowest in the pine monoculture. Live root fractions were initially very high following root contact with minirhizotron tubes, but declined thereafter to approximately 50 percent. Minirhizotron technology has proven to be a useful, non-destructive method for sampling root systems in forestry research.

*BURGER. JUTTA C., and SVATA M. LOUDA. University of Nebraska, Lincoln, NE, 68588, USA. Indirect vs direct effects of grasses on growth of a cactus (Opuntia fragilis): insect herbivory vs competition.

Spatial variation in plant performance is usually attributed to direct mechanisms, such as plant physiological tolerances or competitive interactions. However, indirect mechanisms, such as variation in herbivore pressure mediated by microhabitat, could also create the same pattern. We studied the growth of the grassland cactus Opuntia fragilis under different regimes of grass canopy cover, to establish the extent to which canopy cover plays a direct, competitive role versus an indirect, mediatory role in cactus growth. We altered aboveground microhabitat to create: (1) open canopy, with grass pinned down; (2) shaded canopy, with an open mesh cage staked over the cactus; and (3) ambient grass canopy. We measured seasonal plant growth and recorded changes in insect herbivore pressure in relation to cover. Net growth, defined as change in number of live cladodes in a patch, was highest under the open canopy ($p < 0.05$), as expected. However, the volume and production of new cladodes did not differ among treatments. We reject the hypothesis that physiological constraints or competition by grasses limited cactus performance in high-cover situations. Damage from the cactus moth borer Melitara dentata was lower in the open than in either more shaded microhabitat, and moth damage was the major cause of cladode mortality in the experiment. Increased net growth of unshaded cacti *appears* to be a direct response to release from competition for light, but is better explained as an indirect effect of grass cover. Dense grass cover increased the abundance and impact of the moth borer. Results suggest that indirect effects can strongly influence small-scale spatial patterns of plant growth. Future evaluations of the relative importance of physiology, competition, and insect herbivory to plant performance should be environmentally explicit.

BURKE, INGRID C., PAUL B. HOOK, and WILLIAM K. LAUENROTH. Colorado State University, Fort Collins, CO 80523, USA. The Influence of Grazing and Exclosure on Soil Organic Matter and Nitrogen Cycling in a Shortgrass Steppe Ecosystem.

The shortgrass steppe ecosystem has been grazed by large herbivores throughout recent evolutionary history. Studies that address the influence of grazing by cattle have traditionally used exclosures for the purpose of comparison, though exclosure may represent a more unusual condition than cattle grazing. We are conducting a study at the Central Plains Experimental Range to evaluate the transient and long-term effects of exclosure and grazing on ecosystem structure and function. We have moved 50-year-old exclosures to create new grazing and exclosure treatments in historically grazed and protected areas. Two years after shifting exclosure boundaries, we have estimated soil C and N pools and nitrogen availability. Both total soil C and N were higher in long-term ungrazed than grazed areas, C to a larger extent than N. Mineralizable C and N were higher in long-term ungrazed than grazed soils. Two years of new grazing in previously protected areas and two years of protection of previously grazed areas was sufficient to influence only mineralizable C. Our results suggest that grazing decreases active soil organic matter, and exclosure increases active soil organic matter, which significantly influences nitrogen availability.

BURKEY, TORMOD V. Princeton University, Princeton, NJ, 08544, USA. Extinction in fragmented landscapes: conservation lessons from simple predator-prey systems.

Laboratory communities with three trophic levels of bacteria and protozoa, and computer simulations of simple predator-prey systems, are used to study the effect of habitat fragmentation

on the risk of extinction. Extinction times for populations in unfragmented habitats are compared to populations in sets of isolated habitat fragments with the same overall size. In the lab communities, four bacteria species form the producer level at the base of ciliate bacterivore-predator interactions. The computer model simulates a single predator and a single prey in one large or several small habitat patches, and allows different dispersal rates between fragments. Reproduction and survival are density dependent and stochastic. Predators in fragmented systems go extinct sooner, and in some cases much sooner, than in unfragmented systems. Only area-dependent disturbances can reverse the relationship. Dispersal between fragments alleviates the effect of fragmentation but not enough to make fragmented populations as viable as unfragmented ones.

BURNS, THOMAS P.[1], ANTOINETTE L. BRENKERT[2] and KENNETH A. ROSE[2]. [1]Science Applications International Corporation, Oak Ridge, TN and [2]Oak Ridge National Laboratory. Are simulation models necessary to quantify direct and indirect effects in ecosystems?

Recent experiments claiming to distinguish direct and indirect effects motivate an examination of perturbation theory. We describe an experimental method to isolate the direct effect from the total effect on the abundance of one population resulting from a perturbation to the abundance of another; the difference between the total and direct effect is the indirect effect. We present the results of experimental perturbations using a simulation model of a temperate lake ecosystem under steady-state and time-varying conditions and both step (PRESS) and impulse (PULSE) perturbations. Under steady-state conditions, the indirect effect exceeded the direct effect by a factor of 4. Direct and indirect effects vary in magnitude with the size of PRESS perturbations and timing of PULSE perturbations in time-varying ecosystems. These results raise an important question about current methods of executing and interpreting, in terms of direct and indirect effects, experimental perturbations on populations in natural ecosystems; Given the difficulty of performing in natural or artificial ecosystems the manipulations required to isolate the direct effect of one species on another, can field or laboratory experiments evaluate the relative importance of direct and indirect effects? Until someone rigorously proves otherwise, our preliminary conclusion is that simulation models are necessary to quantify direct and indirect effects in ecosystems.

BUSING, R.T. Forestry Sciences Lab, Corvallis, OR, 97331, USA. Disturbance and the population dynamics of Liriodendron tulipifera: simulations with a spatial model of forest succession.

Population dynamics of Liriodendron were investigated with a spatial simulator of forest community dynamics. Gap size was a key consideration in the simulation of recruitment; prolific recruitment of this shade-intolerant species was unlikely except in large gaps (>0.04 ha). In simulations of long-term forest development Liriodendron was a dominant in early succession, but it was uncommon after 500 years. Simulated basal area of Liriodendron approximated actual levels in forests with a low frequency of severe, large-scale events. Large gap creation by endogenous processes was more frequent when large trees were present (at the understory reinitiation and old-growth stages). Certain simulated disturbance regimes imposed on old forests elevated Liriodendron basal area. Disturbance regime components included patch size, return interval, severity, and spatial dispersion. The greatest increases in Liriodendron basal area resulted from severe patchwise disturbances. Gaps, ca. 0.1 ha in size, formed at intervals <100 yr maintained high Liriodendron levels comparable to those in some primeval forests.

BUTLER, BRETT J. and ROBIN L. CHAZDON. University of Connecticut, Storrs, CT, 06269-3042, USA. Species richness, abundance and spatial heterogeneity in the soil seed bank of a secondary tropical forest.

Species richness, abundance, and spatial heterogeneity of germinants from the soil seed bank were studied in a 16 yr old secondary, tropical moist forest at La Selva Biological Station, Costa Rica. Surface soil (166 cm^3/sample) was collected at grid intersection points of a large quadrat (1 ha, 10x10-m grid, 121 samples) and a nested subplot (100 m^2, 2x2-m grid, 36 samples). Soil was spread out evenly in individual flats over sterilized sand, placed in a screened shade house (30% full sun). Germinating seedlings were monitored over a 10-week period. The 1 ha plot had a seed density of 5621 seeds/m^2 with 34 species observed. Based on a series of 25 randomized species accumulation curves, a Michaelis-Menten fit predicted a species richness of 37.7. The number of observed species was close to the predicted asymptote. Species richness varied from 0 to 9 among individual samples, whereas total abundance ranged from 0 to 38 seeds. Within the 100 m^2 subplot, a seed density of 4633 seeds/m^2 was observed, comprising 26 species—estimated species richness (Michaelis-Menten fit) was 34.1. Both plots produced similar estimates of total species richness, suggesting that the spatial distribution of seeds within this seed bank is highly heterogeneous at relatively small spatial scales.

BUTLER, MARK J., WILLIAM F. HERRNKIND, and JOHN H. HUNT. Old Dominion University, Norfolk, VA 23529, Florida State University, Tallahassee, FL 32306, and Florida Marine Research Institute - Florida Department of Environmental Protection, Marathon, FL 33050. Cascading disturbances in an ailing marine ecosystem impact the spiny lobster nursery of south Florida.

Florida Bay, which separates the mainland from the Florida Keys, is experiencing an unprecedented and rapid series of ecological disturbances that tragically demonstrate the coupled dynamics of this tropical marine ecosystem, which is a key nursery for many species, including the Caribbean spiny lobster. Thousands of hectares of seagrass have died in recent years and it is believed that their loss sparked the blooms of cyanobacteria now widespread in the bay. Those blooms are in turn decimating sponge populations in hardbottom habitat throughout the region. Quantitative surveys at sites inside and outside areas covered by the blooms, both before and after their arrival, revealed significant mortality of all sponge species within weeks at bloom-covered sites and 100% sponge mortality at many sites. Juvenile spiny lobsters, among other animals, rely on sponges for shelter and the near instantaneous loss of sponges has resulted in similar reductions in lobster abundance and significant shifts in shelter use by the remaining individuals. We are currently investigating the ramifications of ecosystem change on the recruitment of lobsters on a regional-scale by coupling field experiments with an individual-based computer model of the system.

CÁCERES, CARLA E. Cornell University, Ithaca, NY, 14853, USA. **Egg bank dynamics and daphnid species diversity.**

The zooplankton community of Oneida Lake, New York includes two *Daphnia* species: *D. galeata* and *D. pulicaria.* Although both species have persisted in the system for at least 30 years, their water-column densities are negatively correlated. One species typically is abundant while the other remains absent or in low numbers. This transient dominance lasts for months in some instances and for years in others and has been attributed to a combination of predation and competition. The recurring pattern of appearance and disappearance raises two questions: (1) how is each species able to persist in the system over the long-term and (2) if the negative correlation is the result of competition, why are both species present in the system? Both species produce diapausing eggs which remain viable in the lake sediments for a potentially long time period. By using theoretical models first proposed by Chesson and Warner (1981), I investigate the hypothesis the reproductive potential stored in these dormant eggs not only allows each species to persist in this system, but also enables long-term coexistence of two potentially competing species.

CAI, BING and ORIE LOUCKS. Department of Zoology, Miami University, Oxford, OH, 45056, USA. A physiologically-structured population model of the earthworm, *Eisenia foetida.*

The effects of environmental stress (e.g., acidic deposition or other toxicity) can be observed at both population and ecosystem levels, but they are almost certainly the result of changes in processes at the level of individuals. Thus, a key question is to develop an individual-based model integrating hierarchically into population or even ecosystem processes. Earthworms, widely used in ecotoxicological studies, have an extensive database on feeding, growth, reproduction, and mortality as affected by pH and other factors. These measurements provide a basis for modeling the behavior and response of earthworm individuals with or without external stressors. In this poster we synthesize experimental results on the earthworm *Eisenia foetida*, deriving coordinated parameters for ingestion, assimilation, maintenance, and energy allocation to growth, as well as reproduction, and modifying known allometeric relationships. The model predictions are in good agreement with data on growth and fecundity of earthworm species, and supports the conclusion that appropriately structured measurements of short-term physiological rates can be used to predict long-term effects of acidity on individuals, populations and ecosystems.

CAMARA, M.D. Dept. EPO Biology, University of Colorado, Boulder, CO, 80309 USA. Are there physiological costs to sequestering allelochemical defenses?: a genetic approach to the chemical/nutritional ecology of the buckeye butterfly.

Larvae of the buckeye butterfly (*Junonia coenia*) can pay a significant growth cost in aquiring chemical defensive compounds from their food. I investigated the mechanism of these costs using a combination of gravimetric nutritional techniques, quantitative genetic experimental designs and quantitative chemical analysis (gas chromatography) to elucidate the interrelationships of nutritional performance and allelochemical defense. In long-term experiments (egg to final larval instar) sibships sequestering the highest levels of iridoids tend to develop more slowly and reach smaller sizes, but these relationships depend upon the concentrations of iridoids available in the diet. In short-term trials (3 days) high iridoid diets had no significant effect on growth rates because caterpillars fed high iridoid diets consumed more food. However, high iridoid concentrations act as quantitative defenses, reducing the digestibility of the diets but not post-digestive efficiency of their conversion into insect biomass. In addition, all standard nutritional indices varied significantly among families indicating considerable genetic variation.

CAMBARDELLA, C.A. USDA-ARS. National Soil Tilth Lab.2150 Pammel Drive. Ames, IA 50011. Temporal dynamics of particulate organic matter N and soil nitrate N with and without an oat cover crop.

Winter cover crops have the potential for reducing NO3 leaching losses by taking up residual soil NO3 in the fall and synchronizing the release of N through remineralization the following spring. The particulate organic matter (POM) fraction may be involved in this internal cycling of N. The research presented here describes the temporal dynamics of soil NO3 and POM N with and without an oat cover crop for a field site in central Iowa. Soil NO3 concentrations were the same in early spring and increased by late spring for all treatments. POM N decreased for all treatments across the growing season. Mineralization of POM N may contribute to the observed increase in the soil NO3 in late spring and, therefore, may be playing an important role in the internal cycling of N in these soils.

CAMERON, DONALD S., DONALD J. LEOPOLD, AND DUDLEY J. RAYNAL. SUNY College of Environmental Science and Forestry, Syracuse, NY, 13210, USA. Effect of landscape position on diversity and richness of vegetation on electric transmission rights-of-way.

Rights-of-way (ROW) are kept free of tall trees to insure reliability of electric service. Selective management techniques such as cut-stump herbicide and stem foliar herbicide are used on some ROW to remove undesirable tree species while minimizing disturbance to shrub and herbaceous communities. Six of these ROW in forested landscapes of New York State were sampled to determine the effect of landscape position (wetland, lowland, upland) on species diversity (Shannon-Weaver index), species richness, and contribution of non-native species. Experimental design was a split-plot 3x2 factorial with landscape position as the whole plot factor and ROW versus the

adjacent woods as the sub-plot factor. ANOVA indicates diversity, richness, and richness of non-natives are greater on the ROW versus the adjacent woods for upland and lowland positions. Wetland positions show no significant difference for these parameters on the ROW versus the adjacent woods. ROW wetlands are more similar to adjacent woods than are uplands and lowlands.

CAMPBELL, DANIEL R. and HAMISH C. DUTHIE. University of Waterloo, Waterloo, ON, N2L3G1, CANADA. Long-term development of a kettle-hole wetland in southern Ontario.

As part of a multidisciplinary study of a kettle-hole wetland in southern Ontario, a paleoecological study was undertaken to determine its long-term development history, including the relative importance of allogenic versus autogenic factors. This wetland is a small, deep kettle-hole, with a very poor, floating fen covering the center of the basin, surrounded by a grounded, mixed-wood swamp, and then by a minerotrophic moat along the upland boundary. Fossil pollen assemblages from a long core were used to reconstruct environmental changes within and surrounding the basin, while peat stratigraphy, sponge spicules and diatom assemblages were used to reconstruct the development of the basin itself. The basin began as an alkaline lake around 12,000 years ago following the melt of an ice-block. It succeeded to a circumneutral lake and then to a moderately acidic peatland surrounding a small open water area. Around 3,000 years ago, a flooding event, possibly associated with an adjacent kettle lake returned the wetland to a moderately acidic shallow lake. Only after European land clearance did the very acidic, Sphagnum-dominated, floating mat extend over the center of the basin. Except for this historical period, changes in the development of the center of this basin do not appear to coincide with changes in the upland pollen assemblages.

CAMPBELL, TIMOTHY S. Wright State University, Dayton, OH, 45435, USA. Eleven years change in a maple-oak woods in west-central Ohio.

Woody plants were surveyed in a 3900 m2 transect of remnant maple-oak woods in 1982 and 1993, located in Greene Co., Ohio. The purposes of the study are to examine changes in overall species composition over the time interval in a fairly old woods for the region and to quantify variation in mortality and growth rates for stems of different sizes and species. Importance values (relative basal area) changed little for the dominant tree species: Acer saccharum (50.3% in 1982, 50.9% in 1993), Quercus alba (9.3%, 9.9%), Fraxinus americana (8.4%, 8.9%), Aesculus glabra (6.2%, 6.5%). Over the eleven years the mortality rate was 10% for stems $\geq$ 10 cm dbh but 21% for stems 4-10 cm dbh. Thus turnover of stems was higher than turnover of species basal area, implying that most species are maintaining themselves in the stand through either replacement or persistence.

CAO, YONG, W. PETER WILLIAMS and ANTHONY W. BARK. King's College London, Campden Hill Road, London, W8 7AH, UK. The robustness of nine similarity indices and a new dissimilarity index for river invertebrate studies.

Due to the confusion about choice of similarity measure, the robustness of nine indices commonly used was evaluated according to their ability to discriminate sampling sites in a lowland river using benthic marco-invertebrate communities. None of them could discriminate all the sites. However, two binary indices, Coefficient of Jaccard, and Brani-Urban and Buser coefficient, appeared superior to all quantitative indices examined. The theoretical variations of species abundance between two communities were classified into four types. Statistically significant differences exist between within-site and between-site observations. However, those indices could respond only to some of those variations and weigh them improperly. The failure would be responsible to their unsatisfactory performance. A new dissimilarity index was presented, which is sensitive to various types and gives ecologically reasonable weight to each of them. The same sets of data were used to test the index. It discriminated almost all the sampling sites.

CAPPELLATO, ROSANNA - U.S. Geological Survey, Atlanta GA, 30360, USA. Sulfur deposition and cycling in two forests of the Georgia Piedmont.

Because of the increase in SO_2 emissions in Georgia since the late 70's, a study was undertaken in adjacent deciduous and coniferous forests to estimate the atmospheric input and above-ground cycling of sulfur. During this study, which was conducted in 1988-89, total annual sulfur input to these forests was 17 kg/ha, which was comparable to sulfur inputs to other sites in the eastern United States. Dry deposition accounted for more than 50% of the total atmospheric sulfur input, and SO_2 was the major source of dry deposition to the canopy. Net flux of sulfur in throughfall (throughfall flux minus precipitation flux) under the deciduous canopy was 1.8 times higher than that under the coniferous canopy. Although the net sulfur throughfall flux was very similar to the total sulfur dry deposition in the deciduous forest, the net sulfur throughfall was only about half of the total sulfur dry deposition. The lower throughfall sulfur flux in the coniferous forest was attributed to retention of SO_2 by the canopy. Lower sulfur concentration in needles from the litterfall (0.68 mg/g) than in needles from the canopy (1.38 mg/g) indicates that sulfur could be accumulating in coniferous wood. Total annual sulfur deposition to the forest floor by throughfall, stemflow, and litterfall was 2.3 and 1.3 times greater than the sulfur required by the deciduous and coniferous forests, respectively, for annual wood and foliage production.

CAPRIO, ANTHONY C. University of Arizona, Tucson, AZ 85721, USA. Millennial length foxtail pine tree-ring chronologies from the southern Sierra Nevada, California: climate inferences for the last 4,000 years.

Long tree-ring chronologies from foxtail pine (***Pinus balfouriana*** Grev. & Balf.) are important proxy records of past climate. Such crossdated chronologies can show sensitivity to climate both as year-to-year ring-width variation and on longer time-scales through fluctuations of upper

treeline position and changes in the distribution of living and sub-fossil wood. Collections from the area of Sequoia National Park in the southern Sierra Nevada, California were made from the lower elevational limit of foxtail to high elevation "ghost forests" where this species was locally extinct and samples were obtained from sub-fossil wood that was found up to 65 m above the present treeline. Foxtail showed a strong annual response to precipitation with a weaker temperature influence at high elevations. I inferred long-term climate trends by examining treeline movement and age distributions of sub-fossil wood between the high and low elevations. Several distinct periods of long-term change were apparent and most obvious at upper elevations. At these sites, increased recruitment was indicated from ~BC 1700-1200, followed by a major decline between ~300-600 AD which was responsible for the majority of tree mortality in these stands. A more recent well dated decline occurred between ~1250-1700 AD, during which all ghost forests I examined originated. Frost rings that were evidence of anomalous climatic events and showed dating consistency among chronologies were found in BC 1627, 1132, 43, and AD 627, 687, 1331, and 1601.

CARACO, NINA F., JONATHAN J. COLE, and DAVID L. STRAYER, Institute of Ecosystem Studies, Millbrook, NY, 12545, USA. **An invasive species alters the spatial and temporal patterns of plankton blooms in the Hudson Estuary: I. Phytoplankton**

Phytoplankton production in large rivers is an important source of organic carbon supporting higher trophic levels. What controls the magnitude of this production or spatial and temporal variation in this production is, however, not well known. Using a model of production in the Hudson River we find that physical variables have strong direct impacts on phytoplankton and are, additionally, key in determining the impact of grazers upon phytoplankton. As the physical environment in the river makes phytoplankton particularly sensitive to benthic grazers, it is not surprising that there was an 85% decrease in summertime phytoplankton biomass coincident with the invasion and establishment of an exotic benthic grazer, the zebra mussel (*Dreissena polymorpha*). Such large decreases were, in fact, predicted from our model. As the zebra mussel invades and becomes established in other turbid rivers throughout the United States we expect extreme alterations of ecosystem processing.

CARD, VIRGINIA M. Ecology Department, University of Minnesota, St. Paul MN 55108. Two hundred years of diatoms: the Big Watab record.

Big Watab is a relatively deep (37 meters max., 100 hectares) clear (Secchi 5-7m) dimictic lake in Stearns County Minnesota. In 1990 and 1991 freeze-cores of the top meter of sediment were collected from the deepest part of the lake. This sediment is sub-annually laminated (i.e. varved). The sediment was embedded with Spurr's epoxy by solvent-exchange and then thin sectioned. The thin sections were analyzed by transect counting at 400x, and the 'samples' (each one a 400μ diameter field-of-view) grouped into annual years. Construction of the annual chronology was supported by the intra-annual pollen cycle (ragweed pollen coinciding with the diatom 'summer') and by long-term trends in the pollen composition (the rise in ragweed pollen, dated at about 1860 to 1880). A two-hundred year annual record of the planktonic diatoms was created and analyzed. Long-term trends reveal the effects of human impact on the lake. Year-to-year variations suggest the effects of winter and spring climates including the timing of ice-out and onset of summer stratification.

CAREY, EILEEN V., EVAN H. DeLUCIA and RAGAN M. CALLAWAY. University of Illinois, Urbana, IL, 61801, USA. Predicted response of stem respiration in ponderosa pine to global climate change.

We measured woody tissue respiration on boles of desert and montane populations of *Pinus ponderosa* growing in the Great Basin Desert and on the east-slope of the Sierra Nevada as part of a study of responses of *P. ponderosa* to global climate change. The differences in temperature and precipitation between desert and montane populations match changes in climate predicted from a doubling of atmospheric CO_2; therefore, these naturally occurring populations represent the difference between present and future climatic conditions for these trees. Allometric relationships derived previously, indicate that for trees of equal diameter, desert trees invest more dry matter in sapwood than montane trees. To maintain greater sapwood volume while maximizing carbon gain, we predicted that desert trees would have lower Q_{10} responses for respiration (increase in respiration with a 10° increase in temperature) thus minimizing losses of carbon due to maintenance respiration in a hotter environment. Mean ln respiration rate per unit of sapwood volume was not different between populations (Desert: 3.24; Montane: 3.13 moles m^{-3} sec^{-1}). Moreover, between population differences in Q_{10} for respiration were not statistically significant (Desert: 2.27; Montane: 2.39). Results suggest that under predicted future climatic conditions increased respiratory losses from woody tissue resulting from increased allocation to sapwood may offset increases in carbon uptake due to enhanced photosynthesis from elevated CO_2.

CARLETON, T.J. Forestry/Botany, University of Toronto, Toronto, Ontario, Canada, M5S 3B2. Understorey plant species diversity and forest floor heterogeneity in eastern white pine (Pinus strobus) and red pine (Pinus resinosa) forests of the Ontario Canadian Shield.

A stand structure and vegetation survey of 170 white and red pine dominated stands yielded little correlation between postdisturbance stand age or stand structure and species richness. Increased correlation was acheived by expressing forest floor habitat variables, including microsite heterogeneity, as a linear combination. Many understorey taxa were lichens, mosses and hepatics. 7,485 joint occurrences between these 83 taxa and 20 microsite substrate variables yielded an 83 row x 20 column contingency table. Correspondence analysis decomposed total chi-squared into 12 significant orthogonal

components (axes), indicating interpretable associations between species and substrata. The results point to the need to explore understorey diversity and species-environment relations at spatial scales sensitive to the growth forms of the plants involved.

CARNEY, HEATH J., NEO MARTINEZ and BRIAN FEIFAREK. Institute of Ecology, University of California, Davis, CA, 95616, USA. Food web biodiversity, patterns and interactions in complex natural ecosystems.

Food webs for three California lakes (Tahoe, Castle, Clear) have been assembled with some of the most detailed and complete data available to date. With this information we have constructed complete descriptive webs, which include all species, and functional webs, which include the abundant and other important species. These webs include up to 794 species in five major categories: algae, macrophytes, microheterotrophs, invertebrates, and fishes. There are clear and significant departures of the California lake food webs from earlier generalizations about trophic architecture and links which were based on smaller and less complete webs. They include high proportions of basal species, low proportions of top species, and much more complex webs with many links per species. These differences are readily explained by the improved information, and by the biology of lake ecosystems. The functional food webs show that strong species interactions, including trophic cascades, are most prevalent at intermediate productivities.

CARLSEN, TINA M. AND STEVEN D. GREGORY. Lawrence Livermore National Laboratory, Livermore, CA, 94551, USA. The effect of standing litter and bird predation on the germination of a rare forb, Amsinckia grandiflora.

In the fall of 1993, we investigated the effect of litter on the germination of the federally-listed endangered plant, Amsinckia grandiflora. Nutlets were sown into plots established in both an area that had been manually cleared of all litter, as well as in an uncleared area. Within the uncleared area, three plots contained standing litter, and three plots had the litter clipped and left lying on the plot. Within the cleared area, three plots were covered with aviary netting, and three plots were left bare. All plots except those covered with aviary netting were instrumented with thermocouples. Germination rates, as well as diurnal surface soil temperatures, were obtained between November 19 and November 30, 1993. There was a significant difference between cleared and uncleared plots, with plots containing litter averaging more than five times the germination rate of cleared plots. There was no significant difference between the germination rates of the plots with standing or clipped litter, or between the bare and aviary netting treatments. Temperature data showed that, compared to plots with litter, cleared plots were warmer during the day and cooler at night . Little is known about the seed bank dynamics of Amsinckia grandiflora, and such a difference in germination success could have implications on restoration strategies for this rare annual forb. (Work performed under the auspices of the U. S. Department of Energy by Lawrence Livermore National Laboratory under Contract W-7405-Eng-48.)

CARPENTER, S., P. CUNNINGHAM, S. GAFNY, A. MUÑOZ DEL RIO, N. NIBBELINK, T. PELLETT & A. TREBITZ. University of Wisconsin & Department of Natural Resources, Madison, WI, USA. Bass and bluegill growth response to macrophyte removal: Design of a replicated whole-lake experiment.

Infestations of Eurasian milfoil have been associated with poor growth of bluegills and largemouth bass in some lakes. Cutting channels to increase the edge/area ratio of dense milfoil beds has been proposed to improve fish growth. Simulation models indicate that the growth response requires harvest of only 10% - 20% of a lake's milfoil beds. Whole-lake manipulations spanning several years are necessary to test this hypothesis. Using data from 37 Wisconsin lakes, we have compared alternative designs for the experiment: two-group, gradient, blocked, and staircase. Interlake variability, power calculations and the pragmatisms of large-scale experimentation favor a two-group design with 5 harvested lakes and an equal number of reference lakes. Large-scale ecological experiments have high costs and must create compelling contrasts to influence managers. These considerations favor simple designs with maximal treatments.

CARROLL, STEVEN B. and PETER C. GOLDMAN. Northeast Missouri State University, Kirksville, MO, 63501, USA. Reproductive components in Viola pedata: analysis of a color polymorphism.

Populations of Viola pedata, birdfoot violet, consist of two morphs that grow intermixed. Plants produce either bicolored flowers (DK), with 2 dark violet petals above and 3 lilac petals below; or uniformly light flowers (LT), with 5 lilac petals. Proportions of the two types vary, but DK is more common in our area. The primary objective of this study was to determine how this polymorphism is maintained. The proportions of pollinator visits to DK and LT did not differ from morph proportions in four populations. Mean flower production/plant was greater in LT than in DK. At two sites where LT was more common, LT flowers also had significantly more ovules/ovary. Fruit production per plant varied significantly with site but not with morph. Seed production/flower varied significantly with site and morph, being greater in LT. Greater flower and seed production by LT may help explain why this less common morph is not eliminated from populations.

CARSON, WALTER P. and C.L. MOHLER. University of Pittsburgh, Pittsburgh, PA 15260, and Cornell University, Ithaca, NY 14853. Early succession in an old-field plant community: effects of suppressing phytophagous insects and removing litter.

Removing phytophagous insects during early succession can increase plant biomass and accumulated litter. An increase in either of these factors can result in a decrease in plant species richness. To disentangle these factors, we suppressed insects in large replicated plots (5x5m) and removed litter in smaller nested subplots (1x1m) through four years of succession. Insects were suppressed using insecticide and litter was removed early each spring. Insect removal significantly increased accumulated litter and the biomass of the dominant plant species, *Solidago altissima,* and resulted in a decline in species richness. Litter removal caused an increase in species richness in both the insecticide-treated and untreated plots. Overall, the effects of litter removal and insect suppression on plant species richness were additive. Phytophagous insects increase species richness apparently by reducing the abundance of the dominant plant species thereby freeing up resources. Litter reduces species richness apparently by reducing the colonization and establishment of annual and biennial species.

CARTER, ELOISE B. Oxford College of Emory University, Oxford, GA 30267, USA. Developing partnerships between ecologists and educators in Georgia.

The Georgia initiative, PEACH: Promoting Ecological Awareness Close to Home, developed at the ESA sponsored workshop was designed to create regional partnerships between professional ecologists and educators to improve ecological education. Through surveys to ecologists and biologists more than 70 indicated an interest in participating in the program and 32 were willing to be the partner for their state district. Fifteen state agencies and organizations met for a workshop sponsored by Oxford College to develop a support network to provide volunteers and a variety of resources. Ecologists attended a workshop at the Georgia Science Teachers Association in 1992. Success of the program is limited by the time and funds required to manage the program and the difficulty of coordinating with state educators.

CHAMBERS, JEANNE C. USDA Forest Service Research, Reno, NV, 89512, USA. Seed entrapment and seedling establishment: Long-term effects of soil particle size and seed morphology.

I examined the fates of both seeds and seedlings of alpine species with and without adaptations for primary or secondary dispersal over a range of uniform and mixed particle size soils on the Beartooth Plateau, MT. Small seed size, antrorse hairs, hygroscopic awns, pappuses and mucilaginous seed coats all resulted in higher entrapment in smaller, more favorable particle sizes. Prolonged exposure (1-yr vs. 4-wk) to the environment resulted in lower retention in the 0-1 cm active soil layer due to horizontal or vertical movement. Seedling emergence and survival depended on the capacity of the different particle size soils to support the biological requirements of the species. Some seedling emergence occurred in particle sizes ranging from < 0.5 mm to 4-8 mm, but few seedlings survived in particle sizes larger than 1-2 mm. For most species, the highest entrapment and retention occurred in particle sizes in which there was little or no emergence. Both seedling emergence and survival were often poorly related to seed entrapment. Understanding seedling establishment patterns in different particle size soils requires knowledge of how relationships between seed morphology and soil characteristics affect entrapment patterns and of soil particle size thresholds for seedling establishment.

CHAMBERS, LALA. S., PAUL. J. HANSON. Ecology Graduate Program, University of Tennessee, Knoxville, TN 37996 USA; and Environmental Sciences Division, Oak Ridge National Laboratory, Oak Ridge, TN 37831-6034 USA. Impact of changing precipitation patterns on CO_2 efflux rates from a forest floor.

A manipulative experiment is being conducted at Walker Branch Watershed, Oak Ridge, TN, to examine the impacts to a deciduous forest ecosystem that might occur given a climatic change scenario of altered precipitation patterns due to increased global temperatures brought about by increasing levels of greenhouse gases. Specifically, the focus here will be on CO_2 efflux rates (soil respiration) from a forest floor where throughfall inputs are being modified. Soil respiration reflects CO_2 losses from roots and microbes. Variations in soil respiration provide direct measurements of forest floor responses to changes in soil moisture content. A 2.5 ha experimental site has been divided into three controlled moisture regimes: a dry plot, an ambient plot, and a wet plot. CO_2 efflux rates are measured with a modified LiCor 6200 closed gas exchange system along with the simultaneous monitoring of soil temperature and soil moisture content. To date, observations have shown no pretreatment patterns across the site.

CHAMPAGNE, DONALD, MICHAEL COHEN, JEROME HOWARD, AND MARK SNYDER. University of Arizona, Tucson, AZ 85721. Diet-induced changes in detoxification enzymes in polyphagous grasshopper species.

We investigated the responses of detoxification systems to diet in two grasshopper species, *Melanoplus differentialis*, an inducible generalist, and *Taeniopoda eques*, an obligate polyphage. We hypothesized that single plant diets would result in induction of specific enzyme systems, and that *Melanoplus* would be induced to higher levels than *Taeniopoda*. We fed grasshoppers one of four plants or a mixture of all plants for five days and then measured eleven enzyme activities in the cytochrome P-450 system. There was no consistent difference in average levels of enzyme

activity between the species. Enzyme activities in both species tended to positively covary and were not differentially induced. Enzyme activities in *Melanoplus* were lower on single plant diets than on the mixed diet, while those in *Taeniopoda* were higher on the single plant diets than on the mixed diet. This suggests that *Taeniopoda* finds it difficult to metabolize large amounts of any single substance, as expected of nonadapted generalist herbivores, but that *Melanoplus* finds it costly to detoxify a complex mixture of substances found in a mixed diet.

CHAMPAGNE, AUDREY B. University at Albany, State University of New York, Albany, NY, 12222, USA. Challenges of creating new forms of science assessment.

Changes in assessment of student attainment are coupled to proposals for the reform of pedagogy for undergraduate science courses. While course syllabi for undergraduate science courses list as objectives understanding science subject matter and the capacity to solve problems, examinations center on students' store of factual information and their ability to solve routine problems. Facing reformers is the challenge to design innovative assessment strategies that do not further constrain the limited resources available for conducting introductory courses. Assessment of science understanding and problem solving each presents different challenges and requires different approaches. For instance, a challenge of innovative assessment of understanding is the development of assessment exercises that elicit the full extent of students' understanding. Another is making judgments about the quality of students' responses for the purposes of assigning grades and modification of teaching practices. Approaches to meeting each of these challenges will be presented.

CHAPIN, F. STUART, III and ANTHONY M. STARFIELD. University of California, Berkeley, CA, 94720 USA and University of Minnesota, Minneapolis, MN, 55108, USA. A model of northern treeline dynamics in response to transient changes in climate.

In order to predict the future distribution of boreal vegetation, we developed what, to our knowledge, is the first model of ecosystem change in response to transient changes in climate and disturbance regime over the next 50-500 yr. The model develops scenarios of change in disturbance regime and ecosystem type in what is currently arctic tundra in response to GCM-based scenarios of climate change. Seed availability, tree growth rate, and probability of fire were the model parameters that most strongly influenced the balance between tundra and boreal forest during transitional climates. The rate of climatic warming strongly affected the time lag between climate change and the simulated ecosystem response but had less effect on the rate or pattern of ecosystem change. The model calculated that a ramped change of 3° in the next century (corresponding to average rate of warming predicted by GCMs) would lead to a 150 yr lag preceeding any change from tundra to forest, followed by rates of forestation of up to 6-12% per decade. The model predicted that tundra would first be invaded by conifer forests, but that the proportion of broad-leafed deciduous forest would increase as climate continued to warm due to increased fire frequency. The pattern of climatic warming had strong effects on simulated rates of conversion from tundra to forest. Rapid step changes in climate or increases in climatic variability both promoted more rapid ecosystem change than did ramped change in climate or climatic oscillations, particularly when oscillations were long relative to the time required for tree growth to reproductive maturity.

CHASE, JONATHAN M. Utah State University, Logan, UT, 84322, USA. Presence and absence of trophic cascades in a simple grassland food chain.

Food chain dynamics can be limited by top predators (i.e., top-down), by resource inputs (i.e., bottom-up), or a combination of both. Recent theory suggests that the relative importance of top-down versus bottom-up control of trophic food chains may be dependent upon the mechanisms underlying the constituent populations' growth; i.e., absolute resource limited consumption or time limited consumption of resources. A prey population limited by time to acquire resources is likely to be reduced by its predator, thus the prey's resource should increase (i.e., a trophic cascade). A prey population limited by the absolute amount of resources available may or may not be reduced by its predator, but should be able to compensate for loss to predation by increasing per capita resource consumption (i.e., no trophic cascade should result). This scenario was experimentally investigated using a simple grassland food chain of predators (wolf spider, *Lycosa* spp.), herbivores (grasshopper, *Melanoplus sanguinipes*), and plants (primarily *Elymus spicatum*). Experimental microcosms were established with either one (plants only), two (plants and herbivores), or three (plants, herbivores and carnivores) trophic levels present. Herbivore resource intake was experimentally manipulated by altering time available for feeding. Time limited herbivore populations were reduced by predators in the three level system, causing a consequent increase in plant abundance relative to the two level system; i.e., a trophic cascade. Absolute resource limited populations showed compensatory mortality in the presence of predators; i.e., individuals compensated for loss to predators by higher consumption and survival relative to the two level system, and no trophic cascade emerged. Natural control plots indicate that plant abundance is limited by herbivores, thus herbivores are not limited by predators at this site.

CHEN, SHU-KANG and SCOTT SUBLER. The Ohio State University, Columbus, OH, 43210, USA. An integrated approach to investigating the effects of pesticides on soil microbial processes and N dynamics.

An integrated approach was used to examine the effects of two fungicides, captan and chlorothalonil, on soil respiration, dehydrogenase enzyme activity (DHA), and nitrogen dynamics. We incubated fungicide-treated soil for 3 to 56 days in the laboratory. Soil was amended with alfalfa leaves or wheat straw to alter rates of microbial activity and N mineralization/immobilization. Captan suppressed peak respiration in unamended and alfalfa-amended soils, but stimulated it in wheat-straw amended soil. In alfalfa-amended soil, captan stimulated DHA during the first week, but not thereafter. Captan also initially suppressed soil nitrification and stimulated ammonification. Captan increased microbial biomass-N in the alfalfa-amended and control soils, relative to the wheat straw-amended soil. Chlorothalonil had similar effects to captan on respiration and DHA, but opposite effects on ammonification and nitrification after 7 days. Results indicate that the two fungicides differ in their effects on N mineralization processes, with captan having a more pronounced influence than chlorothalonil. We conclude that an integrated approach, common to soil ecological studies, can be extended successfully to the investigation of the effects of pesticides on soil systems.

CHENG, WEIXIN, R.A. VIRGINIA and J.D. TENHUNEN. University of Georgia, Athens, GA 30602, USA; Dartmouth College, Hanover, NH 03755, USA; and Univeritüt Bayreuth, 8580 Bayreuth, Germany. Effects of temperature and moisture on tundra soil respiration.

The effects of temperature and moisture on tundra soil respiration rate has been controversial. We investigated the effects of temperature and moisture on tundra soil respiration in a series of controlled laboratory experiments. Large pieces of tundra soil were taken from the Imnavait Creek watershed in the northern foothills of the Philip Smith Mountains in arctic Alaska. Each tundra piece was incubated in a plant growth chamber under a simulated arctic environment. After 3 weeks of stabilizing period, a 20 X 20 cm piece was sampled at the center and separated into surface yellow layer and bottom black layer. Soil respiration rate of each layer was measured on an open air flow system equipped with an Infrared Gas Analyzer. Respiration rates of all the surface soils (yellow layer) was very sensitive to temperature changes. A near perfect exponential relationship between the rate of CO_2 evolution and temperature (2-20°C) was obtained for all the surface soils (yellow layers). The Q_{10} values for the surface soils ranged from 2.45 to 3.21. Respiration of most bottom layer soils (Black) was also very sensitive to temperature changes except a few cases when temperature changes in the lower range (2-10°C) did not significantly affect respiration rates. No significant soil moisture effect on respiration was found within the tested range (100-1000% w/w). These results indicate that temperature is a more important controlling factor for soil respiration than soil moisture in the arctic tundra.

CHIAVELLI, DEBORAH A. AND STEPHEN T. THRELKELD. University of Mississippi, University, MS 38677, USA. Effects of aggregated distributions of *Daphnia* on the metapopulation dynamics of their epibionts.

Protistan and algal epibiont populations that use *Daphnia* as habitat patches must be periodically re-established whenever *Daphnia* molt. Data on molting rates, and our ability to measure time elapsed since molting (using hypodermal retraction stages of *Daphnia*), allow us to predict relative epibiont abundance on individual *Daphnia* and to estimate the turnover rate of the *Daphnia* habitat patches used by an epibiont metapopulation. Because metapopulation dynamics are controlled by patch turnover rate and by colonization, we measured how diel formation of dense *Daphnia* aggregations in small, subalpine beaver ponds affected epibiont metapopulations on the *Daphnia*. We found that the spatial and temporal pattern of *Daphnia* aggregations had spatial and temporal consequences for the epibiont metapopulations within a pond. The demographic characteristics of *Daphnia* in aggregations affect the patch turnover rate, and the density of *Daphnia* in an aggregation affects colonization rates of the epibionts.

CHILDRESS, MICHAEL J. Florida State University, Tallahassee, FL, 32306, USA. The ontogenetic habitat shift of juvenile Caribbean spiny lobsters: a test of the growth-mortality trade-off.

Werner's (1986) model predicts that habitat specific growth and mortality rates determine the optimal size for an ontogenetic habitat shift. I experimentally tested the model's predictions with juvenile Caribbean spiny lobsters, Panulirus argus. Postlarvae were raised under two conditions of initial food availability (high or low) and in the presence or absence of a caged predator, the gulf toadfish, Opsanus beta. Each of the 16 mesocosoms had two microhabitats: a macroalgal mat (settlement habitat) and crevice shelter (post-settlement habitat). Lobsters were located, measured, weighed and videotaped weekly for 19 weeks. Neither the mean size of habitat transition nor the habitat specific growth rate varied significantly with food availability or predation risk. However, the mean time spent in the settlement habitat varied significantly. Habitat transition occurred later from high food algal mats in the presence of the predator and earlier from low food algal mats in the absence of the predator.

CHILDRESS, W. MICHAEL and CHARLES M. CRISAFULLI. Colorado State Univ., Fort Collins, CO, 80523, USA and Mount St. Helens Nat. Volcanic Mon., Amboy WA, 98601. Spatial dynamics in an early successional plant community at Mount St. Helens, Washington.

Annual vegetation surveys were conducted in an early successional plant community at Mount St. Helens from 1983-93 in a 12x14m plot; all individuals were identified and counted in 1x1m quadrats. *Lupinus lepidus* was the initial colonizing species in 1982, and it occupied all 168 quadrats by 1987. None of the other 38 taxa observed in the plot occurred in any quadrat not previously or simultaneously occupied by lupines. Contingency tables were constructed for each taxon for persistence in and dispersal among quadrats with respect to year and occupancy by other taxa. All taxa except lupines showed significant interactions with at least one other taxon for either persistence and dispersal. These spatial interactions among taxa were used to derive a qualitative community matrix for the plant community.

CHINEA RIVERA, JESÚS D. Humacao University College, Humacao, Puerto Rico 00791. Forest recovery after abandonment of agricultural lands in the Humacao municipality in eastern PR.

Puerto Rico, almost completely deforested by 1950, has recovered nearly 1/3 of its former forest cover by 1980. The main objective of this study is to describe the changes in forest area and tree species composition in the Humacao

municipality of eastern Puerto Rico. The soils and abandoned lands (as interpreted from aerial photos of 1936, 1967, 1977, 1985 and 1990) of the study area (nearly 11,500 ha) were digitized into a raster GIS. Results of overlaid maps indicate that abandoned lands increased from 3% in 1936 to 23% in 1990. A larger proportion of the steepest lands was abandoned since the beginning of this period, but more of the less steep lands have been abandoned recently. Sampling of floras of lands with soils of volcanic origin suggests that tree species increments through successional time reach an asymptote after about 20 yr. However, spatial as well as temporal autocorrelation of species composition may obscure such trend.

CHOI, YOUNG D., LINDA L. CHAMBERLIN, and C. ROSS HINKLE. Purdue Univ. Calumet, Hammond, IN 46323, Florida A&M Univ., Tallahassee, FL 32307, and Bionetics Corp., Kennedy Space Center, FL 32899, USA. Undergraduate ecological research projects as a part of Space Life Science Training Program at the Kennedy Space Center.

Space Life Science Training Program (SLSTP), sponsored by the National Aeronautics and Space Administration (NASA), is a summer program at the Kennedy Space Center (KSC) for college students. Ecological projects became a major part of the SLSTP due to (1) active ecological research programs at the KSC in compliance with various federal laws, and (2) the NASA's concern for the protection of biological diversity at the KSC. The 1993 SLSTP offered three projects: (1) Effects of elevated ambient CO_2 on oak (*Quercus* sp.) - saw palmetto (*Serenoa repens*) ecosystem, (2) Effects of fire on the habitats of Florida scrub jay (*Aphelocoma coerulescens coerulescens*), and (3) Use of roadside ditches as a habitat for wading birds (Order Ciconiiformes). Such projects provided an excellent opportunity to the students for exploring the interface between space technology and environmental conservation.

CHOUNG, YEONSOOK. Kangwon National University, Chunchon 200-701, Korea. Clonal structure and ramet growth of lily-of-the-valley, Convallaria keiskei

Lily-of-the-valley, Convallaria keiskei is a rhizomatous plant which rapidly colonizes disturbed forests in Chunchon, Korea. A total of 467 clones were excavated and all ramets in plots were tagged to clarify clonal structure and growth in the field. The oldest ramet observed was 36-years-old. 73% of the clones consisted of 2 to 16 ramets connected by rhizomes reaching a maximum length of 75cm. Most ramets resprouted and new ramets were produced from underground non-branched rhizomes (67%) each spring. This resulted in the coexistence of multi-aged ramets aligned nearly in a linear growth pattern. The resulting age distribution curve of ramets was reverse J-shaped. Ramet production by lateral buds was stimulated by rhizome severing. Shoot growth was completed in the middle of May before tree canopy cover closed and was followed by rhizome growth. Lengths of rhizomes increased with ramet size, while flowering frequency increased with ramet age. In plots observed over 2 years, ramets less than 50cm^2 in leaf area increased in area up to a maximum of 14-fold while the larger ramets showed little leaf area increase. New ramets were fully matured in leaf area and shoot height after 2 years. Overall, rapid, early season shoot growth, high survivorship and ramet production induced by severance enable lily-of-the-valley to rapidly colonize and persist in disturbed sites.

CHRISTIANSEN, TIM A., SUE A. PERRY, and WILLIAM B. PERRY. West Virginia University, Morgantown, WV 26506-6125 USA. Litter temperature and moisture effects on invertebrate density.

Changes in litter temperature and moisture may affect litter invertebrate density. We altered litter temperature (avg. increase of 0.5°C) and moisture (avg. 3% increase) with fiber landscape cloth (6x6m) in an attempt to examine the effect of climate change on soil biota. We established experimental areas on three north aspects and three south aspects in two Appalachian mixed hardwood forests. Total invertebrate density declined 15% in spring and summer and a 20% increase occurred in autumn. Mite (Acari) density was 30% lower in altered litter temperature and moisture blocks as compared to density in reference blocks. Density of 15 other invertebrate orders did not significantly change. Our results indicate subtle changes in litter temperature and moisture altered invertebrate density in these forests. Precipitation quantity influenced litter invertebrate density over a four year period. Mite density significantly increased, whereas springtail density declined during drought years. Carbon and magnesium declined in covered blocks. Microbial biomass increased in covered blocks.

CLANCY, NANCY A. University of Rhode Island, Kingston, RI 02881, USA. Variation in proteins and life history traits among populations of a marine amphipod.

Jassa marmorata is a tubicolous marine amphipod which is widely distributed over diverse habitats. Development is direct; there is no planktonic or dispersal stage in the life cycle. Three major questions are addressed in this model system: 1) do life history traits vary on local geographic scales? 2) is the variation genetically based, or is it a plastic response? and 3) is the life history response adaptive? An inverse matrix technique was used to estimate the vital demographic rates for two field populations. Rates were compared between local patches by using a bootstrap to place confidence intervals about the estimates. Vital rates varied both

spatially and temporally. Results of reciprocal transplant experiments revealed genetic differentiation of growth rates between sites. Allozyme electrophoresis was used to estimate gene flow on local and regional scales. Low F_{ST} values indicated high levels of gene flow among all sites. If individuals disperse among patches, as estimated by gene flow, a plastic response would be more adaptive than genetic differentiation. The incongruity in the spatial patterns of life history and allozyme differentiation suggests that life history traits respond more quickly to local selective regimes.

CLARK, MARK E. and KENNETH A. ROSE. Graduate Program in Ecology, University of Tennessee, Knoxville, TN 37996, USA and Oak Ridge National Laboratory, Oak Ridge, TN, 37831, USA.
Population dynamics of stream resident brook char and rainbow trout in sympatry: implications of an individual-based model.

An individual-based model of sympatric brook char and rainbow trout resident in a high gradient stream is developed to investigate the relationships between population dynamics and fecundity, time of spawning, streamflow and water temperature. Full life cycles of both species are modeled in a heuristic stream with flow, temperature, gradient and invertebrate prey densities typical of a 2nd - 3rd order southern Appalachian stream. Model predictions of densities, growth rates and mortality rates are similar to reported values for southern Appalachian streams. Model simulations indicate that higher fecundity and greater redd success due to timing of spawning of individual rainbow trout could account for rainbow trout outcompeting brook char. Together, fecundity and timing of spawning by rainbow trout yield higher recruitment and tend to offset slight metabolic advantages of brook char.

CLARKE, PAUL D. G., ANTOINE J. MORIN and DAVID J. CURRIE. University of Ottawa, Ottawa, ON K1N 6N5. The weak effects of density–dependent processes and population regulation.

The population regulation hypothesis requires that the per capita growth rate be some function of the population's density $(dN/dt)(1/N) = f(N)$. Though this function make take on different forms, it must be a decreasing monotonic function in order to stabilize the population around some equilibrium density. This implies that there is a negative rank correlation between the per capita growth rate and the population density. Likewise, it also implies that there be a positive correlation between the observed values of the per capita growth rates and those predicted by f(N) if f(N) were known. Using long term population time series data (≥ 9 years) from 70 natural animal populations, the general influence of density-dependent factors upon the abundance of animal populations was inferred from the coefficients of determination for these two predicted correlations. On average, 22.9% and 36.7% of the temporal variability in the per capita growth rate could be statistically related to population density. The remaining portion of the temporal variability was attributed to density-independent factors and random error. It was concluded that the effects of density-dependent processes within natural animal populations were generally weak.

CLAWSON, R.G., B.G. LOCKABY, and R.H. JONES. Auburn University, Auburn, AL, 36849, USA. Responses of amphibian populations to harvesting in floodplain forests of southern Alabama.

Surveys were utilized to determine the effects of harvesting on amphibian populations inhabiting forested wetlands in southern Alabama. Eight sites were surveyed and consisted of 2 stands harvested in March 1991, 2 stands harvested in March 1993, and controls associated with each harvest site. Surveys were conducted on the following dates: 26 April-10 May 1992; 27 Oct.-9 Nov. 1992; 21 March-3 April 1993; 7 Sept.-20 Sept. 1993. Amphibians found in pit traps and on hand collection searches were identified, measured, and weighed. Combined unharvested sites averaged greater species diversity than sites harvested in 1991 during the spring and autumn 1992 surveys. Number of species and total number of amphibians on the sites harvested in March 1993 decreased during the spring 1993, but increased during the autumn 1993 survey. During the first 3 surveys, the largest numbers of amphibians were recorded on the combined sites harvested in 1991 due to the presence of one species, whereas on the fourth survey the largest numbers were recorded on the site harvested in 1993 and its associated control. A shift in species composition was observed on harvested sites. In addition to harvesting, individual site variation, hydrologic regime, and temperature affected numbers and types of amphibians captured.

CLEIN, JOY S., and JOSHUA P. SCHIMEL. University of Alaska Fairbanks, Fairbanks, AK 99775 USA. Mineralization and nitrification during the transition from alder to poplar in the Alaskan Taiga.

Primary succession on the Tanana river floodplains progresses from alder, with an open nitrogen cycle and rapid nitrification, to poplar, with a closed cycle and little nitrification. To determine the mechanism(s) controlling this shift, we transplanted soils between alder and poplar sites with controls held in their home site. Mineralization rates and nitrification potential were measured before placement in the field, after 1 month and over the following growing season. The nitrification potential of the transplanted alder soil was lower than its control, while that of the transplanted poplar soil was higher than its control. This pattern parallels the pattern of NO_3 concentrations in the field. Lab incubations show the ratio of C to N mineralized in poplar was much greater than in alder (40 vs. 20) suggesting that microbes in the poplar soil were N-limited. Our results suggest that the decrease in nitrification as poplar becomes dominant is due to changes in C and N availability rather than any specific chemical effects.

CLONINGER, CHERYL, MARIAN SMITH and KURT SCHULZ. Southern Illinois University, Edwardsville, IL. 62026, USA. Field measurements of stomatal conductance and fluorescence of *Impatiens pallida* in response to high irradiance.

Impatiens pallida is an herbaceous species common to the edges and clearings of moist woodlands in North America. Within this environment, levels of irradiance encountered by *I. pallida* range from deep shade, with only a few sunflecks, to more than three hours of full sunlight/day. Field observations indicate that leaves of *I. pallida* wilt within seconds of exposure to high irradiance and may remain severely-wilted for several hours while in full sunlight. However, stomatal conductance is relatively unaffected during this period. Although fluorescence measurements showed some evidence of photoinhibition in plants in full sunlight, the rapid recovery of F_v/F_m after a return to shade indicated that no heat- or photo-damage had occurred. This strongly suggests that *I. pallida* is adapted for growth in canopy gaps receiving extended periods of full sunlight.

COBB, NEIL S., and THOMAS G. WHITHAM. Northern Arizona University, Flagstaff, AZ 86011, USA. Lack of herbivore deme formation on individual pinyon pines and the potential importance of within-plant heterogeneity preventing deme formation.

We examined the deme-formation hypothesis, which states that sessile herbivores on long-lived hosts become locally adapted to the defensive phenotypes of individual trees. We showed a five-fold increase in resistance by individual pinyon pines (Pinus edulis) to the pinyon needle scale (Matsucoccus acalyptus). Although such variation could represent a significant selection pressure favoring deme formation, two lines of evidence led to rejection of the hypothesis. First, there were no significant differences in mortality among scale populations in a reciprocal transfer experiment. Second, a seven-year experiment showed that mortality of newly founded, incipient scale populations was comparable to established scale populations. We also show that within-tree resource heterogeneity may be so great as to prevent the evolution of demes on individual hosts. Additional transfer experiments from stressed to non-stressed host populations led to herbivore extinction in three years. These results suggest that the pinyon needle scale is adapted to populations of trees, not individual tree phenotypes.

COCHRAN-STAFIRA, L., C.N. VON ENDE, and S.M. SCHEINER. Northern Illinois University, DeKalb, IL, 60115, USA. Sarracenia purpurea pitchers: structure and dynamics of a metacommunity.

The pitchers of Sarracenia purpurea contain a food web composed of bacteria, protozoa, rotifers, and larvae of the pitcher plant mosquito Wyeomyia smithii. We predicted mosquito predation on protozoa and rotifers would impact bacterial community dynamics via cascading trophic effects. Canonical correlation analysis and affinity analysis of census data showed each pitcher contained a unique community. Some taxa were shared among pitchers; others were unique to a particular pitcher. This variation among pitchers prevented detection of a trophic cascade. Predation regulated community structure in experimental pitchers. The pitcher food web is best interpreted as a metacommunity in which individual pitchers are patchily distributed across the bog landscape. Each pitcher contains a portion of the complete food web. The structure of individual pitcher communities is the result of stochastic colonization events coupled with regulation by the direct and indirect effects of predation.

COFFIN, DEBRA P. and WILLIAM K. LAUENROTH. Colorado State University, Fort Collins, CO 80523, USA. Regional analysis of the recruitment of the perennial grass, Bouteloua gracilis: effects of climate change.

We evaluated the recruitment potential by seedlings of the perennial C_4 grass, Bouteloua gracilis (blue grama) for the central grassland region of the U.S. under current climatic conditions and for changes in climate. Four grassland types are found within this large region. B. gracilis dominates the vegetation for one grassland type, the shortgrass steppe, and is common in the other three types (northern and southern mixedgrass, and tallgrass prairies). The geographic distribution of abundance of this species may be explained by its potential for recruitment by seedlings. We used a multi-layer daily time step soil water model to evaluate the probability of recruitment of B. gracilis seedlings for a range of soil textures and a range of current and expected changes in climatic conditions representative of the region. Simulations were conducted using daily precipitation and temperature data for > 200 weather stations. Probability of recruitment increased with increasing temperature and precipitation, and was also positively related to silt content of the soil. Probabilities were lowest in the coolest and driest areas, including parts of the shortgrass steppe. The effects of climate change on recruitment was dependent upon the balance between increases in temperature and decreases in precipitation.

COGBILL, C.V. and P.S. WHITE. Plainfield, VT, 05667, USA, and University of North Carolina at Chapel Hill, Chapel Hill, NC, 27599. USA. Eastern montane spruce-fir forests: history, composition, and structure.

High elevation forests of spruce (*Picea*) and fir (*Abies*), with associated hardwoods, dominate the higher slopes of the mountains of eastern North America from ca. 35 to 49 degr. N. Lat. The southern and northern montane spruce-fir forests have about a 60% overlap in their vascular plants. The absence of large areas of appropriate elevation for spruce-fir in the central Appalachians, the island-like nature of the spruce-fir forests at their southern limit, and probable differences in source areas for the floras, has resulted in a higher portion of endemics and a distinctive floristic composition in the south. Spruce-fir forests were heavily

disturbed by logging both south and north but conservationists were able to protect some large areas of old growth forest in the south. Old growth is rarer in the north. The southern forests, however, have been devastated by infestation by an exotic insect and both northern and southern forests have been affected by pollutant deposition. Red spruce, the species most affected by pollutant effects, may have persisted during the last glacial advance along the Atlantic seaboard. It is the most genetically depauperate and least winter hardy of eastern spruces and this may explain its vulnerability to decline.

COGLIASTRO[1,2], A., D. GAGNON[2] and A. BOUCHARD[1]. [1]Institut de recherche en biologie végétale, Jardin botanique de Montréal, Qc, Canada, H1X 2B2 and [2]GREF, Université du Québec à Montréal, Qc, Canada, H3C 3P8. Site and weed control effects on biomass and nutrition of planted hardwood trees in southern Quebec.

Growth and nutrient analysis of trees in plantation can help improve site classification systems or assess weed control efficiency. Experimental plantations were established in 1988 in southern Quebec on 4 sites (2 tills, 1 sand plain, 1 marine clay), with 2 weed control treatments (herbicide, organic mulch and control), and 4 hardwood species. Biomass and nutrients concentration of different plant parts were mesured for the first two years following plantation. MANOVA showed effects of site and treatment on mineral elements composition of trees. ANOVA showed highest biomass production and [N] with the best weed control (herbicide). This treatment also resulted in higher [Ca] and/or [K] for stems and roots. With herbicide, a weak site effect was detected on biomass and [N], whereas [K] was markedly higher on the sandy site, a compensation effect for low [Mg]. Also, [P] and [Ca] in roots and stems were more affected by site than [N]. An efficient weed control induced luxury consumption of trees, but tended to reduce sites effects on tree biomass and nutrients concentration despite different soils characteristics.

COLE, KENNETH L. National Biological Survey Coop Unit, University of Minnesota, St. Paul, MN 55108, USA. Past equable climates, mixed assemblages, and the regression fallacy.

Equable climates are often invoked to account for Pleistocene mixed (disharmonious) assemblages of plants or animals. However, mixed assemblages are defined by comparison with only modern distributions. Many modern assemblages, such as the western ponderosa pine and the northern hardwoods forests, are mixed assemblages when compared to Pleistocene distributions. Thus, explaining past assemblages with no modern analog by invoking a past equable climate ignores the fact that many modern assemblages have no past analog, yet the modern climate is not considered equable. This logical error is analogous to the regression fallacy in statistics. A change in the variability within assemblages through time cannot be detected if only the presence (and not the absence) of extreme species are considered. Because species also respond to historical and other non-climatic variables, interpretations will inevitably be biased toward equable paleoclimates. A more direct approach is to count those species that presently reside in equable climatic zones. If the species typical of modern equable zones are absent, then the proposed equable paleoclimate becomes tenuous.

COLEMAN, M.D., R.E. DICKSON, AND J.G. ISEBRANDS. USDA Forest Service, Forestry Sciences Laboratory, Rhinelander, WI 54501, USA. Growth and respiration of aspen roots exposed to ozone and elevated carbon dioxide.

Rooted cuttings of three aspen clones (271, O_3 tolerant; 216, intermediate; and 259, O_3 sensitive) were exposed to ambient air (control), ozone (160 ppm O_3, 8 h daily), CO_2 (ambient +350 ppm CO_2), and O_3 + CO_2. Root growth, root respiration, and soil respiration were measured periodically for 12 weeks. After 12 weeks, O_3 caused up to a 48% decrease in root dry weight and 53% decrease in root respiration (μmol plant^{-1}s^{-1}) compared to control treatments. Changes in root dry weight and respiration rate generally followed the O_3 sensitivity rankings of the clones. In contrast, elevated CO_2 vs. control plants caused up to a 63% increase in root dry weight and a 47% increase in root respiration; again there were big clonal differences in response. Compared to the control treatment, there were no consistent changes in root weight due to the combined O_3 and CO_2 treatment, but root system respiration declined slightly. There were no consistent treatment or clonal effects on specific root respiration (SRR) (μmol g^{-1}s^{-1}); however, SRR respiration declined with age. SRR increased with either O_3 or elevated CO_2 for clones 216 and 259, but decreased for clone 217. Aboveground environmental stress affects aspen root growth and physiology in complex ways, and the response obtained has a strong genetic component.

COLLINS, ANGELO. Florida State University, Tallahassee, FL, 32306, USA. Portfolio assessment -- Promises and pitfalls.

Portfolios, collections of evidence of students' knowledge, skill and/or disposition, have been growing in popularity as a mode of assessment for almost ten years. As is true of all modes of assessment, portfolios have strengths and weaknesses that make the more suitable for some assessment purposes than others. Portfolios are especially useful when gathering data about the changes in a students' understanding over a period of time. Portfolios are also useful when both the subject matter and the intended students' understanding is complex and contextual. Because portfolios appear seductively simple, they are subject to abuse -- putting stuff in a folder -- and are easily confused with scrapbooks, folders, and long term projects. The feature that distinguish portfolios from other collections of material is the emphasis on purpose. This presentation will review purpose, design and scoring of portfolios. Issues associated with purpose include both goal and intended use, who decides the purpose, and how to select a purpose that can be achieved in a course or program of study. The main design questions are what are about the types of evidence, what will count as evidence and how much evidence. Two scoring methods, one derived from models of desired outcome and the other based on professional judgment will be presented.

COLLINS, S.L. Ecological Studies Program, National Science Foundation, 4201 Wilson Blvd., Arlington, VA, 22230, USA. Phasing of disturbance and plant community stability.

Disturbances have often been viewed as forces creating spatial and temporal variation in communities. Grasslands, however, may be an enigma because fire is a natural disturbance that is necessary to maintain stability in tallgrass prairie vegetation. In this study, I examined the effect of fire frequency on stability and instability in grassland vegetation. Data are from the Konza Prairie LTER site in which management units are subjected to different frequencies of spring burning. Vegetation composition has been recorded annually in permanent plots since 1981. DCA ordination separated vegetation based on fire frequency, sites burned annually or every 2 years have greater graminoid cover and lower diversity than unburned sites or sites burned every 4 years. DCA axis II separated upland versus lowland sites. Phase-space plots indicated directional change in annually burned and unburned sites, but not sites burned once every 2 years which exhibited no pattern of compositional change over time. Thus, fire is not necessarily a stabilizing force in tallgrass prairies. The degree of change over time at different fire frequencies averaged about 20% which may provide a baseline for developing an operational definition of "climax" vegetation.

CONN, CHRISTINE E. and FRANK P. DAY. Old Dominion University, Norfolk, VA, 23529, USA. Belowground decomposition and nutrient dynamics on a Coastal Plain barrier island.

Litterbag studies on a barrier island chronosequence of dunes and swales indicate belowground decomposition of roots and nutrient immobilization dynamics are influenced by nitrogen availability, litter quality and hydrology. We hypothesized that roots buried in the most nitrogen poor dunes would immobilize nitrogen. However, roots buried in the oldest, most nitrogen rich dune decayed faster and, contrary to our hypothesis, exhibited net nitrogen immobilization. Nitrogen ammendment stimulated decomposition and produced net nitrogen immobilization in the younger, more nitrogen limited dunes. In the saturated soil conditions of swales, woody tissues decayed slower than herbaceous tissues and conserved relatively more nitrogen and phosphorus. Differences in herbaceous litter quality in dunes resulted in different patterns of phosphorus release although decay rates did not differ. Herbaceous roots buried at all sites decayed slower in saturated swales than in the drier dunes. Phosphorus release was greater under saturated conditions.

CONSTABLE, JOHN V.H.[1]; GEORGE E. TAYLOR, Jr.[1,2]; DAVID A. WEINSTEIN[3] and JOHN A. LAURENCE[3]. [1] Desert Research Institute, Biological Sciences Center, Reno, NV 89512; [2] Department of Environmental and Resource Sciences, University of Nevada-Reno, Reno, NV 89509; [3] Boyce Thompson Institute, Ithaca, NY 14853. Modeling the response of mature Pinus ponderosa Laws. to tropospheric ozone: Effects of genotypic variability.

Regionally distributed pollutants (e.g., tropospheric ozone and CO_2) can influence the growth of terrestrial plants. The mosaic of genotypes in natural populations makes it difficult to predict the ecological consequences of pollutants throughout a species' distribution. We simulated the response of Pinus ponderosa Laws. to ambient, sub-ambient and above-ambient tropospheric O_3 for 3 years using TREGRO, a physiologically based tree growth model. Parameters controlling growth and carbon allocation were obtained from the literature and were varied to simulate intravarietal and intervarietal genotypes (western var. Ponderosa and eastern var. Scopulorum) of Ponderosa Pine. Parameter differences between the varieties include physiology, carbon allocation and phenology. Ozone altered 3 year biomass gain (+6% to -61%) and fine root to leaf mass ratio (-8% to -14%) in spite of a small effect on photosynthesis ($\leq$ 10%). Overall, O_3 caused growth differences between varieties to be reduced. The reduction in growth differences between genotypes due to ozone has consequences for regional identification of populations sensitive to the effects of tropospheric ozone.

COOK, EDWARD R. Lamont-Doherty Earth Observatory, Palisades, NY 10964. USA. Red spruce decline in the Appalachian Mountains: what do the tree rings tell us?

The decline and mortality of red spruce (*Picea rubens* Sarg.) in the Appalachian Mountains was first recognized over 20 years ago and its cause has been hotly debated ever since. Tree-ring analysis has played an important role in documenting and interpreting this phenomenon, although the interpretations made from the same red spruce tree-ring data have sometimes led to conflicting claims. These conflicts have arisen partly from the complexity of tree rings as records of environmental change and numerous uncertainties about the histories of the trees and stands being studied. Even so, it has been possible to make some rather general statements about the growth and decline of red spruce based on the tree-ring analysis of thousands of trees growing in the northern and southern Appalachians. In this talk, I will review these basic findings. In particular, I will address the evidence for the decline in the tree-ring data and the degree to which it appears to be anomalous. Two hypotheses formulated to explain the decline in terms of natural phenomena are also examined using tree-ring analysis. These are stand dynamics and climatic change. Neither hypothesis appears capable of explaining the general decline of red spruce in the northern Appalachians, although each is likely to have played a part in the perceived decline at some locations.

COOKE, JERRY L. and KEN L. RISENHOOVER . Texas A&M University, College Station, TX 77843, USA. Landscape Structure and Its Impact on Interpretation of Desert Mule Deer Population Behavior in the Chihuahuan Desert.

This study examined mechanisms affecting mule deer distributions in the Chihuahuan desert. We combined eaphic data and measurments of rainfall to model spatial-temporal patterns of vegetative productivity. Model output was used to model mule deer

movement and to similate deer movements and to predict their distribution patterns. Mule deer distribution ranged from nearly-continuous (summer) to highly-fragmented (spring), depending on rainfall and associated vegetative production. In the simulations, deer occurred mostly in sites having greater vegetative biomass, although some productive sites were unoccupied because they were isolated. Plant biomass alone did not reliably index mule deer population density in this desert system. Taken together, models successfully predicted vegetative production and mule deer dispersion at the landscape level.

CORBETT, ERICA A. and ROGER C. ANDERSON. Illinois State University, Normal, IL, 61761, USA. Prairie restoration on a former strip mine: 15 years later.

Former strip mines have physical and chemical properties that present a challenge for reclamation. Compaction, pH changes, and poor nutrient status hinder natural revegetation. Prairie plants can reduce erosion, improve the soil, and provide wildlife habitat. We examined the success of prairie restoration on a recontoured strip mine spoil site in Grundy County, IL. Prairie species were planted on this site in 1978. Soil pH ranges from 4.4 to 7.1, available phosphorus from 0.5 to 3.0 ug/g, and texture is predominantly a clay loam. Vegetation cover and biomass were sampled in 1980, 81, 92, and 93. Generally, weedy species are increasing on the site. Biomass of weedy species was significantly greater ($p < .05$) in July 1993 than in July 1980 or 81. In addition, the number of weedy species increased. Biomass of prairie grasses did not change significantly across years. However, both Indian grass (Sorghastrum nutans) and big bluestem (Andropogon gerardi) declined in cover between 1980-81 and 1992-93. Switchgrass (Panicum virgatum) did not differ between years. Our data indicate that the site is declining in quality as a prairie and may benefit from prescribed burns.

CORNELL, HOWARD V. AND BRADFORD A. HAWKINS. Department of Biology, University of Delaware, Newark, DE, 19711, USA and NERC Centre for Population Biology, Imperial College, Silwood Park, Ascot, Berks, SL5 7PY, UK. Survivorship patterns and mortality sources of herbivorous insects: some demographic rules of thumb.

Life tables for 124 free-living holometabolous insect herbivores were compiled from the literature. Survivorship and sources of mortality were then correlated with the ecological setting of the herbivore. Exophytic herbivores experience lower immature survivorship than endophytics, but compensate with larger body sizes and fecundities. Natural enemies are a more important cause of death than any other mortality source, including plant factors. Plant factors are more important as mortality sources for endophytics and less important for exophytics, whereas enemies are more important for exophytics and less important for endophytics. Finally, enemies are more important in tropical than in temperate zones, whereas weather is more important in temperate than tropical zones. These patterns should guide the development of an empirically based theory of herbivore demographics.

CORTWRIGHT, SPENCER A. Indiana University Northwest, Gary, IN, 46408, USA. Importance of predator density on potential for direct and indirect effects in an aquatic larval amphibian community.

That predators potentially influence the relative and absolute abundance of prey species through direct and indirect (e.g. trophic links, nonlethal) effects is increasingly emphasized. Careful study of predator density and limitation in nature is essential in order to fully assess the importance of these effects. Four years of data from 30 ponds in southeast Michigan show that predator (insects - Dytiscus, Anax, Lethocerus; salamanders - Ambystoma tigrinum) densities were generally quite low. Field pen (3.0x1.5m) experiments on the influence of predators (natural densities) on prey survival were done. Results indicate that both direct and indirect predator effects were relatively small on three species of amphibian prey. Research on complex predator effects must also focus on factors affecting predator density. Too much emphasis on effects of high density predators will mislead us on the roles of predators in nature. Low predator densities may result from interference, a varying abiotic environment, etc.

COSTANZA, ROBERT. University of Maryland, Solomons, MD, 20688, USA. Ecological Economics: integrating the study of humans and nature

Ecological economics is a transdisciplinary effort to link the natural and social sciences broadly, and especially ecology and economics. The goal is to develop a deeper understanding of the complex linkages between ecological and economic systems, and to use that understanding to develop effective policies that will lead to a world which is ecologically sustainable, has a fair distribution of resources (both between groups and generations of humans and between humans and other species), and efficiently allocates resources including "natural capital". This will require a new approach to science that is comprehensive, integrative, multiscale, pluralistic, and acknowledges the huge uncertainties involved. Examples of integrated assessment and modeling studies at local, regional, and global scales are discussed as cases that both require and force the integration of ecology and economics and help to build common understanding of linked ecological economic systems.

COUGHLAN, JOSEPH C. Johnson Controls World Services, NASA Ames Research Center, Moffett Field, CA, 94035-1000, USA. Regional carbon and water flux simulations with data aggregated with grids and the Ecological Diagnostic System.

Regional simulations of coniferous forest ET and NPP can be computationally limited due to the large amount of detailed landsurface data now available from remote sensing and other digital sources. Aggregation is a method to reduce the data for practical applications. Estimates of the hydrologic budget made with data aggregated into grid cells (sized from 30 m up to 9 km) were insensitive to cell size for a mesic forest watershed but, NPP estimates were sensitive to cell size. Replications of NPP estimates made with large cell sizes randomly placed on the landsurface (9 km) varied by up to 10%. NPP variability is due to the nonlinear averaging of some landsurface characteristics. The Ecological Diagnostic System, a knowledge-based method, also aggregates the nonlinear data, but the aggregations are made for cells with similar ecological function which can reduce aggregation error. The diagnostic aggregation maintains detailed features blurred in large gird cells, is not computationally demanding, and its diagnostic conclusions classify both disturbed and water stressed into ordered classes representing a water stress gradient.

COWIN, S. and M.R. FULTON. Texas A&M University, College Station, TX, 77843, USA. Dissection and Growth Analysis of a Post Oak Savanna Stand.

The post oak savanna of east-central Texas consists of scattered large oak trees (primarily Quercus stellata) that serve as nuclei for the establishment of redcedars (Juniperus virginiana), yaupon (Ilex vomitoria) and some oaks. A 25 X 25 m plot was dissected to quantify spatial patterning and spatial effects on tree growth. Stem disks were taken at the base, 1m, 2m, 4m, 6m and 8m heights of all post oak, redcedar and yaupon individuals having a diameter at breast height. Growth increments for the previous decade were measured from prepared disks. Canopy dimensions (height and extent in cardinal directions), dbh, basal diameter and map location were also recorded for each individual. Leaf area for trees was inferred from sapwood area/leaf area correlations developed from trees harvested nearby. The clustering of redcedar and yaupon under the canopies of large oaks is strong and statistically significant, in spite of the fact that growth increments were highest in the open or on the perimeter of clusters. Most of the variation in growth rates was accounted for by variations in leaf area. The implication is that these trees and shrubs are adjusting to their local environments more through the placement and amount of leaves carried than through physiological adjustments of the leaves themselves.

CRAFT, C.B., S. BARTOW and C.J. RICHARDSON. Duke University, Durham, NC, 27708, USA. Reconstructing historical changes in Everglades hydrologic regimes associated with anthropogenic hydroperiod alterations.

Pollen analysis and Pb-210 dating of peat cores were used to reconstruct shifts in wetland plant communities associated with construction activities (canal excavation, water control structures) to drain the Everglades. Analysis of peat depth increments revealed little (1%) pollen associated with aquatic macrophytes (Nymphaea, Sagittaria) in the upper 10 cm of peat. Below 10 cm, Nymphaea and Sagittaria pollen increased to 10% and 4%, respectively, at a depth of 20 cm and remained constant below this depth. Concurrent with this increase in pollen of aquatic vegetation was a decrease in pollen associated with species adapted to drier habitats. Ragweed, Ambrosia, accounted for 18% of the pollen in the surface peat, decreasing to 1% at a depth of 20 cm. Pb-210 dating indicated that the shift from aquatic vegetation towards species adapted to drier environments began in the early 1900's and corresponded to the first attempts to drain the Everglades.

CRAIG, TIMOTHY P. and JOANNE K. ITAMI. Arizona State University West, Phoenix AZ, 85069, USA. Pre-and post-zygotic barriers to gene flow between host races of *Eurosta solidaginis* (Diptera: Tephritidae).

We studied post-zygotic barriers to gene flow between host races of *Eurosta solidaginis,* a gall-forming tephritid fly, on two species of goldenrod, *Solidago altissima* and *S. gigantea.* Each host race had much higher survival when it developed on it's own host plant than when it developed on the other host plant. Crosses between the two host races had much lower rates of survival than the parentals on both host plants ($P < 0.0001$). The greatest difference in mortality of the host races on their own host plants compared to both the host races on the non-host and the F1's on both host plants was a reduction in early larval survival. The F1 flies that emerged were viable, fertile and produced F2 and backcross offspring. The survival rate of F1 flies was strongly dependent on the genotype of the host plant. In an experiment on clonal replicates of 5 genotypes of *S. gigantea,* F1 survival differed significantly among genotypes ($P < 0.001$). The rate of gall formation by F2 and backcrosses was also significantly lower than that of parentals ($P < 0.05$), providing further evidence of barriers to gene flow.

CRAWFORD, EDWARD R., DAVID W. MARTIN and DONALD R. YOUNG. Virginia Commonwealth University, Richmond, VA 23284, USA. Gap dynamics for barrier island shrub thickets (Myrica cerifera).

Shrub thickets frequently represent an intermediate seral stage in the development of maritime forests on barrier islands. The purpose of this study was to quantify natural thicket gaps to better elucidate barrier island successional processes. The study focused on Hog Island, a primary field site of the Virginia Coast Reserve, where island accretion patterns have produced a chronosequence of soils and Myrica cerifera shrub thickets. Gaps were most frequent in the oldest thickets (> 40 years) at the bay side edge of the island, with only a few gaps formed in the most productive thickets (15-30 years) in the island interior. The sizes and causes of gap formation were variable. Although most gaps were formed due to shrub senescence and competition with vines, disease and weather related disturbances also influenced gap development.

An analysis of both the soil seed bank and the existing seedlings in the thicket understory revealed greater density and diversity in the oldest thickets as compared to the productive mid-island thickets. Myrica cerifera may respond (i.e. recover) most quickly to gaps that form in the mid-island thickets. In contrast, shrub response in older thickets may be limited by competition from vines and by **rapid** seedling establishment from the well developed seed bank. Gap formation in barrier island shrub thickets may accelerate succession towards a maritime forest.

CRAWLEY, MICHAEL J. Imperial College, Silwood Park, Ascot, Berkshire SL5 7PY, UK. Reconstructing the early transitional dynamics of the Park Grass Experiment: new work at Silwood Park.

The Park Grass Experiment at Rothamsted has run continuously since 1856. Its 89 different plant communities have been created by various combinations of fertilizer and lime application. We have a reasonably clear picture of the equilibrium dynamics of these communities, but no information at all on the rapid species turnover that must have occurred during the early years after the treatments had first been applied. I describe a new experiment set up in 1991 at Silwood Park with the aim of studying the transitional dynamics that follow a radical change of inputs. The experiment has plus and minus rabbit grazing, plus and minus molluscs, plus and minus invertebrate herbivores, three plant competition treatments (minus grass herbicide, minus herbs and a control) in addition to 12 different combinations of N, P, K and Mg (applied at the rates used in Park Grass).

CREWS, TIMOTHY E. and PETER M. VITOUSEK. Stanford University, Stanford, CA, 94305, USA. Phosphorus transformations and soil nutrient availability across a long soil chronosequence in Hawai'i.

In 1976, Walker and Syers developed a model of how the chemical forms and biotic availability of soil phosphorus change during soil development. We tested this model by carrying out phosphorus fractionations (modified Hedley et al. 1982) on six volcanic soils, sampled from a monochronosequence spanning 300 years - 4.5 million years. The soil forming factors of climate, vegetation, parent material, and slope were all relatively constant across the soil age gradient. As fractions of total-P, the various pools of phosphorus behaved very much as predicted by the Walker and Syers model. HCl extractable P (presumably calcium phosphates) comprised 82% of total-P in the 300 year old soil at Kilauea, and then decreased to 1% at the 16,000 year old soil at Laupahoehoe. NaOH extractable Pi and Po increased from the youngest site to the 180,000 year old Kohala site, and then declined to the 4.5 million year old Kokee site. Residual-P increased steadily with soil age. To compare relative nutrient availability between chronosequence sites, cation and anion exchange resin bags were buried and removed on a monthly basis. How contemporary nutrient availability relates to long term soil transformations will be discussed.

CRONE, ELIZABETH E. Botany Department, Box 90339, Duke University, Durham, NC, 27708-0339, USA. Complex dynamics in competing species.

A number of recent studies have pointed out the inability of simple models of population regulation to adequately capture the qualitative dynamics of natural populations. One potential problem with these models is that they ignore variation within species or among ecologically similar competing species. I investigated discrete-generation models of competing species to determine whether the dynamics of mixtures of species are intermediate between the dynamics of the species in isolation. When both species are regulated by simple density dependence (density feedback only from the immediate past generation), the dynamics of the mixture fall between the dynamics of isolated lines. For example, a mixture of two species with chaotic and stable dynamics in isolation could undergo limit cycles when together. However, when species have different time lags before density feedback, the community dynamics can be qualitatively different from the dynamics of isolated lines. For example, some competing species which exhibit chaotic dynamics in isolation coexist at stable, constant population densities. This implies that simply adding or averaging single-species parameters does not always predict the qualitative dynamics of mixtures. Furthermore, it suggests that the presence of competitors can be critical to population stability.

CRONIN, JAMES T. Southern Forest Experiment Station, USDA Forest Service, 2500 Shreveport Hwy., Pineville, LA, 71360, USA. Ecological genetics of traits associated with the foraging behavior of a mymarid egg parasitoid.

The foraging behavior of Anagrus delicatus has been studied in detail. Anagrus has a low fixed fecundity (it is proovigenic) and disperses its eggs among many discrete host patches; under-exploiting the patches it visits. Currently, nothing is known of the evolution of this foraging strategy. I have examined the genetic variation in traits associated with oviposition success of a clonal population of Anagrus in California. These traits are fecundity (egg load), body size (hind tibia length, ovipositor length), and oviposition behavior (patch time, number of ovipositions and oviposition rate per patch). Although most traits exhibited significant variation among isolines, only egg load and ovipositor length were repeatable between generations (heritabilities of 0.7 and 0.5, respectively). Genetic correlations were common among traits, including a correlation between oviposition rate and body size and egg load. Implications for the evolution of Anagrus foraging behavior are discussed.

CROOK, ROBERT P. and H. LEE ALLEN. North Carolina State University, Raleigh, NC, 27695, USA. Water and Nutrient Availability effects on Fine Root Nutrient concentrations of a Loblolly Pine Stand.

Little is known about what proportion of nutrients are in the roots of loblolly pine (Pinus taeda) stand and, moreover, less is known about how an imposed resource gradient affects the nutrient concentration and content of various root classes. Research results elicit the response of a tree stand's underground biomass to a resource gradient by estimating the magnitude of a tree stand's root nutrient pool and its flux as the gradient is manipulated from an optimum level to a resource limitation of water and/or nutrients. Two levels of irrigation and fertilization were imposed as treatment, data was analyzed in a 2 by 2 factorial design on a monthly sampling scheme for a period of one year. Loblolly pine roots from the Sandhills of North Carolina were sequentially cored to a depth of 10 cm. Root samples were sorted as live or dead; by diameter class, and analyzed for nutrient concentrations of macro- and micro-nutrients. Fine roots are defined as any root being less than less than a 2 mm diameter, however coarse roots will likewise be analyzed to make good use of the sample material. Root nutrient concentrations are inversely correlated with root diameter. The effects of treatment and root diameter on root nutrient concentrations have no effect for any month of the study period. Root biomass nutrient concentrations and content will be compared to aboveground tree biomass for individual months of the study period.

CROSS, RANDALL E. University of North Carolina - Chapel Hill, Chapel Hill, NC, 27599, USA. Direct and Indirect Interactions in Juvenile Fish and Shrimp in Refuge Habitats.

Laboratory and field experiments were used to study intraspecific and interspecific interactions for two abundant macrofaunal species (*Fundulus heteroclitus* and *Palaemonetes pugio*) which seek refuge in shallow intertidal pools in salt marshes during their juvenile stages. Density, species combinations, and predation were manipulated as main factors determining growth rates and survivorship. Treatments were compared with controls (low density, single species treatments) to determine intraspecific and interspecific effects. Results indicate that fish may negatively affect shrimp growth rates in laboratory microcosms and in field enclosures. Furthermore, predation by adult *Fundulus* may reduce interspecific effects of fish on shrimp growth rates. These results suggest that indirect effects, presumably from selective predation on the dominant juvenile competitor, may reduce interspecific effects on the subordinate species in refuge habitats.

CROWDER, LARRY B., DEBORAH D. SQUIRES and JAMES A. RICE. North Carolina State University, Raleigh, NC, 27695, USA. Non-additive effects of terrestrial and aquatic predators on survival and behavior of a juvenile estuarine fish.

Spot respond to southern flounder by moving into shallow water, enhancing risk of predation to estuarine birds. We conducted an experiment to test the hypothesis that predation by birds and flounder will have significant non-additive effects on spot survival and size-structure. We expected spot to survive less well with both predators than expected from their additive effects. The experiment was a 2X2 factorial with and without flounders and bird access. Flounder reduced spot survival but birds did not. Spot survived *better* with both predators than expected based on additive effects. Mean spot size was unaffected by treatment. Spot moved to shallow water with flounder and they aggregated more tightly with birds. The observed non-additive effects could have been due to flounder avoiding birds, but since all the flounder survived, we favor the idea that spot avoid flounder predation by moving into shallow water and avoid bird predation by aggregating. This aggregation may also further reduce risk of predation by flounders.

CROWL[1], TODD A. AND ALAN P. COVICH[2], [1]Utah State University, Logan, UT, 84322-5210 and [2]Colorado State University, Ft. Collins, CO, 80523. Compensatory responses of a freshwater, tropical decapod guild following large-scale disturbances.

Freshwater shrimp population dynamics and community structure have been monitored since 1988 as part of the LTER project in the Luquillo Experimental Forest, Puerto Rico. During the sampling period, a flood and two hurricanes have impacted the forest ecosystem. The flood scoured the stream channels exporting large amounts of organic materials and small sediments, but also resulted in stream-side landslides that have become a large source of sediment input. The hurricanes resulted in large pulses of organic material in the form of woody debris and leaf material. In addition, tree fall gaps which occurred in the riparian zone resulted in patches of high algal production. Two species of shrimp exhibited prolonged increases in population density due primarily to shortened duration of life stages and decreases in age of first reproduction. We hypothesize that resource cycles enhance the diversity of the decapod guild in these streams. Without spatial and temporal patches, we predict that the predatory shrimp and crab species would become a more dominant structuring force in this community.

CROWLEY, PHILIP H. and KEVIN R. HOPPER. University of Kentucky, Lexington, KY, 40506-0225, USA. Optimal development patterns, predation, and facultative life cycles.

For many semelparous organisms with facultative life cycles, time to maturation hinges on whether a particular juvenile stage is reached by a certain time of year. As a result, cohorts of individuals may split into subcohorts differing in life-cycle duration (e.g. some "biennial" plants, fishes, and relatively long-lived insects). To generate testable predictions about the proportions p and 1-p of individuals adopting the faster and slower life-cycles, respectively, we devised an analytical optimization model of development within a cohort. The model is probabilistic: the actual development trajectory of an individual is assumed to lie within bounds that widen through time in proportion to development rate. There

are two distinct phases of development; at a particular time that ends the first phase, all individuals beyond a critical developmental stage initiate the second phase by joining the fast track, and the others join the slow track. The critical stage is the one for which fitnesses associated with the two different tracks are equal. Results show that greater predation (including herbivory and omnivory) should reduce the fast-track proportion p if faster development increases mortality (e.g. because both development rate and predation rate are mediated by juvenile "activity level", or because plant development trades off against herbivory defense); but greater development-rate-independent predation should increase p.

CROYLE, BRIAN T. and MICHAEL R. WILLIG. Ecology Program, Department of Biological Sciences and The Museum, Texas Tech University, Lubbock, TX, 79409-3131, USA. Habitat associations of two predatory aquatic insects: the role of disturbance.

The distribution of aquatic insects has been associated with substrate characteristics and hydraulic attributes --- their relative importance likely depends upon the frequency of disturbance. Disturbance affects habitat associations by mediating density-dependent selection at the intraspecific and interspecific levels, and by spatially reconstituting landscape elements. We evaluated the effect of disturbance frequency on habitat associations of two predators, Corydalus cornutus (Megaloptera: Corydalidae) and Ambrysus circumcinctus (Hemiptera: Naucoridae), in three rivers of the semiarid Southwest that differ in disturbance regime (in order of decreasing frequency of flooding, the South Llano River, San Saba River, Johnson Fork Creek) but are otherwise similar. For each species, step-wise multiple regression analysis identified substrate (e.g., particle size, vegetation) and hydraulic (e.g., velocity, Reynolds number, Froude number) characteristics strongly associated with density, whereas discriminant function analysis identified important habitat characteristics that distinguish between sites of presence and absence. Regardless of statistical approach, the effect of disturbance regime in modifying habitat associations was taxon-specific as well as season-dependent. Moreover, neither substrate nor hydraulic features dominate habitat associations at any disturbance regime.

CUEVAS, ELVIRA and CARLA ALCESTE. Instituto Venezolano de Investigaciones Científicas, Apartado 21827, Caracas 1020-A, Venezuela. Land use changes and plant cover affects soil organic matter quality as revealed by natural abundance of 13C of the soil fractions.

Two teak, Tectona grandis, plantations of 2 and 13 years of age in the Ticoporo Forest Reserve, Venezuela were sampled for determination of natural abundance of 13C in coarse (2mm - 250 μm) and intermediate (250-100 μm) fractions of soil organic matter (SOM) at 10 cm intervals to 40 cm depth. The area was under pasture during twenty years after natural forest clearing. Teak was planted on similar soils in areas cleared after 4 and 15 years of natural regeneration. The young plantation had 95% grass cover at the time of sampling, whereas the old plantation was 100% teak cover. Organic carbon (%) was similar at all depths for the two sites, but proportion of carbon from C_3 or C_4 sources was significantly different. Coarse fraction in the soil profile of the older plantation had a δ 13C of -27.5 ‰. The coarse fraction of the young plantation ranged from -23 ‰ in the top soil to -18 ‰ in the deeper soil layer. The intermediate fraction of the old plantation still reflects the period under pasture (-23 to -20 ‰). The young plantation site had a stronger signature of the successional C_3 vegetation in the 0-20 cm soil layers indicating the slow formation of more recalcitrant SOM under teak cover. Source of organic matter and relative proportions of SOM fractions are important factors in nutrient availability and SOM stabilization in the ecosystem.

CUI, MUYI and MARTYN M. CALDWELL. Ecology Center, Utah State University, Logan, UT 84322. Effects of enhanced soil P on photosynthesis, root respiration and nutrient uptake of *Artemisia tridentata* in different photosynthetic photon flux densities and CO_2 conditions.

Responses of leaf photosynthesis, root respiration and P uptake by *Artemisia tridentata* seedlings to enhanced soil P were measured under two different photosynthetic photon flux densities (PPFD) and two CO_2 concentrations to study root physiological adjustments to utilize available nutrient resources in a changing soil environment. Root respiration was measured for intact root systems in split-root chambers. Increasing P in 0.2× Hoagland's solution from 0.04 mmol to 2.0 mmol increased leaf photosynthesis by 6% in 3 days, increased nighttime leaf respiration rate by 8% and root respiration by 18%. After PPFD was reduced from 800 to 200 μmol m^{-2} s^{-1}, leaf photosynthesis deceased by 67%, and root respiration increased by 26% in the following day but then decreased by 35% over the next three days. Shading may limit root growth and nutrient uptake by lowering the carbohydrate supply to root systems.

CUNNINGHAM, SAUL A. University of Connecticut, Storrs, CT, 06269-3042, USA
Seed production by an understory palm limited by pollen supply and severe pre-dispersal predation

Seed production in plants can be determined by external factors such as pollen supply and damage by natural enemies, and mediated by the plant via selective carbohydrate allocation and fruit abortion. For Calyptrogyne sarapiquensis, an outcrossing bat-pollinated palm, the number of seed produced per inflorescence is limited by pollen supply and fruit predation, and no fruit abortion or carbohydrate-related control is apparent. Hand-pollination experiments demonstrate that fruit initiation varies with pollen supply, and that none of the variation in fruit initiation can be explained by the carbohydrate-related variables measured (trunk diameter, leaf area and local light environment). Inflorescences with 155 flowers hand-pollinated (N=48) initiated significantly more fruit than inflorescences with 50 flowers hand-pollinated (N=49: comparing medians, 89>26: U test, $p<0.000$), and more than naturally-pollinated inflorescences, even when only considering inflorescences with 155 or more flowers visited by pollinators (N=36, median=45: U test, $p=0.009$). Fruit ripening occurs approximately 10 weeks after initiation. Observation of naturally-pollinated plants indicate that, on average, more than 80% of fruit are eaten by predators before ripening, and fruit abortion is rare. Fruit from the hand-pollination experiment were counted again four weeks after initiation, when only 43% of the fruit remained, and the difference between high and low levels of pollination was still significant (U test, $p<0.000$). The loss of fruit during these four weeks was not explained by carbohydrate-related variables.

CURRAN, LISA M. Princeton University, Princeton, NJ. 08544-1003 USA. Reproductive ecology of mast-fruiting Dipterocarpaceae in Kalimantan, Indonesia: An experimental test of the predator-satiation hypothesis.

Seed production and seedling regeneration of 21 species of mast-fruiting Dipterocarpaceae were monitored in a Kalimantan tropical lowland and hill forest from 1985-1992. Three community-wide mast-fruiting episodes were documented. Seed loss from pre-dispersal and post-dispersal insect and vertebrate seed predators and the relative impact of each species was quantified. Neither insects nor vertebrates were specialized seed predators; rather, they displayed generalized seed preferences for all dipterocarp species. Nomadic vertebrate populations altered foraging ranges and displayed a numerical response linked to the availability of ripe dipterocarp seed. Natural variation in seed production and experimental manipulations of the temporal and spatial pattern of fruitfall provided a direct test of the predator-satiation hypothesis. The reproductive strategy of mast-fruiting Dipterocarpaceae is discussed in relation to the ranging and foraging patterns of dipterocarp seed predators.

CURRIE, DAVID J. and legions of students. Biology Department, University of Ottawa, Box 450, Station A, Ottawa, Ont. K1N 6N5 Canada. Global patterns of species richness and climate.

Why are there many species in some places and few in others? Several studies have shown that the variation in the number of species over continent-sized areas is closely related to the variation in macroclimatic factors: heat and moisture for terrestrial plants, and heat for terrestrial vertebrates. Yet, most of these studies dealt primarily with temperate areas on single continents. If contemporary climate is the principle determinant of large-scale patterns of richness, then richness should be related to climate in similar ways on different continents, regardless of their evolutionary histories. To test the hypothesis, we have gathered published data on the distributions of birds and mammals in temperate and tropical areas. We found that richness varies as a function of potential evapotranspiration in very similar ways on different continents in temperate areas, although there is some significant variation among continents that is unrelated to climate. In tropical areas, richness is more closely related to precipitation and annual climatic variability. Re-analysis of published data on plant richness is consistent with these observations. We conclude that most of the variation in large-scale patterns of species richness can be accounted for by contemporary climate.

CURRIE, WILLIAM S., JOHN D. ABER, WILLIAM H. MCDOWELL and RICHARD D. BOONE. University of New Hampshire, Durham, NH, 03824, USA and Harvard Forest, Petersham, MA, 01366, USA. Forest-floor dissolved organic carbon and nitrogen response to chronic N additions.

In an effort to study ecosystem responses to N deposition leading to nitrogen saturation, nitrogen (as NH4NO3) has been added for six years to two forest stands (Pinus resinosa and mixed hardwoods) in central Massachusetts. The movement of dissolved organics in soil represent important nutrient-cycling links between the C and N cycles, and between decomposition and nutrient availability. We installed zero-tension lysimeters below the forest floor to collect soil solution for chemical analysis and flux calculations. Here we report preliminary analysis from the first year of sample collection. Forest-floor-leachate hydrology shows high variation, composing from zero to 50% of precipitation quantities. Total dissolved N levels are as high as 90 mg/L and dissolved organic C ranges from 15 to 75 mg/L with some significant differences between stands and among treatments.

CURTIS, ANTHONY D. and DEBORAH A. WALLER. Old Dominion University, Norfolk, VA, 23529, USA. Seasonal rates of nitrogen fixation (acetylene reduction) in Reticulitermes termites.

The hindgut bacteria of Reticulitermes (Isoptera; Rhinotermitidae) fix atmospheric nitrogen (N). We examined seasonal rates of N fixation in Reticulitermes on the Eastern Shore of Virginia by using the acetylene-reduction assay. N-fixation (acetylene-reduction) rates were related to log temperature; rates peaked during moderate temperatures in October but were low during hot summer months and cold winter months. These results were consistent with laboratory experiments in which N-fixation rates in Reticulitermes were optimal at 26°C and low at 22°C and 32°C.

CURTIS, PETER S. The Ohio State University, Columbus, OH, 43210, USA. Leaf level gas exchange and carbohydrate metabolism at elevated CO_2: is a consensus emerging?

Many predictions concerning whole plant, population, and ecosystem level responses to rising atmospheric CO_2 are predicated on functional changes occurring at the leaf level. Net CO_2 assimilation (P_n), dark respiration, stomatal conductance, and non-structural carbohydrate content (TNC) have been among the most intensively studied responses in long-term exposures of trees

to elevated CO_2. A central theme in these studies has been the degree to which downregulation of photosynthesis occurs, and the role of nutrient availability in this response. At moderate to high leaf N, both conifer and hardwood species show sustained increases in P_n over months to years, together with substantial increases in TNC. Low leaf N, however, significantly reduces P_n stimulation by high CO_2. Effects on respiration are more variable, and may be tied to changes in leaf mass, growth rate, or N content. Important areas of uncertainty are in the interaction between leaf and canopy level responses and the regulation of the P_n response by other environmental variables, particularly light intensity.

CUSHING, PAULA E. University of Florida, Gainesville, FL, 32611, USA. Using molecular techniques to study the population structure of a spider ant-guest.

Many arthropods have evolved close symbiotic relationships with ants. My research focuses on a species of spider in the genus Masoncus (Linyphiidae) found within the nest chambers of the southern harvester ant, Pogonomyrmex badius (Formicidae). Certain ecological and life history parameters led me to hypothesize that the dispersal rate of spiders between ant nests would be low and that inbreeding of spiders within a nest would be high. To test my hypothesis, I collected 40 spiders from three different ant nests. Two of the nests were nearest neighbors and the third was 35 km away. I used the Random Amplified Polymorphic DNA (RAPD) technique to analyze the degree of polymorphisms both among spiders within each nest as well as among spiders from different nests. I found a higher degree of polymorphism than expected within each of the nests as well as a high degree of band sharing among the spiders from neighboring nests suggesting relatively high dispersal rates per generation. The data failed to support my hypothesis of low dispersal rates and high inbreeding.

CUSHMAN, J. HALL and STEPHEN G. COMPTON. Stanford University, Stanford, CA, 94305, USA and Department of Pure and Applied Biology, University of Leeds, Leeds, LS2 9JT, England. Geographic and taxonomic distribution of an indirect interaction: ant-tended homopterans benefit figs across southern Africa.

Although species pairs and assemblages often co-occur across large geographic regions, ecologists know very little about the outcome of their interactions on such spatial scales. Here, we assess the geographic distribution and taxonomic diversity of an indirect interaction involving ant-tended homopterans and fig trees. Previous experiments with this system have shown that one fig species at one site benefits indirectly from the presence of a homopteran, because the latter attracts ants that reduce both the effect of pre-dispersal seed predators and parasitoids of pollinating wasps. Based on this work, we present a non-experimental test of four conditions that must be met in order to support the hypothesis that indirect benefits in the fig system are geographically widespread and taxonomically diverse. Regardless of the region or tree species involved, 1) fig trees must be attacked by a range of non-pollinating wasps whose larvae feed on developing ovules or parasitize pollinating wasps (i.e. fig trees have ecological 'problems' that tending ants may be able to solve); 2) ant-tended homopterans must commonly occur on the figs of trees; 3) homopteran-tending ants must be sufficiently aggressive to deter non-pollinating wasps, but not the pollinating wasps; and 4) ant densities on figs must commonly reach levels that are known to significantly reduce the negative effects of non-pollinating wasps. Data from over 500 trees provide strong evidence that this indirect interaction involves at least 23 Ficus species and occurs throughout much of southern Africa.

CYR, HELENE. University of Toronto, Toronto, Ont, M5S 1A1, Canada. Inter-annual variability in population densities: does it vary with species body size?

Population densities vary from year to year in nature, casting uncertainty, of largely unknown magnitude, on short-term measurements. In terrestrial systems, inter-annual variability in population densities has been found to decrease with increasing species body size. To test the generality of this pattern, I gathered published density measurements from 75 populations of phytoplankton, zooplankton and fish sampled during at least four consecutive years in a wide range of lakes. Inter-annual variability, measured as the standard deviation of log(density), varies between 0.06 and 1.8 in aquatic populations, a range similar to that found in terrestrial systems. Populations of planktonic algae differ the most in inter-annual variability, but these differences are not related to the size of the algae nor to their taxonomic affiliation. Similarly, at a larger-scale, inter-annual variability in population densities of algae, invertebrates and fish is not related to species body size. These results stress the importance of environmental conditions on inter-annual variability in population densities.

DACEY, JOHN W.H. and BERT G. DRAKE. Woods Hole Oceanographic Institution, Woods Hole, MA, 02543, Smithsonian Environmental Research Center, Edgewater, MD 21037, USA. Stimulation of methane emission by atmospheric carbon dioxide enrichment in marsh vegetation.

Long term enrichment of CO_2 in the atmosphere over a wetland increased CH_4 emission. Emission was measured at the time of peak biomass and net ecosystem CO_2 assimilation in a C_3 sedge community where a sustained increase in carbon storage in response to experimental elevated CO_2 has been observed over the past seven growing seasons. Methane emission from the sites exposed to present normal ambient CO_2 averaged 1.37 mol $m^{-2}min^{-1}$, while emission from CO_2 enriched sites (normal ambient CO_2 +340 ppm) averaged 2.46 mmol $m^{-2}min^{-1}$ (1.97 and 3.54 mol $m^{-2}day^{-1}$, respectively). Although only a small percentage of the carbon flow through wetlands escapes as CH_4, these preliminary emission measurements suggest that the response of wetlands to elevated CO_2 may have important consequences for atmospheric methane.

DAEHLER, CURTIS C. and DONALD R. STRONG. University of California, Davis, CA, 95616, USA. High herbivore densities have limited impact on Spartina alterniflora's invasion of San Francisco Bay.

Spartina alterniflora, a perennial salt marsh grass, was introduced to San Francisco Bay in the mid-1970s from the Atlantic coast of North America. It's invasion of Pacific estuaries threatens to transform open mud flats, which are important feeding sites for shore birds, into dense monocultures of tall grass. We investigated the impact of two sap feeding herbivores, Prokelisia marginata and Trigonotylus uhleri, on vegetative growth and seed production in S. alterniflora. Both herbivores are largely Spartina specialists. P. marginata annually reaches outbreak densities approaching 1000 individuals per stem. Insecticide treatments in the field reduced herbivore densities but did not consistently increase rate of vegetative spread or seed production. Excluding herbivores from inflorescences in the field using polyproplylene tubes also failed to increase viable seed set. A greenhouse experiment demonstrated only some significant differences in dry mass and tiller production between herbivore-infested plants and herbivore-free controls. Herbivory by these two sap-feeding insects, though apparently great, is insufficient to much harm S. alterniflora or control its invasion of San Francisco Bay.

DAILY, GRETCHEN C. and PAUL R. EHRLICH. University of California, Berkeley, CA, 94720, USA and Stanford University, Stanford, CA, 94305-5020, USA. Influence of social status on individual foraging and community structure in a bird guild.

We investigated the influence of social interactions on individual foraging behavior and community structure of frugivorous birds in southern Costa Rica. Interspecific social status influenced access to food in several ways, including: (1) subordinates were interrupted more and tended to have shorter foraging bouts than dominant species ($n > 1{,}000$ bouts); (2) subordinates spent a smaller fraction of foraging time actually feeding (as opposed to looking about) than did dominants ($> 7{,}000$ video-taped head movements). At the community level, species composition of foraging assemblages was compared at isolated fruiting trees situated in an agricultural landscape near ($< .5$ km) and far from (> 6 km) a 225-ha tract of primary forest. Whereas the full complement of avian frugivores foraged at the near trees, visitors to the far trees were predominately of high social status. We consider how high social status or other traits might account for this difference in exploitation of human-controlled habitat.

DALGAARD, PAULA. University of Toronto, Toronto, ON, M5S 3B3, CANADA. A 4-year neighborhood-model competition field experiment using black spruce (Sb) (Picea mariana) seedlings with mountain maple (Acer spicatum), red raspberry (Rubus idaeus), Cinna latifolia (a grass), or Sb neighbors.

72 cleared 1-m. radius plots over a soil texture gradient on a boreal clear-cut were each planted in 1985 with one of the above neighbor species, & in 1986 with 4 operationally-grown pre-measured Sb seedlings, planted at decreasing distances from neighbor stems, with a 5th outside each plot. Neighbors & targets were measured non-destructively in the 1st &/or 2nd growing season; plots were weeded & perimeters pruned for 4 years, then trees destructively. Target yearly diameter increment is related to neighbor proximity & biomass both by rank order & by continuous "amount of neighbor" as early as 14 months post-planting. Small amounts of grass over its short survival period significantly reduced Sb growth, as did light competition for all species, and root competition on poor soil.

DALY, CHRISTOPHER and RONALD P. NEILSON. Oregon State University, Corvallis, OR, 97333, USA and USDA Forest Service, Corvallis, OR, 97333, USA. Landscape-scale simulation of climate-induced water balance and vegetation distribution in the Reynolds Creek watershed, Idaho.

Little work has been done to model the influences of climatic variability on terrestrial ecosystems at the landscape scale because of the need to address the complex interactions between landscape components both above and below ground. A hybrid landscape model has been developed that links an equilibrium, point-based vegetation model (MAPSS) with a transient, grid-based water routing scheme that simulates cell-by-cell subsurface drainage and transport (Wigmosta model). The model was applied to the Reynolds Creek watershed, Idaho, for the years 1984-1986 to simulate vegetation form and leaf area and hydrologic parameters such as soil moisture and runoff. The hydrologic portion of the model was assessed with fixed vegetation derived from a detailed vegetation map. After hydrologic calibration, the model was allowed to predict non-woody vegetation leaf area and distribution (woody vegetation could not be predicted in the 3-year time frame of the simulation). Results show good predictive capability for both hydrology and leaf area distribution, and suggest that the model can be used to assess the effects of future climatic conditions on hydrology and vegetation in a small watershed.

DALY, HERMAN E. School of Public Affairs, University of Maryland, College Park, MD 20472-1821 USA. Natural Capital as Limiting Factor in Production and Consumption: Concepts, Evidence, Implications.

A look at the relative importance of complementarity versus substitutability between natural and manmade capital in both production and consumption. Reasons for emphasising complementarity and the consequent issue of a limiting factor are given, along with an analysis of cultivated natural capital into its components, and a discussion of limiting components. Cases and policy implications will be discussed.

DAMMAN, HANS and NAOMI CAPPUCCINO. Carleton University, Ottawa, Ontario, K1S 5B6, CANADA and Université du Québec à Montréal, Montréal, Québec, H3C 3P8, CANADA. Why some herbivores are destined to be rare: a comparative study of irruptive and non-irruptive species.

Many non-outbreaking species of plant-feeding insects disperse their eggs over many host plants instead of laying them in masses. This spatial pattern of egg-laying may reduce density-dependent reduction of fecundity or increase in mortality, or it may represent a way of minimizing the variability in mortality and fecundity (i.e., risk spreading). We performed field experiments in which we compared the consequences of aggregated and non-aggregated dispersion on three pairs of outbreaking and non-outbreaking herbivores: two goldenrod-feeding aphids, two goldenrod-feeding beetles, and two birch-feeding Lepidoptera. Spreading out did not reduce density-dependent mortality or fecundity loss. In some cases mortality was actually higher for widely scattered individuals. The spatial variance in mortality was much lower for uniformly spaced herbivores, however, supporting the hypothesis that non-outbreaking species do indeed spread the risk.

DAVIDOWITZ, GOGGY. University of Arizona, Tucson AZ, 85721. The relationship between the mean and variability in precipitation across biotic communities and its evolutionary implications.

Environmental variability can have important evolutionary consequences for many aspects of population biology, such as phenotypic plasticity and the timing of life-history events. Previous studies suggest that desert biomes are characterized by high variability in precipitation in both space and time. These studies show a linear inverse relationship between the mean and variability of precipitation across biomes. I examined precipitation variability along a gradient from the desert to the ponderosa pine forest biome in the southwest United States, using a data set encompassing 301 weather stations, 15,645 station-years, and 13 biotic communities. A clear, decreasing exponential relationship exists between the mean and variability of precipitation. Contrasting results of this and previous studies may be attributed to the differences in the sample sizes and the statistics of variability used. This non-linear relationship may suggest a threshold of adaptations to environmental variability rather than a gradual change in population adaptations along this gradient.

DAVIDSON, ERIC A., SUSAN E. TRUMBORE, and DANIEL C. NEPSTAD. The Woods Hole Research Center, Woods Hole, MA, 02543, USA, and University of California, Irvine, CA, 92717, USA. Soil carbon dynamics in forests and pastures of the eastern Amazon.

Forests of the seasonally dry eastern Amazon are evergreen because they extract water with deep roots. Roots are also sources of carbon deep in the soil profile. The soil C inventory below 1m depth is >20 kg C m^{-2} at Paragominas, Brazil, which is greater than the inventory of the top 1m of soil (10 kg C m^{-2}) and the above-ground forest biomass (15 kg C m^{-2}). The $\Delta^{14}C$ of soil organic matter (SOM) at 8 m depth is -850‰, which indicates that most, but not all, of the deep soil C is very old. About 2-5 kg C m^{-2} between 1 and 8m depth (10-25% of the total C in SOM) cycles on decadal time scales. Soil $^{14}CO_2$ measurements support this estimate. Modern C deep in the soil could be lost if land-use change affects rooting depths and soil C inputs. Degraded and abandoned pasture soils have lost 1.6 kg C m^{-2} in the top 1m of soil relative to the forest soil. Loss of soil C below 1m cannot be reliably detected with standard inventory analyses, but a complete below-ground C budget constrains a model of residence times of soil C pools and permits estimation of the effects of land use change and root inputs on soil C dynamics.

DAVIS, JONATHAN P., BRUCE L. HAINES and DAVID C. COLEMAN. University of Georgia, Athens, GA 30602, USA. Fine root dynamics and rhizosphere ecology along an elevational gradient in the southern Appalachian mountains, USA.

Fine root dynamics and rhizosphere ecology have been investigated in the following plant community types: a pine-oak stand on a xeric ridge (782m), a cove hardwood stand (795m), two mixed oak stands (865m, 1001m), and a northern hardwood stand (1347m). Root biomass turnover is estimated from roots sorted from 15cm deep soil cores taken monthly. From early data in this long-term (LTER) study we estimate fine root mass to vary along this elevational gradient from 5–7 Mg/ha and total root mass to vary from 13–18 Mg/ha. Many aspects of rhizosphere ecology have been studied *in situ* on the steep slopes of these stands with mini-rhizotron boxes. Microscopic photography in these boxes demonstrates the seasonal progression of root initiation, elongation, browning, senescence and decomposition. Images of this progression as well as the seasonal development of root architectures, mycorrhizal colonization of roots, and faunal consumption of mycorrhizae will be shown.

DAY, FRANK P. and EVERETT P. WEBER. Old Dominion University, Norfolk, VA, 23529, USA. Effects of elevated CO_2 on root length density, distribution, and turnover in a scrub oak - palmetto community in central Florida.

Open-top chambers (about 4.5 m^2) were used to quantify the effects of elevated CO_2 on the belowground portion of the plants in a scrub oak-palmetto community at Kennedy Space Center, Florida. The experiment included 3 CO_2 enriched chambers (700 ppm CO_2), 3 ambient air chambers (350 ppm CO_2), and 3 reference plots without chambers. Minirhizotron observation tubes were installed at a 30° angle to a depth of about 1 m in each plot and outside the plots. A minirhizotron color video camera was used to obtain images of the roots 3 times a year to quantify changes in root length density. Elevated CO_2 chambers had greater root length densities than the ambient air chambers in November, 1992 (535 mm/mm^2 vs. 429 mm/mm^2). There was a bimodal distribution of roots by soil depth that appeared to be more accentuated in the elevated CO_2 chambers. Preliminary analyses suggest that fine root turnover may be more rapid under CO_2 enriched atmospheres. Elevated CO_2 appears to increase root production and affect vertical distribution patterns of fine roots.

DAY, THOMAS A. West Virginia University, Morgantown, WV, 26506-6057, USA. Influence of stomatal aperture on UV and visible light environment within leaves.

While stomatal aperture plays a critical role in regulating leaf gas exchange, it may also have a significant influence on light environment within the leaf. This may be particularly important with respect to UV. Because UV-screening compounds occur primarily in the epidermis, stomatal pores may provide an important pathway for UV reaching the mesophyll. The influence of stomatal aperture on the light environment within foliage was assessed by simultaneously monitoring stomatal aperture (with a gas-exchange system) and leaf internal light environment (with a fiber-optic microprobe). In amphistomatous leaves of garden pea (Pisum sativum), stomatal opening was paralleled by about a 20% increase in levels of UV-B light (λ=320 nm) in the upper mesophyll. In contrast, stomatal aperture did not have a large influence on levels of blue light (λ=450 nm) in the upper mesophyll. Effects of stomatal aperture on UV-B light levels in the upper mesophyll were less apparent in foliage with large amounts of epicuticular waxes covering stomatal pores, such as conifer needles. Stomatal aperture, as well as epidermal water status, appear to have a significant influence on the UV-screening effectiveness of some amphistomatous leaves.

DEARING, M. DENISE. University of Utah, Salt Lake City, UT 84112 USA. The Physiological Effects of Plant Secondary Compounds on the North American Pika

The North American pika, *Ochotona princeps*, a food hoarding herbivore, collects and stores a diet that is high in phenolic compounds. Typically, high phenolic diets have adverse effects on mammals, ranging from reduction in nitrogen digestion to toxicity. To elucidate the physiological effects of phenolics on pikas, I conducted replicated digestion trials. Pikas were fed phenolic-free control diets and experimental diets containing phenolic-rich *Acomastylis rossii*; this species is commonly collected by pikas for their caches. Apparent digestibility, nitrogen digestion and fiber digestion all decreased significantly when pikas consumed a diet containing *A. rossii*. In addition, the concentration of a detoxification by-product, uronic acid, increased significantly on *A. rossii* diets. In separate feeding trials comparing normal and phenolic-reduced *A. rossii*, pikas consumed significantly more phenolic-reduced *A. rossii*. These results demonstrate that pikas have the ability to discriminate between varying phenolic concentrations, and that the phenolics in *A. rossii* have adverse physiological effects on pikas. This further supports the argument that pikas delay consumption of *A. rossii* in their cache until the phenolics have decayed to less detrimental concentrations.

DEBIASE, ADRIENNE E. and BARBARA E. TAYLOR. Savannah River Ecology Laboratory, Aiken, SC, 29802, USA. Diversity and distribution of zooplankton in ponds on the Southeastern coastal plain.

The Southeastern coastal plain is scattered with numerous Carolina bays and other isolated temporary wetlands, which are unstudied in comparison to wetlands in other regions of the United States. We studied 88 Carolina bays and other temporary ponds on the upper coastal plain of South Carolina. These ponds support diverse planktonic communities, including several species as yet undescribed. Species distribution and diversity were most strongly linked to hydrology, rather than factors such as pond area or past disturbance. Ponds with longer duration were more diverse, mainly in the number of cladocerans. Correlations between species distribution and vegetation type or geomorphic region were observed for some species. Assemblage similarity decreased with distance between ponds, suggesting that dispersal is poor.

DeCOSTER, JAMES, K. University of North Carolina, Chapel Hill, NC, 27599-3275, USA. Changes in predictability of tree damage across a wind disturbance gradient in a Southeastern forest.

The identification of risk factors that predict whether a tree will sustain damage is central to understanding the impact of catastrophic wind storms on forest communities. Factors such as species and size have been shown to influence whether a tree will be damaged in a wind storm. However, predictability varies with disturbance intensity. In part this is an artefact: statistical power is greatest at intermediate frequencies of damage. In addition, the ability of specific tree attributes to predict damage should vary with disturbance intensity. This variation in predictability was tested with data from Southeastern forests that have been impacted by catastrophic wind storms. The overall predictability of tree damage that is strictly attributable to the predictive tree factors varies along a disturbance gradient. Moreover, the various factors that predict tree damage change in their relative effectiveness along the disturbance gradient.

DEHAYES, DONALD. The University of Vermont, Burlington, Vermont 05405 USA. Freezing injury to montane *Picea rubens*; the potential role of and mechanisms for natural and anthropogenic perturbations.

Winter injury occurs frequently to current-year needles of red spruce in the northern Appalachians and appears to be caused by subfreezing temperatures rather than foliar desiccation. Under ambient conditions, the maximum depth of cold tolerance achieved by red spruce needles in midwinter is barely sufficient to avoid freezing injury at common winter temperatures. Therefore, any perturbation that would decrease midwinter cold tolerance by just a few degrees substantially increases the

probability of freezing injury. Laboratory and field experiments have demonstrated that extended winter thaws and exposure to ambient and simulated acidic cloud water increase the freezing sensitivity of red spruce. Repeated experiments have been unable to demonstrate a consistent negative influence of ambient or elevated ozone concentrations or elevated N on cold tolerance or freezing injury susceptibility. Rapid freezing, especially following solar heating of needles, has also resulted in some injury to both current-year and year-old needles, under laboratory conditions. Visible freezing injury and winter cold tolerance appear to be associated with relatively low foliar Ca concentrations. It is hypothesized that Ca leaching by acidic cloud water could increase freezing susceptibility by modifying membrane structure and/or permeability.

DELCOURT, HAZEL R. and PAUL A. DELCOURT. University of Tennessee, Knoxville, TN, 37996, USA. Lessons from the past: paleoecological insights for conserving biodiversity on southern Appalachian landscapes.

The southern Appalachian Mountains traditionally have been viewed as a center of origin for endemic species and a refuge for boreal and subtropical species at the peripheries of their ranges. High species richness observed today resulted in large part from episodes of Quaternary climate change, during which north-south continuity of migration corridors facilitated landscape-scale shifts in ranges. Populations of rare northern species have persisted in the southern Appalachians since the Pleistocene because of habitat diversity maintained by natural geomorphic disturbances such as shifting stream courses in mountain gaps and landslides on steep slopes that create open glades within an otherwise forested landscape. Modern land use has resulted in a semi-natural landscape mosaic in which increasing fragmentation of forest islands has diminished landscape connectivity, removing travel corridors that were important to the survival of many taxa during the Quaternary. Accelerated climate change in a future Greenhouse world could result in more rapid turnover of species composition along regional ecotones, increasing the probability of local extinction for many species. To conserve biodiversity it is imperative to maintain a landscape matrix in the Appalachians that will maintain connectivity between patches of suitable habitat to allow for future northward range shifts.

DEMARS, B. G. and R. E. J. BOERNER. Ohio State University, Dept. Plant Biology, Columbus, OH 43210, USA.
Nutrient dynamics and resorption by the spring ephemeral Cardamine concatenata (toothwort) in two deciduous forest stands in relation to topography.

Models of deciduous forest nutrient cycling often assume that spring ephemerals play a significant role in vernal nutrient dynamics. This can only be true if these ephemerals take up/turnover significant nutrient captial. To determine what proportion of the nutrients contained in the biomass of C. concatenata (formerly Dentaria laciniata) is cycled internally, we measured foliar nutrient dynamics and resorption in these plants in two forest stands (Greene County, Ohio) and three slope positions (upland, midslope, lowland). Maximum foliar N and P were greatest at upper slope and floodplain positions, respectively, and lowest at mid-slope positions. There were interstand differences in maximum foliar N but not for P. There were no significant slope or stand differences in N in senescent leaves; in contrast, there were intersite and slope effects on P in senescent leaves, with midslopes having the lowest P concentration and those from upper slope positions having the greatest concentration. Mean apparent N and P resorption were 68.8% and 76.1%, respectively, with no differences between stands or slope positions. Data from other years and species will also be presented.

DENNO, ROBERT F. University of Maryland, College Park, MD, 20742, USA. Density-related dispersal and its consequences on the population dynamics of phytophagous insects.

The extent to which phytophagous insect populations are influenced by density-dependent factors continues to be the subject of extensive ecological debate. Specifically, I examine how dispersal may act in a broadly density-dependent way to influence population dynamics. Experimental evidence is provided from a variety of insect taxa (Orthoptera, Homoptera, and Lepidoptera) which supports the notion that dispersal is density dependent. The consequences of density-related dispersal on local population growth are examined in the contexts of emigration and reduced fecundity resulting from reproductive costs associated with flight. For several species, there is a negative relationship between population growth and the proportion of dispersers in the population. Homopterans furnish strong support that dispersal may be the single most important factor contributing to density-dependent change in population size.

DE OLIVEIRA, PAULO, E. and PAUL A. COLINVAUX. Smithsonian Tropical Research Institute, Panama City, Panama. The consequences of Pleistocene climate change on lowland neotropical vegetation.

Palynological reconstructions indicate that lowland tropical America was subject to intense cooling during the last ice-age. The descent of presently montane taxa into the lowlands of Amazonia and Minas Gerais indicate temperature depressions ranging from 5 ^{o}C to 9 ^{o}C cooler-than-present. The strengthened incursion of southerly airmasses caused a reassortment of vegetation throughout Amazonia. Presently allopatric species are found to have been sympatric as novel forest assemblages formed and dissolved. Modest drying, perhaps a 20% reduction in precipitation, accounts for all the records that show a Pleistocene expansion of savanna. No evidence is found to support the fragmentation of Amazonian forests during glacial times, and the hypothesis of forest refuges as an explanation of tropical speciation is rejected on empirical grounds.

DEVELICE, R.L., W.E. QUEITZSCH, and E.H. HOLSTEN. USDA Forest Service, Chugach National Forest, Anchorage, AK, 99503, USA. Undergrowth vegetation succession following beetle-induced tree mortality and fire in southcentral Alaska.

Spruce bark beetles (Dendroctonus rufipennis) and fire play significant roles in shaping the composition of Picea glauca forests on the Kenai Peninsula, Alaska. Undergrowth vegetation composition was monitored on 30 1 m^2 permanent plots following beetle-induced tree mortality and surface fire over an 11-year and 7-year period, respectively. Species richness did not change on the burned plots but declined 24% on the not-burned plots. Cover of Calamagrostis canadensis and Epilobium angustifolium increased significantly while Linnaea borealis decreased significantly on both the burned and not-burned plots. Compositional changes resulted in changed vegetation types, as identified by cluster analysis, for about half of both the burned and not-burned plots. Little or no Picea or Betula papyrifera regeneration occurred during the monitoring period. It appears that regeneration requirements (e.g., mineral soil) for Picea and Betula are not produced as a result of spruce bark beetle infestations and light, spring surface fires.

DEVYLDER, YVETTE M. and MARK R. WALBRIDGE. George Mason University, Fairfax, VA, 22030, USA. Changes in orthophosphate and extracellular phosphatase activity in water samples collected over a growing season from Great Lake Pocosin, NC.

We investigated growing season changes in waters from four areas along a landscape gradient in a pocosin wetland in the Great Lake Pocosin, NC. Water samples were collected monthly from June through October, 1993 from a short pocosin area, adjacent Great Lake, and from two canals and two streams that drain the Great Lake Pocosin. Samples were analyzed for both orthophosphate concentrations and extracellular phosphatase activity. Orthophosphate reached maximum concentrations in August in the pocosin(55.6 ug/L), and in September in both Great Lake(14.0 ug/L) and the streams and drainage canals(55.6 and 80.7 ug/L, respectively). Extracellular phosphatase activity reached maximum values in September at all sites, ranging from 5,280 ug *p*-nitrophenol/h-L in Great Lake to 15, 343 ug *p*-nitrophenol/h-L in the short pocosin. The positive relationship between orthophosphate concentration and phosphatase activity suggests the importance of extracellular phosphatase enzymes in influencing P availability in these ecosystems. Phosphatase activity did not appear to be inhibited by the presence of humic substances in pocosin waters.

DIAL, ROMAN and JONATHAN ROUGHGARDEN. Stanford University, Stanford, CA, 94305, USA. Theory of Marine Communities: The Intermediate Disturbance Principle.

The theoretical validity of the intermediate disturbance principle is investigated for hierarchic competition between marine species with space-limited adults and pelagic larvae. The model explicitly incorporates larval settlement. Conclusions include: (1) To coexist at all, the competitively subordinate species must be more weedy, *i.e.,* must surpass the dominant in either benthic ability, or pelagic ability, or both. (2) The intermediate disturbance principle is a moderate-to-high settlement phenomenon. (3) At low settlement, a subordinate that sufficiently surpasses the dominant in pelagic ability will coexist without disturbance. (4) At high settlement, a dominant with greater benthic ability excludes the subordinate at all levels of disturbance. (5) If the intermediate disturbance principle holds for some level of settlement, then increasing disturbance drives the dominant extinct first.

DIAS-FILHO, MOACYR B. *EMBRAPA-CPATU, C. Postal 48, Belém, Brazil.* **Physiological response of an Amazonian gap-invader species to growth under high and low light.**

During a 66-day period, I investigated, in controlled environment cabinets, under high (800-1000 µmol m^{-2} s^{-1}) and low (200-350 µmol m^{-2} s^{-1}) light regimes, the physiology, morphology and growth of *Solanum crinitum*, a woody treelet known to invade forest gaps, active pastures and abandoned agricultural areas in Brazilian Amazonia. High-light grown plants (HL) had higher light saturated rates of photosynthesis than low-light plants (LL). No significant difference in dark respiration was observed between light regimes. Relative growth rate was initially (at 22 d) higher for HL, becoming similar between treatments at the last two harvests (44 and 66 d). Leaf area ratio and specific leaf area were higher for LL. Leaf weight ratio was similar between treatments, while root weight per total plant dry weight was 20 % higher for HL. High-light grown leaves had less nitrogen per unit of weight and more per unit of area than low-light leaves. These results suggest that light is very important to the performance of this species and that the differential responses to light conditions may contribute to or detract from its ability to succeed in natural and agricultural environments or to endure control strategies.

DIBBLE, KIM M. and F.E.R. MCCAULEY. University of Calgary, Calgary, AB, T2N 1N4, Canada. Food-dependent aggregation, mobility and dynamics of *Ceriodaphnia dubia* and *Daphnia pulex.*

Models of spatially-structured predator-prey dynamics have predicted that differences in individual mobility and foraging behaviour may affect spatial distribution, and consequently, population dynamics. It was shown that two freshwater cladoceran zooplankton differ in swimming speed and ability to locate regions of high food concentration. *D.pulex* are more mobile and better able to locate high food regions than *C.dubia*. Using these findings, it was predicted that *C.dubia* populations would be more aggregated and more stable in smaller environments than *D.pulex*. Experiments showed that *C.dubia* populations were more aggregated than those of *D.pulex* but not more stable. *C.dubia*'s limited mobility produced fixed rather than ephemeral patches that did not alter population stability.

DIFFENDORFER, JAMES E. University of Kansas, Lawrence, KS, 66045. Scale Mediated Effects of Habitat Fragmentation on Movements of Three Small Mammal Species (Sigmodon hispidus, Microtus ochrogaster and Peromyscus maniculatus).

We studied effects of habitat fragmentation on movements of cotton rats (Sigmodon hispidus), prairie voles (Microtus ochrogaster), and deer mice, (Peromyscus maniculatus), living in a fragmented landscape using 7.7 years (1984-1991) of mark-recapture data. The 6 ha study area included 0.5 ha blocks of three patch sizes (5000 m^2, 288 m^2 and 32 m^2). Within blocks, as fragmentation increased, all species moved farther and lower proportions of animals moved; patterns consistent with optimal foraging theory. Across the entire study area, species showed different responses to fragmentation. Deer mice switched between blocks most, prairie voles the least. A Markov matrix model predicted animal abundances among blocks with surprising effectiveness. For all species, no trends were found between block size and the net number of animals a block either imported or exported, indicating "source-sink" dynamics were not occurring among blocks on our study site. No single general process sufficiently explains the species varying responses to fragmentation. Understanding the species' natural history and patch utilization behavior best explains these species-specific responses to fragmentation.

DILUSTRO, JOHN J. and FRANK P. DAY. Old Dominion University, Norfolk, Virginia, 23529, USA. Aboveground biomass and net primary production along a barrier island dune chronosequence.

Aboveground biomass was examined along a chronosequence of dune communities on Hog Island, a Virginia Coast Reserve LTER site. The dominant species are Ammophila breviligulata and Spartina patens. Aboveground biomass was harvested monthly from ten quadrats on dunes 6, 24, 36, and 120 years old. Sampling was conducted from April to November 1993. Biomass values were greater for younger dunes. Spartina patens biomass was greater than Ammophila breviligulata for the 6, 24, and 36 year old dune ridges. It also showed a pattern of decreasing biomass with increasing dune age; in July it ranged from 72 g/m^2 to 5 g/m^2. The same month showed less variation in Ammophila breviligulata; it increased from 17g/m^2 to 39g/m^2 across increasing dune age. Ammophila breviligulata had greater biomass for only the 120 year old dune. There appeared to be a midsummer decline in biomass due to drought conditions. This variation in production of aboveground biomass across dune age may be controlled by moisture, microclimatic conditions and soil nitrogen levels.

DIONNE, MICHELE, TY CORNEAU, KELLY GESTRING and BILLY PALMATIER. Wells National Estuarine Research Reserve, Wells, ME, 04090, USA and University of New Hampshire, Durham, NH, 03824, USA. Restoration of New England salt marsh habitat: initial hydrologic, plant and animal responses.

Impoundment and fill are two common sources of salt marsh disturbance. In 1992 we began monitoring marsh sites selected for hydrologic manipulation to counteract such disturbances. We documented pre-manipulation conditions in hydrology and vegetation at both an impounded and a dredge-spoil site. Post-manipulation hydrology and vegetation has been assessed at one site thus far, and post-manipulation fish assemblages have been assessed at both sites. We are also monitoring an "accidental"(in 1988) hydrologic manipulation site. At each site, we measure water table depth and salinity; and % cover, density, height and biomass of plants. Fish were sampled with fyke nets on evening ebb tides. At the impounded site, pre-manipulation data indicate a complete loss of tidal hydrology and salt-marsh plants. At the dredge-spoil site, pre-manipulation data reveal high water tables, reduced salinities, and increased densities of Spartina alterniflora and Phragmites australis. Hydrologic manipulation was followed by changes in ground water levels and salinity consistent with improved tidal exchange. At the accidental site, plant recolonization has been very uneven, due to subsidence. Post-manipulation fish abundances were reduced compared to reference sites. The extent and rate of recovery will become evident as we continue monitoring.

DIXON, MARK D., W. CARTER JOHNSON, and CURTIS S. ADKISSON. South Dakota State University, Brookings, SD, 57007, USA and Virginia Polytechnic Institute and State University, Blacksburg, VA, 24061, USA. Jays, oaks and weevil larvae: Tritrophic interactions?

We examined responses by blue jays (Cyanocitta cristata) to a mixture of infested and non-infested acorns to see if jays selectively consumed nuts containing weevil larvae (Curculio) as a protein amendment to a high tannin, all-acorn diet (see Johnson et al. 1993. Oecologia 94:159-164). We also tested whether overwinter caching reduced tannin levels in acorns, making them more digestible to the jays. Acorns were X-rayed to determine infestation status and then offered to individual jays in an aviary setting. Jays handled and consumed non-infested nuts significantly more often than infested nuts, and use of infested nuts did not during continued exposure to a high tannin diet. Acorns in simulated caches did not differ significantly in tannin level from uncached acorns, and jays lost mass rapidly on both cached and uncached acorn diets. Thus, these initial results are not consistent with our original hypotheses: jays did not make extensive use of weevil-infested nuts and caching did not appear to improve the quality of an all-acorn diet.

DIXON, PHILIP M. Savannah River Ecology Laboratory, Aiken SC, 29802, USA. Using nearest-neighbor designs and analyses in ecological experiments.

Most ecological experiments handle spatial variation either by ignoring it (e.g. completely randomized designs) or by identifying putatively homogeneous areas (e.g. a blocked design). Analyses of data from two experiments, estimating density effects on frog growth and variety differences in yield of triticale, show that there can be large correlations ($r = 0.51$ and $r = 0.72$) between residuals on adjacent plots.

Nearest-neighbor ANOVA methods use the spatial correlation among residuals to improve the estimation of treatment effects. Incorporating the spatial correlation reduces the variance of treatment effects by 50-75%, depending on the size of the correlation and the arrangement of plots in the field. This decreased variance is equivalent to that from experiments that are 2x or 4x larger. Potential problems include estimating the spatial correlation, adjusting the error degrees of freedom, and confounding the treatment and spatial effects if there are few replicates. The consequences of these problems will be illustrated.

DONOVAN, LISA A., JAMES H. RICHARDS AND ELIZABETH J. SCHABER. University of California, Davis, CA, 95616, USA.
Soil chemistry and woody plant leaf chemistry along a toxic ion gradient at Mono Lake, CA.

In the Mono Lake basin, CA, lake level decline over the last 1000 years has exposed alkaline substrates (pH 9.5-10.5) that differ in nutrient and toxic ion content. The shrub Sarcobatus vermiculatus (greasewood) is the only plant spanning the gradient from mature dunes to recently exposed playas. We examined the chemistry of soils and S. vermiculatus leaves along this gradient. Water soluble B and Na in surface soils were lowest in mature dunes (~5 and 500 mg kg^{-1}, respectively) and increased at least 10 fold across the transects. Differences between surface and deep soils were also smallest in dunes and increased toward the lake. As with soil, leaf B and Na were lowest for dune plants, 58 ppm and 6 %, respectively, and increased to maximums of 234 ppm and 13 % for plants on recently exposed substrates. Gradients of other elements (K, Ca, Mg, and S) in soil and leaves were less distinct. Soil nitrogen was very low across most of the transect (<0.02%) with the exception of a recently formed berm at lake edge. In contrast, leaf nitrogen values were very high (2.4 - 4.4 %) with maximums occurring mid-way along transects. The highly variable leaf chemistry of S. vermiculatus is indicative of plasticity in toxic ion tolerance and nutrient physiology that allows it to dominate communities across this range of harsh soil conditions.

DOOLEY, JAMES L. and MICHAEL A. BOWERS. Blandy Experimental Farm, P.O. Box 175, Boyce, Virginia, 22620, USA. The demographic consequences of habitat patch structure in an old-field rodent community.

Recent simulation models have predicted that the demography of populations should be influenced by both patch attributes (size, shape and isolation) and movement between separated populations. To test these predictions we created a system of patches in old-field habitat and monitored the demography of two rodent species (P. leucopus and M. pennsylvanicus). While a small number of "residents" did exhibit higher densities and longer persistence times on large patches for P. leucopus, transient individuals exhibited higher densities on smaller patches. Also, in contrast to model predictions, landscape effects were only manifest for the longer dispersing species. That our results fail to broadly validate model predictions suggests that future research efforts must include more sophisticated consideration of social structure and movement patterns.

DORFMAN[1], KATHERINE, COLIN NICHOLS-ORIANS[1] and ROBERT S. FRITZ[2]. [1]Williams College, Williamstown, MA 01267, USA and [2]Vassar College, Poughkeepsie, NY 12601, USA. Behavioral and physiological responses of *Calligrapha multipunctata bigsbyana* larvae to parental and hybrid willows.

Ecologists have found that hybrid plants are often more susceptible to herbivory than the parental species. Using 3rd instar larvae of *Calligrapha multipunctata bigsbyana*, obtained from eggs laid by wild caught adults, we measured their preference for and performance on leaves of three willow taxa: *Salix sericea*, which produces phenolic glycosides, *S. eriocephala*, which produces condensed tannins, and hybrids, which produce both chemical types at approximately one half the concentration. All willows were potted and grown under identical conditions and larvae were reared on *S. bebbiana* for the first two instars. Larvae prefer hybrid leaves, although hybrids and *S. eriocephala* support growth equally well. Larvae eat very little of, and hence grow poorly on *S. sericea*. *S. eriocephala*, however, is the least digestible. From these results, we suggest that phenolic glycosides deter feeding at high, but stimulate it at low concentration, and that tannins reduce leaf digestibility. In this system, acceptability and digestibility combine to create hybrid susceptibility.

DORNBIRER, J.A. and R. L. SANFORD, JR., University of Denver, Denver, CO, 80208, USA. The spatial distribution of *Astragalus osterhoutii*, a rare and endangered plant, in relation to soil selenium and phosphorus levels.

Astragalus osterhoutii, a member of the Fabaceae family and a known selenium accumulator, is a rare and endangered plant endemic to areas along Muddy Creek and Troublesome Creek in Grand County, Colorado . A population of these plants has been threatened by plans for the construction of a dam and impoundment on Muddy Creek. The object of this study of the effects of soil selenium and phosphorus levels on the spatial distribution of the plants is to facilitate the task of locating adequate transplantation sites. The mapped spatial distribution in two plots revealed that the plants are arranged in a nonrandom clumped pattern. Paired soil samples taken within clusters of A. osterhoutii and in areas where no plants were found growing, were analyzed for selenium and NaHCO3 extractable phosphorus . Total and organic NaHCO3 extractable phosphorus in samples taken outside the clusters of plants is significantly higher than levels inside. The levels of phosphorus and selenium in *A. osterhoutii* tissues and the selenium levels of the soil were analyzed for comparison with soil phosphorus. Se-P interactions are discussed in relation to spatial distribution.

DOUCET, COLLEEN and PAUL B. CAVERS. University of Western Ontario, London, Canada, N6A 5B7. Seed colour variation and dormancy in the bull thistle, *Cirsium vulgare*.

Cirsium vulgare (Savi) Ten. is listed as a noxious weed in Ontario and is widespread thoughout the southwestern part of the province. Despite its demographic success, the bull thistle is faced with many competitive disadvantages. One of these is its reputed lack of a persistent seed bank. Past studies have shown that less than 1% of the seeds at the surface of the soil, remain viable after one year. In other studies where seeds were buried at depths of at least 15 cm, it was found that at least 50% of the seeds were still viable after 3 years. In our work, we have found that seeds (achenes) buried at depths of 15 cm may acquire an induced dormancy, and therefore be unable to germinate when brought to the soil surface. The proportion of seeds that are dormant after burial seems to vary according to seed colour. These preliminary results suggest that the darker seeds play a role in the establishment of a short-lived persistent seed bank.

DOW, BEVERLY D., MARY V. ASHLEY and HENRY F. HOWE. University of Illinois at Chicago, Chicago, IL 60607, USA. Microsatellite analysis of mating system in bur oak (Quercus macrocarpa)

In spite of the ecological importance of wind-pollinated trees in the temperate zone, previous studies of mating system in these plants has relied on indirect evidence (e.g. pollen traps and dyes) or been hampered by lack of polymorphic genetic markers. Microsatellites (tandemly repeated simple sequences) have several advantages for population genetic studies, since they are abundant in the genome, highly variable and can be amplified from minute quantities of low quality DNA by PCR. We have identified several dinucleotide microsatellite alleles in Quercus macrocarpa by screening a library of small fragments for $(CA/GT)_n$ and $(GA/CT)_n$ repeats. In contrast to mammalian genomes, the $(GA/CT)_n$ motif is more abundant and longer in average length (n =16.4 versus n = 7.25) than the $(CA/GT)_n$ motif. Since longer microsatellites are more likely to exhibit polymorphims, PCR primers were designed from the sequences flanking several $(GA/CT)_n$ microsatellite regions. Allelic diversity of PCR products is high among adults in a small stand of oaks at our study site in northern Illinois. The microsatellite data have allowed us to determine paternity of acorns from a known maternal tree as well as parentage of established saplings.

DOW, DAVID D. NMFS/Northeast Fisheries Science Center, Woods Hole, MA, 02543, USA. Use of satellite remote sensing to estimate aboveground marsh biomass at Grand Bayou, LA.

Landsat Thematic Mapper (TM) data have been employed either in the form of raw data(digital counts) from bands 1,2, 3, 4, 5, and 7 or in the form of ratioed digital count data (vegetation index and reflectance ratio) to estimate the aboveground biomass of a Spartina patens dominated marsh at Grand Bayou, LA. Aboveground live and dead biomass was harvested at 35 stations in May 1984 and was utilized to develop predictive regression equations of marsh biomass from satellite data. An independent accuracy check of these predictive regression equations was done at a mature marsh site and a site burned in January 1984. For the raw digital counts a simple regression based upon bands 5 or 7 (shortwave infrared) gave the best estimate of dead biomass, while a stepwise regression utilizing bands 1, 2, 3, and 4 (visible and near infrared) was best for estimating live biomass. The best predictive regression for ratioed data employed the vegetation index for the live biomass and different versions of the reflectance ratio for the dead and total biomass. The independent accuracy check showed good predictive capability at the mature site for live, dead, and total biomass, but at the burned site poor predictions were evident with dead biomass being underestimated and live biomass being overestimated.

DOYLE, THOMAS W. and IRENE D. HESSE. National Wetlands Research Center, 700 Cajundome Blvd., Lafayette, LA, 70506, USA and Center for Wetland Resources, Louisiana State University, Baton Rouge, LA, 70803, USA Growth of baldcypress in a Louisiana swamp treated with tertiary wastewater.

Some municipalities in coastal Louisiana are flooding natural wetlands and swamps with tertiary wastewater as a means of improving water quality and enhancing ecosystem productivity. In this study, we investigated the impact on baldcypress growth from nutrient enriched overflow from a municipal sewage facility at Breaux Bridge, Louisiana over the last 30 years. Growth chronologies were developed from tree ring measurements of overstory cypress taken from a treated and control site in the same drainage system adjacent to the treatment plant. Differences in growth response between treatment sites showed no consistent pattern of growth enhancement or decline relative to yearly effluent discharge. The treated site, however, did show less sensitivity to drought. These findings offer a baseline for evaluating the effects of chronic and long-term application of treated effluent on the health and productivity of forested swamp ecosystems.

DOYON, FRÉDÉRIK, JEAN-FRANÇOIS GIROUX and DANIEL GAGNON. GREF, Université du Québec à Montréal, C.P. 8888, Succ. A, Montréal, QUÉBEC, H3C 3P8, CANADA. Effects of different forest management strategies on the abundance of bird species in hardwoods forests.

Integrated resource managers need to evaluate the impact of different forest management strategies on wildlife. In this study, the abundance of bird species was compared between sylvicultural systems often used for hardwoods (strip cutting and selection cutting) and a non-managed forest. A total of 217 fixed radius (60 m) point counts, distributed in three habitat types within the treated and control forests, were monitored twice during the 1993 breeding season. An analysis of variance of ranks showed that 11 species were affected ($p<0.05$) by the

management system, 7 by habitat type, and 5 by both. Eight of 47 habitat variables were found to be significant in discriminating between management strategies, allowing the classification of 73% of the stands. The most important variables were the sapling cover , the herbaceous layer and the seedling cover. Furthermore, an analysis of variance showed that the effect of management on bird abundance was related with these discriminant variables.

DRAKE, BERT G., PERESTA, GARY J. AND ESTHER BEUGELING. Smithsonian Environmental Research Center, Edgewater, MD, 21037, USA. No decline in effect of elevated atmospheric CO_2 on net ecosystem CO_2 exchange (NCE), biomass production and tissue nitrogen concentration [N] of a C_3 plant community in a Chesapeake Bay wetland after 7 years.

Field experiments using normal ambient or elevated CO2 (= normal ambient + 340 ppm) have been carried out on three plant communities. In Scirpus olneyi (C_3), elevated CO_2 increased NCE and growth of roots and shoots and reduced [N]. We found no evidence that these responses to elevated CO_2 declined in the course of seven years of measurements. The reduction of the [N] had consequences for ecosystem carbon cycling through indirect effects on dark respiration, decomposition and plant/insect and plant/microbe interactions.

DRENNER, RAY W., KIRSTEN L. GALLO, ROBERT M. BACA, JASON RICE, J. DURWARD SMITH AND C. MICHAEL EDWARDS, Texas Christian University, Fort Worth, TX, 76129, USA. Synergistic regulation of phytoplankton biomass by omnivorous fish and nutrients.

Recent studies have suggested that differences in food web structure can dramatically alter how organisms will respond to nutrients that regulate primary productivity. To examine how the effects of omnivorous fish interact with nutrients to regulate phytoplankton biomass, we conducted a pond experiment and three tank-mesocosm experiments, all of factorial design in which two or three levels of omnivorous fish were cross-classified with two levels of nutrient addition. In the mesocosm and pond experiments, fish and nutrients had significant interaction effects on chlorophyll. The combined effect of fish and nutrients was greater than the sum of the separate effects of fish and nutrients.

DREWA, PAUL B. and WILLIAM J. PLATT. Louisiana State University, Baton Rouge, LA, 70803, USA. Analysis of plant community organization in longleaf pine savanna habitats.

Plant community composition and zonation along topographical gradients in the headwater regions of longleaf pine savannas in LA and FL were examined using abundance data. Analysis of data for herbaceous species using minimum variance cluster analysis and principal components analysis revealed three habitat types: upland longleaf pine, seepage bog, and baygall (LA) or titi/cypress swamp (FL). Addition of hardwood species to the analysis obscured the three habitat types. Canonical correlation analysis and ANOVA were subsequently employed to evaluate the effectiveness of dendrogram 'cut level' combinations in accounting for intrinsic boundaries in both vegetation data sets. These analyses provide further evidence that zonation becomes less clearly defined as a result of hardwood shrub distributions that have been altered by past fire management practices.

DRURY, STACY A. Wright State University, Dayton, OH, 45435, USA. Are maples replacing oaks in Ohio's hill country?

Recent studies suggest maples (Acer) are replacing oaks (Quercus) in the eastern deciduous forest. I sampled 42 500 m^2 plots in relatively mature oak forests (>70 years old) on south and west facing slopes to determine if this trend extends to southeast Ohio. Maples dominated the smaller size classes, comprising 45% of the saplings (all stems > 1.37 m tall and < 10 cm dbh), 45% of all stems from 10 to 30 cm dbh, and 5% of the trees > 30 cm dbh. Maples were in the understory of all plots, but rarely in the canopy (7 of 42 plots). No maples were larger than 50 cm dbh. Oaks followed a different pattern, dominating the upper size classes (83% of stems > 40 cm dbh) with few small trees and saplings (29% of stems from 10 to 30 cm dbh and 7% of the saplings). Oaks dominated the overstory of all plots, but occurred as saplings on only 22 of the 42 plots. If present environmental conditions persist, maples will replace oaks as the dominant canopy genus in these Ohio forests.

DUFFY, J. EMMETT. University of California, Davis, CA 95616.
Resource specificity and evolutionary divergence in a species-rich tropical shrimp genus

Intimate associations between species are the hallmark of high-diversity ecosystems. Does symbiosis promote diversification? The sponge-dwelling shrimp genus *Synalpheus* contains dozens of host-specific species, many living in sympatry. To assess the importance of differential resource (host) use in promoting divergence in such animals, I measured behavioral, demographic, and

genetic (allozyme) differentiation between demes of *S. brooksi* occupying 2 sponge species in Panama. Hierarchical sampling showed that shrimp demes in the two sponges differed consistently in population density, % of mature females, and prevalence of parasites. Shrimp from the two sponge species also differed in behavioral preferences for those sponges. Both hierarchical F statistics and allele frequency heterogeneity revealed significant genetic differentiation between shrimp populations occupying different hosts on the same reef. Finally, on one of 3 reefs, lab assays revealed elevated levels of intersexual aggression (mating incompatibility) in pairs of shrimp taken from different host species, compared with pairs from the same host species. Thus, for resource specialists, significant evolutionary divergence can proceed in the absence of strong extrinsic barriers to gene flow.

DUNCAN, RICHARD P. University of North Carolina, Chapel Hill, NC 27599-3280, USA. A model of mast seeding in forest trees.

The advantage of mast seeding is hypothesized to be an economy of scale resulting in greater seed output or survival in mast years. I develop a model to explore the effects of concentrating reproductive effort into occasional mast years on the number of offspring produced by forest trees. In the model, adult trees occupy discrete sites and disturbances that provide openings for colonists occur at each site with a constant annual probability. Each year a tree can either reproduce or store its resources for use in a future reproductive event (a mast year). The advantage of delaying reproduction is that a greater than proportional number of seeds survive to be juveniles in mast years. Seeds are dispersed randomly among sites and seeds that survive to be juveniles compete with each other for space in disturbance openings with the winner chosen by lottery. I assume that selection favors trees that leave more offspring. The model predicts masting should be favoured, and the interval between mast years should increase, with a decreasing probability of disturbance and lower juvenile output. Intermast interval is positively correlated with longevity in North American trees of the genera *Pinus* and *Quercus*, consistent with the prediction that intermast interval should be greater in trees with a lower disturbance probability.

DUNNE, JENNIFER A. and V. THOMAS PARKER. San Francisco State University, San Francisco, CA 94132, USA. Seasonal soil moisture patterns and establishment of Pseudotsuga menziesii in chaparral.

Pseudotsuga menziesii is invading chaparral in Marin County, California. Landscape scale invasion patterns suggest that safe sites for P. menziesii establishment are associated with Arctostaphylos species. We planted P. menziesii seeds beneath neighboring stands of two chaparral dominants, Arctostaphylos glandulosa and Adenostoma fasciculatum. While there was no significant difference in germination beneath either species ($p > .50$), significantly more seedlings survived through their first dry season (6/5/93 to 10/16/93) under A. glandulosa (16.7%) than under A. fasciculatum (3.3%) ($p < .001$). We hypothesized that seedling survival patterns are associated with differential soil moisture profiles during the long dry season. Significantly more seedlings died due to apparent drying under A. fasciculatum (84.8%) than under A. glandulosa (58.9%) ($p < .05$). Periodic measurements of soil water potentials under both chaparral species revealed that on 9 of 10 days when readings were taken during the 1993 dry season, water potentials were significantly higher under A. glandulosa ($p < .002$). We recorded the most pronounced difference in average water potential at a 20 cm soil depth near the end of the dry season (10/6/93), with A. glandulosa at $-4.30 \pm .230$SE MPa and A. fasciculatum at $-6.13 \pm .324$SE MPa. These results support the hypothesis that higher water retention in soil under Arctostaphylos glandulosa during the critical dry season facilitates Pseudotsuga menziesii seedling survival.

DUNNING, JOHN B. and H. RONALD PULLIAM. Institute of Ecology, University of Georgia, Athens, GA, 30602. Habitat use in complex landscapes that change through time.

Many organisms occupy habitats that change in suitability over short periods of time. When these habitats are distributed as patches embedded in complex landscapes, population dynamics may be dependent on the changing temporal distribution of habitat patches. We have studied temporal landscape changes and their influences on Bachman's Sparrow (Aimophila aestivalis) which is a pine woods endemic in the southeastern USA. In our study areas, the sparrow is resident primarily in early successional habitats such as clearcuts, but suitability of the clearcuts depends on factors such as age since planting, the species of pine present in the clearcut, soil type and management strategies. The "time window of suitability" for each individual clearcut can vary from 3-8 yr post planting. Field studies showed that sparrow occupancy of clearcuts is dependent on the landscape distribution of suitable patches, and that this distribution changes rapidly from year to year in our study area. We show through a spatially-explicit population model that, as the landscape changes through time, the sparrow population can survive or go extinct locally depending on the time windows of suitability of clearcuts.

DUTILLEUL, PIERRE. Department of Plant Science, McGill University, MacDonald Campus, Ste-Anne-de-Bellevue, QUEBEC H9X 3V9, CANADA. Modified correlation analysis with autocorrelated and heteroscedastic sample data.

Autocorrelated and heteroscedastic sample data do not satisfy the postulates of independence and homogeneity of variance required by classical *t*-testing based on Pearson's *r* statistic in correlation analysis. Various solutions were proposed to overcome the problem. Recently, and under restricted forms of stationarity, a modified *t* test was developed (Dutilleul 1993, which was inspired by the pioneering, multi-purpose work of G.E.P. Box, based on an effective sample size taking into account autocorrelation and heteroscedasticity of the variables analyzed for correlation. In the present communication, it is shown how those limited stationarity assumptions may be relaxed under the repeated-measures model, and a spatio-temporal version of Dutilleul's modified *t* test is proposed under a doubly multivariate normal distribution model. Both extensions are illustrated by study cases in forestry and aquatic ecology.

DWYER, GREG, University of Massachusetts, Amherst, MA 01003, USA. The Uses of Theory in Ecology: Do Insect Pathogens Drive Cycles of Defoliating Lepidoptera?

The hypothesis that pathogens drive cycles in defoliating Lepidoptera was first developed in the form of a mathematical model, and further elaborations of the theory have struggled with the same hypothesis for some fourteen years. The basic approach has been to add various complications to the original basic model, to test whether the addition of biological detail enhances or reduces the possibility of cycles in the insect population. Interestingly, this procedure has produced very little consensus as to whether pathogens really are responsible for population cycles in defoliating Lepidoptera. I will review this literature in order to make two points about the relationship between theory and data in ecology. The first is that ultimately only experiments and observations from the field can choose between competing theories. The second is that the most difficult step in developing a mathematical model in ecology is choosing which details are most important, a step which must be guided by data. These points are intended to demonstrate that field biologists must invevitably be involved in the creation of theory.

DYER, ANDREW R. and KEVIN J. RICE. University of California, Davis, Davis, CA, 95616, USA.
Clone determination and genetic variability of Nassella pulchra using Randomly Amplified Polymorphic DNA.

We collected leaf tissue from closely spaced individuals in several, naturally occurring, populations of the bunchgrass Nassella pulchra. Extracted genomic DNA was amplified using Randomly Amplified Polymorphic DNA (RAPD) techniques and analyzed electrophoretically. Multiple polymorphisms allowed us to identify banding patterns for individual plants. Although N. pulchra fragments easily from mechanical disturbance, the clone-forming ability of this species has not been investigated. RAPD was a quick and simple method for determining whether closely spaced plants were clonal individuals. Given the level of clonal propagation recorded in this study, we concluded that recruitment into the N. pulchra populations was primarily a function of sexual reproduction. Genomic amplification was also effective in assessing the level of genetic variation within and between sample populations.

DYER, LEE A. Department of EPO Biology, University of Colorado, Boulder, CO 80309, USA. Nasty specialists and tasty generalists? A predator's point of view.

To evaluate the roles of predation and chemistry in the evolution of diet breadth and to determine the effectiveness of various larval defenses, I offered 80 species of lepidopteran larvae to colonies of the tropical ant Paraponera clavata. Using logit models to compare predictors, I found that a prey's chemistry and diet breadth were the most important determinants of probability of prey rejection by P. clavata. Specialists and prey with unpalatable extracts were rejected by the ants more than generalists and prey with palatable extracts. Other less important, but significant, predictors of prey rejection included developmental stage and morphology. Late instar caterpillars were rejected more frequently than early instars and hairy caterpillars were rejected more frequently than caterpillars with other morphologies. Coloration, size, and plant chemistry were not good predictors of rejection by the ants. My results suggest that predation could be an important force in shaping the narrow diet breadths of lepidopteran herbivores and that chemistry is a possible mediator of the interaction between predation and diet breadth.

DYER, M. I. and LINDA L. WALLACE. University of Georgia, Athens, GA, 30602, USA and University of Oklahoma, Norman OK, 73019, USA. Control of plant productivity variation by herbivores.

We have conducted a survey of literature reporting production responses of a variety of plants in aquatic and terrestrial ecosystems to determine variance in grazed systems where authorities reported contrasting ungrazed controls. We used coefficient of variation (CV) to test the null hypothesis that variation in plants or vegetation plots subjected to grazing equals that of ungrazed conditions. Our initial findings show that CV for grazing is significantly less ($p = 0.0027$) than ungrazed controls. We argue this indicates a greater degree of predictability exists in grazed systems in contrast to ungrazed, suggesting the importance of biotic compared to climatic controls. Thus, we pose the hypothesis that climate tends to regulate variance in productivity between years, whereas biotic controls, such as herbivory, regulate variance within years.

EASTERLING, MICHAEL R. and STEPHEN P. ELLNER. North Carolina State University, Raleigh, NC 27695, USA. Hatching strategies in a random environment: A structured model.

Hatching strategies are studied in a model of copepod dynamics in a random environment. The strategies are the fraction of dormant eggs that hatch each year. A matrix with random elements describes the population dynamics. The model extends the models of D. Cohen (1966 J Theor Biol 12, 119-129) and S. Ellner (1985 Theor Pop Biol 28, 80-116) by adding structure to the egg bank. The structure results in a fraction of the dormant eggs being unavailable for hatching each year. The analysis focuses on deriving a small variance approximation for the population's long term growth rate and relating this growth rate to the egg bank structure and the environmental parameters. The model shows that adding sturcture can have a significant effect on the optimal hatching strategy. The structure favors reduced dormancy.

EBERT-MAY, DIANE. Northern Arizona University, Flagstaff, AZ, 86011, USA. Assessment in ecological education.

During the last decade, national policy studies recommended ways science faculty can restructure introductory science courses to increase scientific literacy of all undergraduates. Science courses should include learning that is experiential, investigative, hands-on, meaningful to students and faculty, and makes connections to other disciplines. However, these studies offer no evidence or documentation of "what works." This symposium focuses on ways and means to empirically derive substantive curricula, courses, and assessment in ecological education. First, we present an overview of the applicability of research models to the study of interactions within academic systems. Second, we examine a suite of innovative assessment strategies that do not further constrain limited resources for undergraduate introductory ecology and other science courses. These strategies include various scoring rubrics for alternative evaluation techniques that objectively evaluate the specified outcomes of courses, and portfolios. The purpose, design and scoring of student portfolios is described in terms of the evidence faculty need for evaluating students' knowledge, skills, and disposition. Finally, criticisms of existing standardized tests (e.g. SATs and GREs) are examined and alternative ways of improving standardized components of science assessment are reviewed.

EDINGER, BRUCE B. and CORY B. FRIBLEY. Valparaiso University, Valparaiso, IN, 46383, USA. Relative importance of ant mutualists for tended larvae of the federally endangered Karner blue butterfly, *Lycaeides melissa samuelis* Nabokov, in northwest Indiana.

Ant mutualists tending second brood Karner blue butterfly (KBB) larvae were studied at the Indiana Dunes National Lakeshore during June and July, 1993. About 295 larvae were discovered and monitored every two to three days until pupation or disappearance. Tending rates were high; only 51 of 500 visits to larvae revealed no ants. Mean larval survivorship was highest when *Lasius neoniger* tended (4.3 d), intermediate when other ants tended *Formica montana, F. schaufussi,* and others (2.2 d), and lowest when untended (0.5 d). KBB larval growth rates for these groups were, in mm/day, 0.81, 0.79, and 0.59, respectively, but they were not significantly different. A KBB population near Albany, NY studied by Savignano (1990) found lower proportions of KBB larvae tended and equivocal effects on the larvae from of ant tending on the larvae. Management for KBB restoration will be discussed.

EDWARDS[1], MARY E., BRUCE P. FINNEY[1], NANCY H. BIGELOW[1], D. GALE GARDNER[1], and WENDY R. EISNER[2]. University of Alaska[1], Fairbanks, AK, 99775, and Ohio State University[2], Columbus, OH 43210. Vegetation and lake-level history at Birch Lake, interior Alaska.

In interior Alaska (mean ann. precip. ca 350 mm) lakes should be sensitive to changes in the P/E ratio. At Birch Lake, near Fairbanks, lake levels rose dramatically 11,000-9200 years ago, fell 9200-8500 years ago and then rose rapidly, probably in a few hundred years. Some major changes in vegetation appear coincident with the lake-level changes, but others do not, or are hard to interpret. Populus woodland expanded during the first transgression, but subsequently declined while lake levels were still high. 9000-8000 years ago Picea glauca expanded then decreased, its abundance apparently negatively correlated with moisture availability. The lake rise at ca 8000 yr B.P. is slightly preceded by regional expansion of Alnus. Data suggest that a complex interaction of climatic and non-climatic factors determined vegetation dynamics during the late-Quaternary in interior Alaska.

EDWARDS, NELSON T. and PAUL J. HANSON. Oak Ridge National Laboratory, Oak Ridge, TN, 37831-6034, USA. Bole respiration in a closed-canopy upland oak forest before and after soil moisture manipulations.

A throughfall displacement system was established in an upland oak forest stand on Walker Branch Watershed in the fall of 1993. Three 80x80 m plots were established adjacent to each other. The system is designed to displace 33% of the throughfall from one plot to another with one ambient plot. Pretreatment and first year post-treatment bole respiration rates were determined at intervals throughout the 1993 and 1994 growing seasons on mature Acer rubrum L., Quercus alba L, and Quercus prinus L. Maintenance and growth respiration data will be presented. Preliminary analysis of the pretreatment data, expressed as CO_2 evolved per unit of cambial surface area, showed positive correlations between tree diameter, sapwood volume, and respiration rates during the "dormant" season. However, these correlations did not appear during diameter growth, indicating that cambial activity may be the major source of CO_2 efflux from the bole surface durng the growing season.

EDWARDS, THOMAS C., JR., GRETCHEN G. MOISEN, and D. RICHARD CUTLER. National Biological Survey, Utah Cooperative Research Unit, Utah State University, Logan, UT 84322-5210, USDA Forest Service, Intermountain Research Station, 507 25th Street, Ogden, UT 84401, and Department of Mathematics and Statistics, Utah State University, Logan, UT 84322-3900. Use of cluster sampling to assess map uncertainty in remotely-sensed vegetation maps: incorporation of a cost function.

With the increasing demand for broad-scale vegetation maps for conservation planning comes the need for adequate measures of map uncertainty. Unfortunately, costs of assessing maps at ecoregional scales may be prohibitive. In order to maximize their efficiency, sample designs should be selected based on a cost function and prior information about spatial autocorrelation of map error. Given some prior knowledge about the spatial pattern of map error, cluster sample designs can be constructed which are more efficient than simple random or systematic sampling for cost functions with high primary to secondary sample unit cost ratios, a typical pattern when

assessing uncertainty of ecoregion-scale maps. We describe application of a cluster-based sampling design incorporating a cost function to determine the appropriate sampling design for assessing map uncertainty in a vegetation cover map for the state of Utah. While cluster sampling may be more cost effective for estimating misclassification probabilities, estimating other measures of map uncertainty using dependent data need further exploration.

EGGLESTON, DAVID B. and DAVID A. ARMSTRONG. North Carolina State University, Raleigh, NC, 27695, USA and University of Washington, Seattle, WA, 98195, USA. Larval supply, active substrate selection, and post-settlement survival as determinants of estuarine Dungeness crab recruitment.

High densities of 0+ Dungeness crab (ca 300 m2) have been observed in intertidal oyster-shell habitats several days after megalopal arrival into Grays Harbor, WA compared to their relative absence in nearby mud habitats. To define the mechanisms underlying this habitat-specific pattern in abundance we concurrently examined four components of recruitment in intertidal shell and mud habitats at two different geographic locations: (1) water column supply of megalopae, (2) settlement patterns of megalopae after 2 h, (3) post-settlement survival after 48 h, and (4) density of 0+ crabs over the summer growing season. Our results indicated that: (1) crab megalopae actively select to settle in shell versus mud, (2) settlement strength reflected water column supply of megalopae, and (3) post-settlement mortality or emigration after 48 h decoupled larval supply and settlement patterns from first instar abundance. These results suggest that substrate selection can affect distribution of juvenile crab, and density-dependent mortality or emigration is a key factor regulating local population size.

EHMANN, WILLIAM J. Utah State University, UMC 5305, Logan, UT, 84322, USA. Spider co-occurrence on sagebrush shrubs: evidence for assembly rules and priority effects.

Spider assemblages on individual sagebrush shrubs were collected over three field seasons in northern Utah to evaluate co-occurrence patterns at the individual, species, and guild levels of organization. In addition, field tests for priority effects in which the identity of a pioneer colonist affects subsequent assemblage development were performed in one season. At all three levels of organization evaluated, spider assemblages on shrubs were non-random in pattern ($P < .0009$). Comparison of observed assemblage state frequencies to those predicted by a probabilistic model assuming no significant spider-spider interactions yielded significant differences at both the species and guild levels ($P < .001$). A priority effect was detected in which jumping spider pioneers reduced abundances of trapping (web-building) spiders in subsequent assemblages ($P = .019$). Existing information suggests that shrub spiders may follow deterministic assembly rules based on negative spider-spider interactions including cannibalism, intraguild predation, and interguild predation. Stochastic processes, such as dispersal, can also affect assemblage development, at least in the short term (3-4 days).

EHRLICH, PAUL R. and GRETCHEN C. DAILY. Stanford University, Stanford, CA, 94305, USA, and University of California, Berkeley, CA, 94720, USA. Ecological economics and the carrying capacity of Earth.

We discuss critical biophysical and socioeconomic factors that influence the relationship of human population size to Earth's carrying capacity. We characterize the role of socioeconomic equity in human fertility patterns and in the sustainability of the world agricultural system, across the spectrum of levels of organization: between sexes within households, between regions within nations, and internationally. We also examine economic and ecological approaches to the measurement of sustainability, and discuss the extent to which changes in economic policy alone might succeed in transforming human societies into sustainable enterprises.

ELIASON, SCOTT A. and EDITH B. ALLEN. San Diego State University, San Diego, CA, 92182-0057, and University of California, Riverside, 92521-0124, USA. Competition for soil water between Mediterranean annual grasses and Artemisia californica in southern California coastal sage scrub.

Artemisia californica, a dominant shrub in the coastal sage scrub community of southern California, was grown in the field in plots of maintained densities of Mediterranean annual grasses. The objectives of the study were to determine (1) the degree to which soil water is depleted at given depths by the grasses, (2) how xylem water potentials of Artemisia seedlings are affected by water depletion by the grasses and (3) how Artemisia seedling biomass production is related to xylem water potential and to grass density. Five grass densities were arranged in a complete randomized block design with three replicate blocks. The three higher densities of grass depleted soil water more than the two lower densities resulting in lower soil water potentials, lower Artemisia xylem water potentials and lower Artemisia growth in the three higher density plots. Natural recolonization of Artemisia is slow or absent in stands of Mediterranean annual grasses. Our research showed that the grasses probably inhibited growth of the Artemisia californica seedlings by depleting soil water.

ELY, JOSEPH S. and DAVID J. GIBSON. University of West Florida, Pensacola FL, 32514, USA and Southern Illinois University, Carbondale IL 62901, USA. Vegetation pattern analysis of a barrier island off the Gulf Coast of Florida before and after beach nourishment.

During the Summer of 1990 ca 7.14 x 10^6 m^3 of dredge spoil was deposited on the seaward side of Perdido Key, a barrier, island off the Gulf Coast of Northwest Florida. A permanent line transect was established, ca 200 m contiguous 0.5 m by 0.2 m quadrats, and was sampled three times a year between autumn 1989 and autumn 1993. Presence of all plants species was recorded. Data was analyzed through ordination procedures and Hill's two and three-term local variances. *Uniola paniculata* and *Schizachyrium maritimum* were the most frequent taxa between 1989 and 1993. DCA ordinations of samples and species revealed large patterns of distributions among the old beach and nourished beach. Species showed multiple scales of pattern within a matrix of *Uniola paniculata* and *Schizachyrium maritimum*. Maximum scales of vegetation pattern have significantly fluctuated since beach nourishment. Patch size (mean square values) increased between 1989 and 1993. This indicates that nourishment increases community heterogeneity.

ELLIOTT, KATHERINE J. and JAMES M. VOSE. USDA - Forest Service, SEFES, Coweeta Hydrologic Laboratory, Otto, NC 28763, USA. Competition indices for white pine (Pinus strobus L.) seedlings planted on prescribed burn sites in the southern Appalachians.

We evaluated the competitive environment around planted white pine (Pinus strobus L.) seedlings and examined how pine seedling growth responded to competition from naturally regenerating herbaceous and woody species for two years following prescribed burning. We used distance-independent and distance-dependent indices of competition to determine if competitors reduced resource availability, determined if white pine seedlings responded to resource reduction by competitors, and evaluated the species-specific contribution to the competitive environment by using canonical correspondence analysis (CCA). Distance-independent measures of competition were not as well correlated with pine seedling growth as were the distance-dependent measures. Competition was not as important in 1991 as in 1992 and ordinating the species with CCA did not improve the predictability of the competitive environment. By 1992, competition became more important and individual species had differing effects on pine growth. Light was the most important resource limiting diameter growth and the tall tree species were responsible for the reduction in light availability to pine seedlings.

ELLISON, AARON M. and ELIZABETH J. FARNSWORTH. Department of Biological Sciences, Mount Holyoke College, South Hadley, MA, 01075, USA and Department of Organismic and Evolutionary Biology, Harvard University, Cambridge, MA 02138, USA. Animal-plant interactions, community structure, and ecosystem dynamics in mangrove forests.

Biotic interactions generally are neglected in empirical studies and models of mangrove ecosystems. We review published literature and our 8 yrs of data on interactions between red mangroves (*Rhizophora mangle*) and invertebrates in Belize, and assess their role in structuring mangrove forests. Pre-dispersal propagule predation by insects and post-dispersal propagule predation by crabs are major factors regulating recruitment success. In stable or expanding (accreting) mangrove swamps, insects routinely consume ≤30% of leaf tissue of seedlings and saplings, while isopod crustaceans consume roots. Lepidoptera larvae occasionally defoliate and kill entire saplings. Mature trees suffer less than seedlings or saplings from herbivores, but still lose a significant fraction of NPP to primary consumers. In erosional environments, a diverse invertebrate fouling assemblage occurs on submerged mangrove roots. Isopods consume 20-75% of aerial root tissue. Root-encrusting sponges facilitate root growth directly by providing nitrogen to growing roots; up to 10% of total ecosystem N input may result from N-fixation by sponge-dwelling cyanobacteria. Sponges and ascidians indirectly facilitate root growth by protecting roots from isopod attack. We suggest that biotic interactions must be included in accurate models of mangrove community structure and ecosystem dynamics.

ELLNER, STEPHEN and PETER TURCHIN. North Carolina State University, Raleigh NC 27695-8203, USA and USDA Southern Forest Experiment Station, Pineville, LA 71360,USA. Chaos in a 'noisy' world: methods and evidence from time series analysis.

Chaos is usually presented as a strict alternative to random effects ('noise') such as environmental fluctuations or external disturbances. We argue that strict separation between chaotic and noisy dynamics is unnecessary and misleading, and present a theoretical approach which allows for exogenous, unpredictable perturbations of a system's dynamics. Chaos is defined as "sensitive dependence on initial conditions". A chaotic system will amplify over time, whereas a nonchaotic system dampens, the effects of exogenous noise. Chaos can be detected in data by using nonlinear time series modeling to estimate the Lyapunov exponent, which quantifies the amplification or dampening rate. We have applied 3 families of time series models to a collection of over 60 lab and field population data series. We find a wide range of dynamics, from stable and noise-dominated to weakly chaotic. Populations are clustered near the transition between stability and chaos. In such cases the fluctuations in short-term "local" sensitivity to initial conditions, and local predictability, are more important than the dichotomies of stable vs. chaotic and deterministic vs. stochastic, that have been emphasized to date.

ELSIK, CHRISTINE G. and RICHARD B. FLAGLER. Texas A&M University, College Station, TX, 77843, USA. Effects of EDU and Ozoban on the response of shortleaf pine to ozone.

Two greenhouse studies were undertaken to determine the effects of ethylenediurea (EDU) and sodium erythorbate (Ozoban), on the response of shortleaf pine to ozone (O_3). Seedlings of two half-sib families of shortleaf pine, S2PE3 and S3PE9, and a third "woods-run"

selection were exposed to four levels of O_3 in continuous-stirred tank reactor chambers. Ozone was dispensed at the levels of 0, 50, 100, and 200 ppm for 7 h day^{-1} for 12 weeks. For the EDU study, the chemical treatment levels were 0, 150, 300, and 450 ppm EDU. For the Ozoban study, the chemical treatment levels were 0 and 1030 ppm Ozoban. Ozone levels greater than 0 consistently resulted in foliar injury and decreased net photosynthesis. In the EDU study, all three selections exhibited linear decreases in leaf area and in foliage, stem and root biomass as O_3 concentration increased. In the Ozoban study, only the woods-run and S2PE3 selections exhibited an O_3 response in leaf area and in the biomass components. There were no seedling responses to Ozoban alone, but necrotic lesions that were not caused by O_3 appeared on EDU-treated plants in each selection. There were no EDU x O_3 interactions. Regression analysis revealed an Ozoban x O_3 interaction on leaf area and total, stem, and foliage biomass of the woods-run selection, the most O_3-sensitive selection. Ozoban provided increasing protection as O_3 concentration increased.

EPSTEIN, H.E., W.K. LAUENROTH, I.C. BURKE and D.P. COFFIN. Colorado State University, Fort Collins, CO 80523, USA.
Productivity of dominant grasses along gradients of precipitation and temperature in the central U.S.

We analyzed the productivity of several grass species along a gradient of mean annual precipitation from 270 mm to 1020 mm, and along a gradient of mean annual temperature from 6.5 °C to 12.0 °C. We used species production data from Soil Conservation Service range site descriptions, climate data from 296 USGS weather stations, and ARC/INFO to spatially integrate the data sources. Shapes of productivity curves along the gradients varied amongst species. Mean annual precipitation explained at least 54% and up to 89% of the production of *Bouteloua gracilis*, *Buchloë dactyloides*, *Andropogon gerardii* and *Schizachyrium scoparium* ($p < .001$). Mean annual temperature explained at least 58% and up to 74% of the production of *B. gracilis* and *B. dactyloides* ($p < .001$). Mean annual temperature did not explain much of the variation in production of *Agropyron smithii* and *Stipa comata*. Mean annual precipitation was more explanatory than mean annual temperature. Productivity responses of individual species showed similar patterns within functional types (e.g. C_3, C_4, stress-tolerators, competitors).

ETTEMA, CHRISTIEN H.[1], DAVID C. COLEMAN[1], GEORGE VELLIDIS[2], RICHARD LOWRANCE[3]. [1]University of Georgia, Athens, GA 30602-2202, USA, [2]University of Georgia, Tifton, GA 31793-0748, USA, [3]USDA-ARS, Tifton, GA 31793-0946, USA.
Soil microbial activity and nematode fauna reflecting nutrient input processing in managed and restored riparian forests.

Soil microbial activity and nematode diversity and function were measured as indicators of the role of the soil food web in nutrient processing in two riparian forests in the southeastern coastal plain. Seasonal field data were collected in both a mature riparian forest bordering a conventional agricultural field (Gibbs Farm, 'GF') and a restored riparian forest wetland downslope of a dairy waste application site (Dairy Wetland, 'DW'). Microbial activity, nematode community structure (abundance, diversity, trophic and life strategy groups) and levels of soil nitrate, ammonium, organic nitrogen and carbon were assessed. Initial nematode data from the GF site indicate distinct generic differences between the zones of the riparian forest with a shift from a bacterivore dominated fauna to a fungivore/omnivore dominated fauna when going from the grass-buffer strip into the forest to the streamside. In the DW site, higher numbers of bacterivorous, r-selected nematodes were found in an area with relatively high levels of soil inorganic nitrogen while in other areas of the wetland omnivorous, K-selected nematodes were dominant. Soil biological and chemical data will be analysed with multivariate methods and correlations will be tested.

EUBANKS, MICKY D. AND ROBERT F. DENNO. University of Maryland, College Park, MD, 20742, USA.
Prevalence and ecological significance of omnivory in "predaceous" insects.

Omnivory, defined here as feeding on both prey and plant material, is a common phenomenon in "predaceous" insects. Omnivorous "predators" are found in at least twelve families and seven orders and include insects with diverse morphologies, physiologies, and life histories. Omnivorous feeding habits may have profound effects on the population ecology of these insects. Omnivory will effect survival if mixed diets of prey and plant are nutritionally superior or if plant feeding acts as a refuge during periods of low or no prey availability. Omnivory will effect fecundity if mixed diets of prey and plant are nutritionally superior and lead to a larger number of offspring produced or the production of more viable offspring. Omnivory will effect migration if plant feeding produces immigration and emigration rates that are not correlated with prey density.

EVANS, R.D., A.J. BLOOM, S. SUKRAPANNA and J.R. EHLERINGER. University of Arkansas, Fayetteville, AR, 72701, USA; University of California, Davis, CA, 95616, USA; University of Utah, Salt Lake City, UT, 84112, USA.
Nitrogen isotope composition of plants grown on nitrate or ammonium.

Quantifying natural variation in nitrogen isotope composition ($\delta^{15}N$) may provide new insights into patterns of plant nitrogen use. Studies that examine plant $\delta^{15}N$ typically assume that fractionation does not occur during nitrogen uptake, and leaf $\delta^{15}N$ values reflect those of the entire plant. However, fractionation (0 - 10‰) has been observed in most carefully controlled studies. We tested both assumptions by growing plants on nitrate or ammonium, the two predominant forms of plant-available nitrogen. Whole-plant $\delta^{15}N$ values were not significantly different from source $\delta^{15}N$ for plants grown on nitrate or ammonium, indicating no fractionation with uptake of either form. Plants grown on nitrate exhibited considerable intra-plant variation in $\delta^{15}N$; leaf $\delta^{15}N$ was almost 6 ‰ greater than root $\delta^{15}N$, and 2‰ greater than the mean $\delta^{15}N$ value for the whole-plant. No intra-plant variation in $\delta^{15}N$ was observed for plants grown on ammonium. This suggests that whole-plant $\delta^{15}N$ values reflect those of the nitrogen source, but the degree to which leaf $\delta^{15}N$ reflects the nitrogen source may depend on the form of nitrogen used by the plant.

EYSTER-SMITH, NANCY M. Bentley College, Waltham, MA 02154, USA. The Internet as a component of ecological and environmental science education.

The resource potential of the Internet for students and faculty interested in ecological and environmental information will be presented with an overview of the types of electronic information on the Internet useful for educational purposes. These types of electronic information include databases, bibliographies, press releases, federal publications, library catalogs, bulletin boards, news groups, and newsletters, in addition to interchange of ideas through e-mail. Some of the more positive aspects of the use of the Internet include global connections with other ecologists, communication with experts in the field, rapid response and current data, and educational and job opportunities. While there are some negative aspects, such as the overwhelming amount of information and the possibility of plagiarism, the Internet provides students and faculty with a valuable educational tool. Although ESA members may be most familiar with our society's LISTSERV ECOLOG-L, this presentation will promote the use and understanding of the Internet among colleagues and students for our educational benefit. Handouts with detailed information will be provided.

FAIRWEATHER, PETER G. and PETER S. PETRAITIS. Macquaire University, N.S.W. 2109, Australia and University of Pennsylvania, Philadelphia, PA 19104-6018, USA. Dining at the cafeteria: predation on mussels and barnacles.

Predators were offered a smorgasbord of mussels and barnacles. Groups of mussels alone, barnacles alone, and both species together were placed in mid and low zone on Swan's Island, Maine during the summer of 1993. Numbers of predators were censused eight times and analyzed as a two-way repeated-measures ANOVA. Greater numbers of predatory crabs, snails and seastars were drawn to mid zone treatments than to the low zone treatments. The gastropod Nucella lapillus was the most common predator. Mussel survivorship was lower in the mid zone, but the effect of intertidal height was not significant when analysis was adjusted for the number of Nucella. Size of mussel had no effect on its fate. Within mid and low zones, prey combinations had no effect on total number of Nucella found at the treatments. The number of attacks on barnacles by Nucella depended on whether barnacles were offered alone or with mussels. Nucella attacked fewer barnacles in the presence of mussels. In contrast, Nucella attacked mussels alone and mussels with barnacles at the same rate.

FALKNER, M.B., and T.J. STOHLGREN[1]. National Biological Survey[1], Natural Resource Ecology Laboratory, Colorado State Univ., Ft. Collins, CO, 80523, USA. Evaluating the contribution of small national park areas to regional biodiversity.

Conservationists have voiced concern whether setting aside small national parks and reserves for conservation can be effective in securing a substantial proportion of regional diversity. We summarize the available information on species richness and diversity for 41 National Park Service units in the Rocky Mountain Region. Species richness (species/site) increases predictably as park size increases, yet species diversity (species/area) shows a negative relationship with park size. For example, small parks (<100 km^2) show 50 times greater floral species richness and 200 times greater faunal species richness per unit area compared to larger parks (>100km^2) in the region. The main reason for this high combined diversity is the relatively small overlap among biotas of the various parks. Larger parks tended to have more information about their natural resources than smaller parks that have historically received less funding for research and resource management activities, yet this study suggests that the small parks have a disproportionate share of regional biodiversity and an understated role in the conservation of biodiversity in the region.

FARNSWORTH, E. J. and F. A. BAZZAZ. Harvard University, Dept. of OEB, Biological Labs, 16 Divinity Avenue, Cambridge, MA, 02143, USA. Reproductive allocation and output in herbaceous annuals of the genera *Polygonum, Ipomoea*, and *Cassia* in elevated CO_2 environments

In assessing the capacity of plants to adapt to rapidly changing global climate, we must elucidate the impacts of elevated carbon dioxide on reproduction, fitness and evolution. We investigated how elevated CO_2 influenced reproduction and growth of plants exhibiting a range of floral displays, the implications of shifts in allocation for fitness in these species, and whether related taxa would show similar patterns of response. Three herbaceous, annual species each of the genera *Polygonum, Ipomoea*, and *Cassia* were grown under 350 or 700 ppm CO_2. Vegetative growth and reproductive output were non-destructively measured throughout the full life span, and biomass calibrated with a subsample harvest at first flowering. Viability and germination studies of seed progeny were conducted to more precisely characterize fitness. Timecourse and numbers of floral buds, flowers, unripe and abscised fruits differed between CO_2 treatments. Genera differed significantly in their phenological responses to elevated CO_2. *Polygonum* and *Cassia* species (but not *Ipomoea*) showed accelerated, enhanced reproduction. Elevated CO_2 ameliorated trade-offs between vegetative and floral production. However, seed "quality" and fitness were not always directly correlated with quantity produced. Species within genera responded more consistently to CO_2, indicating that phylogeny and life form may be general predictors of performance under global change.

FAY, PHILIP A, DAVID C. HARTNETT, AND ALAN K. KNAPP. Kansas State University, Division of Biology, Ackert Hall, Manhattan, KS, 66502-4901, USA. Plant and gall-insect responses to resource availability and competitors.

A set of field and common garden experiments examined the ability of *Silphium integrifolium* to compensate for the effects of gall formation by the cynipid gallwasp *Antistrophus silphii*. In the field with natural levels of competition from neighboring plants, high experimentally-induced gall densities had uniformly negative effects on *Silphium*, and there was no regrowth from axillary meristems after gall formation. In a parallel garden experiment where *Silphium* was free from competition, experimentally galled plants produced extensive regrowth from axillary meristems when supplemented with water and fertilizer. This regrowth replaced

reproductive output lost to galls in the absence of extra resources. Resources and plant competitors had weak effects on gall insect performance and parasite loads. These results show that the competitive environment and resources regulate the dominance of galls over lateral meristems, and therefore the ability of *Silphium* to regrow after gall attack. Study of of sink-source interactions in the plant are required to understand the mechanisms controlling plant responses to insect attack.

FERRARI, JAMES B. University of Minnesota, St. Paul, MN, 55108, USA. Leaf litter quality, nitrogen cycling, and maintenance of a Michigan hemlock-hardwood mosaic.

The effects of forest canopy composition on light, litterfall chemistry, and soil nitrogen (N) cycling rates were studied in a hemlock-hardwood forest in Upper Michigan. Light, litterfall, N mineralization, and sugar maple seedling growth rates were measured at 50 locations on a 7.2 ha mapped forest plot. Lignin : N ratios of leaf litter were: hemlock (18.6), yellow birch (16.0), sugar maple (15.3), and basswood (11.4). These four species made up 98% of annual leaf litterfall. Lignin : N ratios of leaf litter were negatively correlated with annual mineralization and nitrification rates and with soil pH. Nitrogen cycling rates were highest (131 kg $N \cdot ha \cdot yr^{-1}$) where basswood and sugar maple litterfall were high, and lowest (28 kg $N \cdot ha \cdot yr^{-1}$) where hemlock and yellow birch litter predominated. Sugar maple seedling growth occurred mainly in early May; rates were highest beneath the hardwoods, where spring light levels were significantly higher. The mosaic of old-growth hemlock and hardwood patches is thus mirrored by distinctive growing conditions in the understory. The effect of leaf litter chemistry on soil N may be to create a positive feedback that maintains the landscape-scale canopy mosaic at Sylvania Wilderness Area. Sugar maple seedlings may not invade hemlock patches due to low nitrate availability and/or to low light levels in spring.

FIELD, CHRISTOPHER B., F.STUART CHAPIN, III, HAROLD A. MOONEY, ELISABETH A. HOLLAND and NONA R. CHIARIELLO. Carnegie Institution of Washinton, Stanford, CA 94305, USA, University of California, Berkeley, CA 94720, USA, Stanford University, Stanford CA 94305, USA, National Center for Atmospheric Research, Boulder, CO 80303, USA, and Stanford University, Stanford, CA 94305, USA. The Jasper Ridge CO_2 project: First-year biomass from Micro-Ecosystem for Climate Change Analysis (MECCA) experiments.

Elevated atmospheric CO_2 stimulated photosynthesis but produced a mixed pattern of biomass responses in natural California grassland. In artificial ecosystems with six single species growing on low-fertility serpentine soil, addition of 20 g m^{-2} of N, P, and K led to dramatic increases in annual net primary production (NPP) (mean increase > 500%) and consistent decreases in root fraction. Elevated CO_2 (ambient plus 350 μmol mol^{-1}) had almost no effect on annual NPP at natural nutrient levels, but stimulated biomass production by a mean of 15% with added nutrients. Root fraction did not change consistently with elevated CO_2.

FIEDLER, PEGGY L., RICHARD D. LAVEN, and MICHAEL VASEY. San Francisco State University, San Francisco, CA 94132,USA; Colorado State University, Ft. Collins, CO 80523, USA; and San Francisco State University, San Francisco , CA, 94132, USA. The implications of rare-common species differences for conservation and management.

Data on rare species suggest certain generalizations regarding life history and genetic differences between rare taxa and their common congeners. Such differences will be reviewed with respect to the type of rarity and life history patterns for plants, primarily, but significant inferences will be drawn for certain vertebrate and invertebrate taxa. While such observations regarding rare-common differences can be made, we stress that the observed differences are largely correlative, characteristic, and may be consequential, but they are not necessarily causative. This makes the potential conservation strategies for rare taxa less certain and generalizable because the conservation of rare entities must address, and ultimately ameliorate, the causes of rarity in addition to their consequences. We will suggest management and research approaches based on our rather limited knowledge of rare-common differences that should enhance our conservation efforts of rare taxa.

FINZI, ADRIEN C., and CHARLES D. CANHAM. University of Connecticut, Box U-42, Storrs, Ct., 06269 and Institute of Ecosystem Studies, Box AB, Millbrook, N.Y., 12545. Patterns of sapling growth response to a natural gradient of light and nitrogen availability in transition oak - northern hardwood forests of the northeastern U.S.

Interactions between light availability and nitrogen availability in temperate forests has been implicated as a major force determining forest community structure. We tested this hypothesis by collecting 50 individuals of 6 different species growing under a range of light and nitrogen conditions in and around Great Mountain Forest in northwest Connecticut. Using maximum likelihood estimation we predicted sapling radial growth response to light and nitrogen using a modified double Michealis-Menton function. Interspecific differences in the coefficients describing radial growth as a function of light and nitrogen availability were then included in SORTIE, a spatially-explicit model of northeastern forest dynamics. Interspecific differences in growth response to light were more important in determining forest community composition than were interspecifc differences in radial growth response to nitrogen availability. These results suggest that the interaction between light and nitrogen availability may influence community structure only at larger spatial scales.

FISCHLER, MICHELLE, R. SHARIFI & P. RUNDEL. Whittier College, Whittier, CA 90602 and University of California, Los Angeles, CA 90024. Gas exchange and nitrogen use efficiency of stems and leaves of stem photosynthetic species.

Maximum photosynthetic rates were measured for leaves and stems of a number of stem photosynthetic species after they had developed a new flush of leaves in the spring. Tissue samples were also analyzed for nitrogen content in order to determine nitrogen use efficiency and its relationship to the maximum photosynthetic rates that can be achieved by leaves and stems of stem photosynthetic species. A previous study comparing gas exchange and nitrogen use efficiency of 13 year old Prosopis glandulosa, a mesquite that uses leaf photosynthesis, and P. kuntzei, a leafless mesquite that utilizes stem photosynthesis revealed that the maximum photosynthetic rate for P. glandulosa was 60% higher than that measured for P. kuntzei; however, nitrogen and chlorophyll content of P. glandulosa were twice that of P. kuntzei. The results of this survey agree with the results obtained in the previous study in that nitrogen use efficiency of stems and leaves differ very little.

FISCUS, EDWIN L., CHANTAL D. REID and KENT O. BURKEY. USDA/ARS and North Carolina State University, Raleigh NC, 27606, USA. "Interactive effects of O_3 and CO_2 enrichment on photosynthetic acclimation. II. Non-biochemical limitations."

Non-biochemical limitations in photosynthetic acclimation to elevated atmospheric CO_2 and O_3 may be partitioned between stomatal diffusion and energy capture. To determine the importance of these limitations on the mechanisms of photosynthetic acclimation, soybean (*Glycine max*) plants were grown in a 4 CO_2 x 3 O_3 combination in open-top field chambers for one growing season. Midday stomatal conductance was measured in the field at regular intervals through the season. Chlorophyll fluorescence measurements were made both *in situ* and on leaf discs in the lab. Stomatal conductance was highest in ambient CO_2 x charcoaled-filtered air (2.4 $cm.s^{-1}$) and decreased with increasing CO_2 and/or O_3, the lowest conductance being in high CO_2 x 1.5 O_3 (50% of control). Quantum efficiency was significantly reduced by O_3 (72% of control) and although it was also reduced somewhat by high CO_2 (90% of control), in combination the reductions due to O_3 exposure lost statistical significance, indicating that high CO_2 moderated this aspect of O_3 damage. A shift among non-biochemical limitations of photosynthesis is suggested when plants are exposed to a combination of these trace gases.

FISHER, ANDREW S. and DONALD J. LEOPOLD. SUNY-College of Environmental Science and Forestry, Syracuse, NY, 13210. Vegetation patterns along hydrologic gradients in abandoned agricultural peatlands in Central New York.

Forested sapric peatlands that are cleared of natural vegetation and drained by ditching are used for agriculture. The process of organic soil subsidence in time renders these mucklands unfit for continued cultivation. Once abandoned from agriculture, successional changes are affected largely by the interaction of microtopography and the hydrologic regime. Gradient and pattern analyses were used to investigate spatial patterns of species in relation to hydrologic variation at two different scales. Species indicative of high soil moisture conditions show strong fidelity to ditches or low topographic positions, while "drier" species dominate higher positions. Low variation in groundwater pH, conductivity, and dissolved calcium across strong hydrologic gradients suggests soil moisture as the most important factor in species patterning in these abandoned mucklands.

FISK, MELANY C. AND STEVEN K. SCHMIDT. University of Colorado, Boulder, CO, 80309, USA. Seasonal patterns of microbial biomass, nitrogen utilization, and respiration in alpine tundra soils.

Seasonal relationships between microbial activity and the microbial N pool were investigated in alpine tundra soils. Both microbial activity (respiration) and gross mineralization were variable over time, with greater N immobilization relative to respiration later in the season. In monthly laboratory incubations microbial activity was consistently stimulated by added carbon and also responded to water additions in August. Nitrogen additions alone did not influence microbial activity, but did result in increased N immobilization and stimulated growth on added C. So while soil microbes generally were C limited, the soil biomass was able to immobilize exogenously supplied N as well as to utilize carbon more efficiently with greater N availability. These responses of the biomass indicated seasonal flexibility in microbial N use, resulting in a more stable microbial biomass early in the season compared to greater immobilization potentials of the biomass later in the season.

FLAGLER, RICHARD B. and JOHN E. LOCK. Texas A&M University, College Station, TX, 77843, USA. Effects of EDU and Ozoban on the growth of shortleaf pine seedlings in the field.

Two field studies were conducted to determine the response of shortleaf pine seedlings planted in the field to ethylenediurea (EDU) and sodium erythorbate (Ozoban), both of which possess antioxidant properties, and were developed to protect plants from ozone (O_3). Seedlings originated from two half-sib families of shortleaf pine, S2PE3 and S3PE9, and a third "woods-run" selection. For the EDU study, the chemical treatment levels were 0 and 300 ppm EDU. For the Ozoban study, the chemical treatment levels were 0, 515, 1030, 1545, and 2060 ppm Ozoban. Seedlings were sprayed monthly with the appropriate concentration of antioxidant chemical for two years. EDU increased leaf area and foliage, stem and root biomass for all three selections; the response of the woods-run selection was the

greatest. Height growth was increased by EDU only in the woods-run selection. Diameter growth was not affected by EDU. In the Ozoban study, only family S2PE3 exhibited a biomass response to Ozoban, with increased biomass as Ozoban application rate increased up to the highest rate, at which point there was a small decrease. Height growth was not affected by Ozoban. Diameter growth of the woods-run selection increased as Ozoban application rate increased, with a slight decrease at the highest application rate. Diameter of the other selections was not affected by Ozoban. Both chemicals appeared to provide some protection to shortleaf pine against ambient O_3.

FLAMM, RICHARD, O.[1], ROBIN GOTTFRIED[2], ROBERT G. LEE[3], ROBERT J. NAIMAN[3], MONICA G. TURNER[4], and DAVID WEAR[5]. [1]Florida Marine Research Institute, St. Petersburg, FL, 33701, USA, [2]The University of the South, Sewanee, TN, 37375, USA, [3]University of Washington, Seattle, WA, 98195, USA, [4]Oak Ridge National Laboratory, Oak Ridge, TN, 37831, USA, [5]USDA Forest Service, Research Triangle Park, NC, 27709, USA. Simulating landscape change in the Olympic Peninsula using spatial ecological and socioeconomic data.

Ecological and socioeconomic data were integrated to study landscape change for the Dungeness River basin in the Olympic Peninsula, Washington State. A multinomial logit procedure was used to evaluate twenty-two maps representing various data themes to derive transition probabilities of land cover change. Probabilities of forest disturbance were greater on private land than public. Between 1975 and 1988, forest cover increased, grassy/brushy covers decreased, and the number of forest patches increased about 30%. Simulations were run to estimate future land cover. These results were represented as frequency distributions for proportion cover and patch characteristics.

FLATT, PATRICIA M., ROBERT L. SANFORD JR., and WILLIAM J. PARTON. University of Denver, Denver, CO, 80208, USA, and Colorado State University, Ft. Collins, CO, 80523, USA. Resource Quality and Leaf Decomposition Rates of the Hawaiian Tree, Metrosideros polymorpha, as Affected by Nutrient Additions.

Decomposition rates are strongly influenced by the resource quality of senescent leaves, especially in ecosystems that are nutrient limited. Productivity during primary succession on young lava flows is Nitrogen(N) limited because of the low N-content. Thus, they provide a unique opportunity to study the effects of fertilizer treatments on nutrient dynamics and decomposition. The resource quality of M. polymorpha leaves was modified by periodic fertilization of field plots following a factorial design on a young lava flow in Hawaii. Phosphorus(P) fertilization increased the P-content of senesced leaves, and this resulted in increased decomposition rates. In contrast, senescent leaves from N-fertilized plots were not significantly different from control leaves in either N-content or decomposition rates. Decomposing leaves immobilize more N and P from the fertilized plots than for leaves from the control plots. CENTURY simulations fail to adequately predict nutrient elemental loss patterns and model modifications are discussed.

FLEBBE, PATRICIA A. USDA Forest Service and Virginia Polytechnic Institute and State University, Blacksburg, VA 24061-0321, USA. Scales of variability for trout abundance in the Southeast: from pool to region.

This study was designed to determine the amount of variance in trout abundance across the southern Appalachian region (~500 km) and to partition that variance among three smaller spatial scales: local area, individual stream, and habitat unit. Basinwide estimates of trout populations were made in 37 headwater streams during 1989-1993. Basins were assigned to one of nine local groups, based on proximity in time (weeks) and space (10-20 km). Each stream (2-10 km length) consisted of 120-1300 habitat units (pools and riffles) that were sampled for trout over a period of days. Trout abundance (numbers and biomass) was determined for habitat units and aggregated to the larger scales. Simulations and statistical analyses were used to examine the spatio-temporal scales into which total regional variance could be partitioned. Of the total variability in trout abundance across the region, very little (0-3%) was observed among local groups of streams. Variability in trout numbers across the region was relatively evenly divided between scales of habitat unit (50-60%) and individual streams (40-50%), but variability in trout biomass was concentrated at the scale of individual habitat units (80-90%). With an increasing emphasis on research and management of trout at watershed to regional scales, new approaches are needed that are sensitive to the multiple scales at which trout abundance may vary.

FLECKER, ALEXANDER S. Cornell University, Ithaca, NY, 14853, USA. Biological disturbance and the structure of tropical riverine communities.

Tropical streams often contain abundant assemblages of fishes that process large volumes of sediment. Such sediment feeding activities represent a potential source of biological disturbance, which has been largely ignored by ecologists working in running water systems. Here I provide evidence that benthic-feeding fishes in neotropical streams can serve as important agents of biological disturbance via sediment feeding and bioerosion. I present results from field exclosure/enclosure experiments conducted in the Venezuelan Andean piedmont that examine the importance of different fish trophic guilds on stream community structure. Sediment-feeding fishes were found to exert strong indirect effects on the composition of stream invertebrate assemblages. In contrast, the direct effects of insectivorous fishes on benthic invertebrates were relatively weak even though they consume large numbers of stream insects. The selective exclusion of the seasonally abundant detritivore, Prochilodus mariae, reveals that this fish species is a particularly strong interactor, as the removal of this fish alone results in dramatic changes in community structure. It appears that the important mechanism to explain these findings is that biological disturbance by fishes modifies the distribution of sediments, which plays a crucial role in determining microhabitat quality.

FLEMING, D. MARTIN[1], DONALD L. DEANGELIS.[2,3] and LOUIS J. GROSS[2]. [1]National Biological Survey, Everglades National Park, Homestead, FL 33030, USA, [2]University of Tennessee, Knoxville, TN, 37996-1300, USA and [3]Oak Ridge National Laboratory, Oak Ridge, TN, 37831, USA. ATLSS: Across trophic level system simulation for the freshwater areas of the Everglades.

The Everglades of South Florida are characterized by complex patterns of spatial heterogeneity and temporal variability, with water flow being the major factor controlling the trophic dynamics of the system. A key objective of modeling studies for the system is to compare the future effects of alternative hydrologic scenarios on the biotic components of the system. Due to the varying scales at which trophic interactions occur, and the importance of population structure and individual behavior for population prediction in higher trophic level organisms, use of a single modeling approach is not appropriate. We will describe a scheme to integrate three approaches for different trophic levels of the system: (1) process models for lower trophic levels (including benthic insects, periphyton and zooplankton), (2) structured population models for five functional groups of fish and macroinvertebrates, and (3) individual-based models for large consumers (wood storks, great blue herons, white ibis, American alligators, white-tailed deer, and Florida panther). These are integrated across the freshwater landscape of the Everglades and coupled to GIS maps for cover type. Spatial scales of resolution for the models are as small as 100 m, with the capability to vary this based upon the scale of available input data. The system is then coupled to a hydrology model, and used to assess the effects of alternative proposed restoration scenarios on trophic structure.

FLEMING, THEODORE H., SANDRINE MAURICE, and JAMES L. HAMRICK. University of Miami, Coral Gables, FL 33124 USA, University of Arizona, Tucson, AZ 85721 USA, and University of Georgia, Athens, GA 30602. Pollinator limitation and the evolution of trioecy in the cactus, Pachycereus pringlei.

The giant columnar cactus Pachycereus pringlei (cardon) has a geographically variable breeding system. In the Sonoran desert of mainland Mexico, its populations are gynodioecious in the southern 1/3 of its range and trioecious in the northern 2/3s. In Baja California, its populations are trioecious in the southern 2/3s of its range and gynodioecious in the northern 1/3. We tested two hypotheses to explain this pattern: (1) a "limited gene flow" hypothesis, which predicts that substantial genetic differentiation that is concordant with variation in sex ratios occurs among cardon populations; and (2) a "limited nocturnal pollinator" hypothesis, which predicts that this pattern reflects concordant variation in the abundance of cardon's major pollinator, the bat Leptonycteris curasoae. Results of an electrophoretic survey of cardon populations do not support hypothesis (1). Three lines of evidence support hypothesis (2): the geographic distribution of Leptonycteris maternity roosts, field observations on time of arrival of bats in different cardon populations, and a theoretical model which shows that pollinator limitation can lead to evolutionarily stable trioecy in this cactus.

FLOWER, LINDA S. AND JOHN A. GAMON. California State University, Los Angeles, CA, 90032-8201, USA. Estimation of wildflower population density and distribution with spectral reflectance

Spectral reflectance and spectral mixture analysis were used to examine flower densisty and distribution in *Eschscholzia californica* (California poppy), an annual with distinctive orange petals. *E. californica* flowers yielded a characteristic reflectance spectrum that was readily isolated and quantified from a composite canopy reflectance spectrum using spectral mixture analysis. Strong linear correlations emerged between the flower "endmember fraction" (representing the amount of orange flowers present) and the area covered by flowers in photographic images. These promising results suggest that spectral reflectance can be used to study population dynamics of flowering annuals that often undergo large interannual swings in population size and distribution.

FLOYD, M. LISA, WILLIAM H. ROMME, ALLAN LOY. Prescott College, Prescott, AZ, Fort Lewis College, Durango, CO, National Park Service, Mesa Verde, CO. A GIS based vegetation classification of Mesa Verde National Park.

One of the initial steps in modeling fire effects on cultural resources at Mesa Verde National Park was the creation of a digital vegetation map so that the fir potential of each plant community could be predicted. The National Park Service provided Landsat TM and SPOT panchromatic data from 1990 for use as a spatial and spectral base. An unsupervised classification of the image data showed that 17 % of the image was classed as shadow, obscuring important vegetation characteristics. To mitigate these topographic effects, a hyperspherical direction cosine transformation was used to separate the spectral and illumination information. The transformed spectral image data was then reclassified. Ground truth efforts were guided by this reclassification and involved releve stand analyses of over 300 sites, each located with GPS. Species cover and abundance ratings were clustered with TWINSPAN. This ordination was used to guide the final supervised classification of the image data, using training signatures developed from the mean spectral signatures of the clustered sample points. Thus, spectral and field information were related to one another. As a result, the vegetation is clustered into 17 classes.

FLOYD, TED. Pennsylvania State University, University Park, PA, 16802, USA. Effects of bird and arthropod predation on creosotebush herbivores.

I compared the relative roles of bird and arthropod predation on the community structure and population densities of the herbivorous insects that inhabit creosotebush (Larrea tridentata). I removed predators from 24 creosotebushes in each of 3 sites (72 shrubs total) according to a 2 X 2 design of 6 bird-excluded, 6 arthropod-excluded, 6 bird- and arthropod-excluded, and 6 control shrubs. I conducted these experiments at the Jornada Long-Term Ecological Research (LTER) site in the Chihuahuan Desert of southwestern New Mexico. I removed birds with nylon-netting exclosure cages, and arthropod predators were hand-picked and removed nightly. I identified and counted all arthropods (herbivores and predators) during crepuscular and nocturnal censuses at intervals of 0, 45, and 90 days following the establishment of predator removals (in mid-May of 1993). By the end of the experiments (early August), herbivore populations had increased and community structure had been altered on experimental shrubs at all 3 sites, but the results varied considerably as a function of treatment and site. These experiments highlight the consequences of spatial heterogeneity for ecological research, even across small distances within fairly homogeneous environments.

FLUM, T., S,C. NODVIN, H.L.H. RHODES, E.M. WILLIAMS, M.M. MALICK, A.K. ROSE, J. SHUBZDA, and S.B. LOWE. National Biological Survey-Cooperative Park Studies Unit, University of Tennessee, Knoxville, TN, 37996. USA Longitudinal changes in stream water chemistry from seventeen high elevation watersheds in the Great Smoky Mountains National Park.

A plan for monitoring water chemistry at 274 sites across the Great Smoky Mountains National Park was developed in response to observations of high levels of atmospheric S and N deposition. Sites range in elevation from 1675 m to 268 m, including five or more sites from each of 17 different watersheds. Bedrock geology plays a major role in stream chemistry, particularly where streams flow through the Anakeesta Formation where there is pyrite weathering. Streams in these areas have pH values as low as 4.6 and are devoid of brook trout. The ancient and highly eroded mountains have poor soil buffering capacity and streams across the Park are either sensitive to acidification (ANC < 200 µeq/L) or extremely sensitive (ANC < 50 µeq/L), especially above about 900 m. Un-logged, old-growth forests on the highest peaks are leaching large amounts of deposited N to streams so that at elevations above 900 m nitrate is the dominant anion with concentrations from 20 to 60 µeq/L (1240 to 3720 µg/L). Nitrate concentrations decline rapidly below 900 m, probably due to a combination of; 1) relatively young forests uptaking N from the soil, 2) dilution, and 3) uptake and sequestering in the stream. The relative role of these processes remains unknown.

FOLKE, CARL. The Beijer International Institute of Ecological Economics, Box 50005 , S-104 05 Stockholm, Sweden. Biological Diversity and its Sustainable Use: An ecological economics synthesis.

The paper focus on functional diversity and the production and maintenance of ecological services that underpin human welfare. Ecological services are analyzed in relation to the role of organisms in ecosystem performance and resilience. Two major functional groups are identified; keystone process species and life-insurance species. Direct and indirect human driving forces that cause the loss of biological diversity are exemplified and discussed in the context of ecological discontinuities and thresholds. Management and policy that can reverse the current trend, and even enhance biodiversity are suggested, including ecotechnology and the use of traditional ecological knowledge. It is stressed that institutions that are adaptive and work in synergy with ecosystem processes and funtions are critical and their development needs to be stimulated at all levels.

FORD, MARK A. and JAMES B. GRACE. Louisiana State University, Baton Rouge, LA, 70803, USA and National Wetlands Research Center, Lafayette, LA, 70506, USA. Herbivory impacts on soil elevation and soil accretion in a brackish marsh of coastal Louisiana.

In rapidly subsiding wetlands, such as those in the Mississippi delta region, the persistence of marshes is dependent upon sufficient soil accretion to outpace rate of subsidence. This study was conducted in order to assess the impact of mammalian herbivores, especially nutria and wild boar, on soil accretion processes. The use of exclosures in conjunction with feldspar and benchmark techniques allowed us to measure the effects of herbivore exclusion on surface accretion, marsh elevation changes, vegetation, and litter production. Herbivory has been found to have substantial effects on standing biomass as well as species composition. Herbivores have also been found to increase the decomposition of material on the soil surface because of the destructive nature of their feeding habits. Changes in soil surface elevation over time indicate that while herbivory appears to have a significant effect on sedimentation, it does not seem to be the dominant variable affecting soil elevation changes in this system.

FORE, S. A.* and S. I. GUTTMAN. Miami University, Oxford, OH, 45056, USA (*present address Savannah River Ecology Laboratory, Aiken, SC, 29801, USA). Genetic structure of Helianthus occidentalis in a preserve with fragmented habitat.

The overall objective of this study was to examine the genetic structure of Helianthus occidentalis Riddell (western sunflower) in a landscape where suitable habitat is fragmented. This insect-pollinated, perennial forb with gravity-dispersed seed is listed as a threatened plant in Ohio but is locally abundant in the barrens of the Edge of Appalachia Preserve System in Adams Co., OH. However, the distribution of these barrens is fragmented by woodlands with several barrens in a region located <200 m apart and regions being separated by >1.5 km. Leaf samples were collected from individuals at regular intervals along transects established in each of eight barrens. Genotypes were inferred from allozyme phenotypes revealed by starch gel electrophoresis. Although observed heterogeneity (H_o) was significantly different among the barrens, there was no linear relationship between H_o and sample size. Hierarchical F-statistics indicated that more of the genetic differentiation was among sites within a region (0.084) rather than among regions (0.016). This suggests that gene flow may be low among sites within a region. Conservation efforts for this species in this preserve should focus at the regional level; regions with numerous barrens that have high levels of differentiation and high levels of heterozygosity should be selected.

FORTIN, MICHEL and YVES MAUFFETTE. Université du Québec à Montréal, GREF, C.P. 8888 Succ. A, Montréal, Qc, Canada, H3C 3P8. The biology and the feeding preference of forest tent caterpillar (*Malacosoma disstria* Hbn) reared on sun and shade seedlings.

Plants grown under different environmental conditions (e.g. light intensity) may alter the chemical characteristics of their leaves. Hence, these chemical changes may influence the biology and the behavior of phytophagous insects. The purpose of this study was

to verify the biological performance and feeding preference of forest tent caterpillar (*Malacosoma disstria* Hbn.) for foliage from sugar maple seedlings growing in full sunlight and in the shade. The results indicated that larval development was significantly reduced (by 3 days) and that survivorship was significantly superior (43.5%) for insects reared on sun seedlings. However, the pupal weights were not significantly different for insects reared on seedlings from either light intensities. Finally, 4th and 5th instar larvae showed a feeding preference for sun leaves. These results suggest that light conditions can have indirect effects on the population dynamics of the forest tent caterpillar.

FOX, GORDON A., and BRUCE E. KENDALL, University of the South, Sewanee, TN 37383, USA, and University of Arizona, Tucson, AZ 85721, USA. Dispersal and population dynamics: stability and chaos

Dispersal is widely thought to stabilize population dynamics. We have studied the interaction of local population dynamics and dispersal for systems of 2 and 3 patches, with local dynamics given by the logistic map, and passive dispersal. The important results are: (1) As pointed out by Hastings (1993), dispersal tends to stabilize population dynamics that would otherwise be chaotic. However, our results show that the strength of this effect depends on the similarity of the patches -- if the growth rate r is very different between patches, the stabilizing effect is small. (2) Chaotic transients are preserved even when dispersal stabilizes the long-run dynamics. In the presence of noise, these transients can be more important than the long-run dynamics. Thus, while dispersal can stabilize population dynamics, it doesn't necessarily do so.

FRADKIN, STEVEN C. and JOHN J. GILBERT. Dartmouth College, Hanover, NH, 03755, USA. Does Daphnia pulex behaviorally avoid toxic Anabaena?

Freshwater zooplankton have been shown to alter their positions in the water column to avoid a variety of factors, such as predation. In this study we examined the ability of Daphnia pulex to behaviorally avoid patches of toxic cyanobacteria(Anabaena). We hypothesized that Daphnia highly susceptible to toxic Anabaena should orient away from high concentrations of these algae. Daphnia were monitored at 2 hr intervals for 6 hrs in laboratory columns in which there was a steep gradient of toxic Anabaena in addition to a uniform vertical distribution of food algae (Cryptomonas). Data were analysed with repeated measures ANOVA. In comparison with control columns (No Anabaena), treatment columns showed no significant difference in Daphnia distributions. Daphnia in treatments frequently occupied areas of dense Anabaena concentration. Our results do not support the hypothesis that Daphnia behaviorally orient away from concentrations of toxic cyanobacteria.

FRANCIS, M. LYNN, SCOTT L. COLLINS, SUSAN M. GLENN. University of Oklahoma, Norman, OK, 73019, USA. Vegetation mapping of the Tallgrass Prairie Preserve using Landsat Thematic Mapper Imagery.

The Nature Conservancy funded this vegetation study of their 30,000 acre Preserve in NE Oklahoma. Landsat TM imagery (8/91) and the results of field sampling of 96 10 m^2 grassland and 52 10 m^2 woodland plots (8/92) were used to produce vegetation analyses and a map of the Preserve from which future management decisions may be based. Eight classes of grassland vegetation and 2 classes of woodland were produced from Cluster Analysis, DCA and MRPP of field sample data. Due to the smaller scale heterogeneity of prairie (<30 m^2) compared to the 30 m^2 scale of the imagery, these classes were not mappable with TM imagery. Savanna (<40% canopy) and woods (>40% canopy) were mapped successfully. Image classifications were performed using ISODATA in ERDAS using band combinations TM4, TM3 and TM2, TM2, TM3, TM4 and TM5 and Principal Components Imagery.

FRANK, DOUGLAS A., RICHARD S. INOUYE, NANCY HUNTLY, G. WAYNE MINSHALL, and JAY E. ANDERSON. Idaho State University, Pocatello, ID, 83209, USA. The biogeochemistry of a north-temperate grassland with native grazers: N dynamics in Yellowstone National Park.

We examined N cycling on the northern winter range of Yellowstone National Park, home for large over-wintering herds of elk (*Cervus elaphus*) and bison (*Bison bison*). We measured plant and soil N, net N mineralization, and the flux of N from ungulates to the soil over one year at 5 topographically diverse sites within a watershed, ranging from ridgetop to riparian valley bottom. Results indicated (1) landscape position and soil microclimate affected N dynamics, and (2) annual mineralization was positively related to soil N content. In addition, estimated rates of N fluxed from ungulates to the soil, both urine-N and fecal-N, averaged 27.0 kg/ha/yr, and was 4.5 times the amount of N in senescent plants. These results indicate that grazers are a particularly important component of the N budget of this grassland ecosystem.

FRANKLIN, SCOTT B., DAVID J. GIBSON, PHILIP A. ROBERTSON, and JOHN T. POHLMANN. Southern Illinois University, Carbondale, IL, 62901, USA. Use of Parallel Analysis for determining significant factors.

Numerous ecological studies have used Principal Components Analysis (PCA) or Factor Analysis (FA) for exploratory analysis and data reduction. Determining the number of significant factors is the most crucial problem the researcher confronts when using PCA or FA. An incorrect choice may lead to the underextraction of components, but usually results in overextraction. Parallel Analysis (PA) has proven consistently accurate in determining thresholds for

significant factors and variable loadings. Eigenvalues from a research data set prior to rotation are compared with those from a matrix of random values of the same dimensionality (p variables and n samples). PCA and FA eigenvalues from research data greater than the PA eigenvalues from random data would be retained. We reviewed articles utilizing PCA or FA from 1987 to 1993 from *Ecology*, *Ecological Monographs*, *Journal of Vegetation Science*, and *Journal of Ecology*. Parallel Analysis was applied for each PCA/FA found in the literature using the same number of variables and samples. Of 69 analyses (in 50 articles), 56 (81.2%) considered no threshold rule. According to the PA results, 43 (62.3%) overfactored the data. This overfactoring has resulted in widespread, and potentially misleading, interpretation of spurious components.

FREDERICKSEN, T.S., B.J. JOYCE, K.B. KOUTERICK, T.E. KOLB, J.M. SKELLY, K.C. STEINER, J.E. SAVAGE, and K.R. SNYDER. Pennsylvania State University, University Park, PA, 16802, USA. Response of different-aged black cherry trees to ambient ozone exposure.

Black cherry (Prunus serotina Ehrh.) is a valuable commercial timber species which is also highly sensitive to ozone relative to other eastern deciduous tree species. Studies of ozone effects on forest trees have been restricted mostly to experiments using small seedlings under controlled conditions. Yet, mature trees may differ from seedlings in physiology, morphology, and exposure to air pollutants. An experiment was conducted in 1993 to determine differences in ozone uptake and foliar injury symptoms between open-grown seedlings, forest saplings, and mature forest trees of black cherry in northcentral Pennsylvania. Seedlings grew under the highest ozone concentrations and also had greater seasonal ozone uptake due to higher rates of stomatal conductance. However, because of their indeterminate growth habit, seedlings had lower cumulative ozone uptake per leaf lifespan than saplings or mature trees, both of which had determinate shoot growth. Although greater initially for seedlings, foliar injury was nearly identical between size classes by the end of the growing season. Leaves in the lower crown of larger trees had lower ozone uptake than leaves in the upper crown, but exhibited more foliar injury symptoms. Lower crown leaves received more effective exposure to ozone because of their thinner leaves and had less available photosynthate for repair or replacement of damaged tissue.

FREIDUS, DANIEL. University of Michigan, Ann Arbor, MI, 48109, USA. Indirect effects of herbivory: are higher-order interactions important?

To test for higher-order interactions, I independently quantified the direct effect of an oligophagous herbivore (Colorado potato beetle (CPB), Leptinotarsa decemlineata) on a host plant (potato, Solanum tuberosum) and the competitive effect of potato on soy (Glycine max), a non-host plant of CPB. Assuming there would be no higher-order interactions, I generated a composite function predicting the indirect effect of CPB on soy when all three species are grown together. In plots with all three species, I measured the actual indirect effect of CPB on soy. The null prediction based on the assumption that there were no higher-order interactions accurately described the indirect effect of CPB on soy. Therefore, I conclude that higher-order interactions are not important in this system. If further studies show this to be generally true of the interaction between herbivory and plant competition, indirect effects of herbivores could be predicted from the performance of isolated two-species combinations.

FRISBIE, MALCOLM P. and RICHARD L. WYMAN. Eastern Kentucky University, Richmond, KY, 40475, USA and Edmund Niles Huyck Preserve, Rensselaerville, NY, 12147, USA. A field test of the effect of acidic rain on ion balance in a woodland salamander.

Earlier laboratory studies demonstrated that red-backed salamanders, Plethodon cinereus, are susceptible to osmotic disruption by low pH substrates. In natural systems, however, acidic input from precipitation may be mediated by soils before it impacts salamanders. We tested the effect of acidic rain on sodium balance in salamanders by confining individuals in enclosures in two forest types (hemlock, beech) for 34 d. Enclosures received artificial rain of either pH 3 or 5 every 3-4 d. Soils inside enclosures in the hemlock forest were more acidic than those in the beech forest at the outset. At termination, $[H^+]$ of soils was greater inside pH 3- than pH 5-enclosures, but did not differ between forest types. Salamanders in pH 3-enclosures in both forests had lower body sodium levels than salamanders in pH 5-enclosures. Thus, acidic precipitation in these forest ecosystems significantly altered soil pH and had a pronounced physiologic impact on an abundant terrestrial inhabitant.

FRITZ, ROBERT S. Vassar College, Poughkeepsie, NY 12601, USA. Resistance of hybrid and parental willows to herbivores over three years.

Two species of willows (Salix sericea and S. eriocephala) and their hybrids were studied to test 4 hypotheses concerning the effects of hybridization on resistance. Plants were identified using morphological traits and RAPD band analysis was used to verify the genetic status of some parental and hybrid plants. The densities of 11 herbivore species were censused on marked parents and hybrids. We found the greatest support for the Additive and Hybrid Susceptibility hypotheses over the three years. One species supported the Dominance hypothesis, and one species in one year supported the Hybrid Resistance hypothesis. Guild membership was not a good predictor of similar responses of species to hybrid versus parental plants. This study demonstrates the diversity of responses of phytophages in response to interspecific hybridization, and indicates that year-to-year variation can be significant, which might indicate the influence on environmental variation on the expression of hybrid resistance.

FROST, THOMAS M. and PAMELA K. MONTZ. University of Wisconsin, Madison, WI, 53706, USA. Zooplankton Community responses during three years of recovery following the experimental acidification of Little Rock Lake, WI.

Little Rock Lake in northern Wisconsin was the site of an experimental acidification experiment that began with a baseline period in 1984 at pH 6.1 and ended in 1990 at 4.7. To examine the effects of acidification, the lake's zooplankton community was contrasted between the treatment basin and reference basin at biweekly intervals during this period. We have continued monitoring zooplankton at the same frequency since then to examine the recovery process. By summer of 1993, the average pH reached 5.3 and many zooplankton species originally reduced during acid treatments (e.g., *Holopedium gibberum* and *Mesocyclops edax)* had returned to near pre-treatment levels. In contrast, some other species (e.g., Keratella cochlearis) have not recovered. Experimental tests of the mechanisms underlying species changes have shown that species interactions rather than direct chemical responses explain most of the observed patterns.

FRY, JANN E. and SCOTT K. GLEESON. University of Kentucky, Lexington, KY, 40506, USA. Root response to resource patches in five grass species.

Plant roots are known to proliferate in patches of high levels of limiting resources. We tested two aspects of this response in grasses 1) a quantitative prediction that proliferation should be proportional to supply and 2) the ecological prediction that later successional species should be less responsive. In the first experiment, sorghum (*Sorghum vulgare*) and soft red winter wheat (*Triticum aestivum* L.) were grown in four-chambered pots and supplied with a range of nutrient levels. Wheat showed no differential response, but Sorghum fine roots showed a linear response to nutrient levels when aggregated across pots. Overall plant growth was affected by total nutrients but not by heterogeneity of supply. In the second experiment, one early successional species (*Agropyron repens*), and two late successional species (*Andropogon gerardi* and *Schizachyrium scoparium*), were tested in two-chambered pots. Only the early successional species showed significant root proliferation response. High levels of variation in root response may be in part due to multiple and conflicting functions of roots.

FRYXELL, JOHN. University of Guelph, Guelph, Ontario, N1G 2W1, Canada. Predicting predator functional responses in complex communities.

I used detailed experimental studies of constraints on rates of energy intake to predict optimal diet selection by beavers and, more importantly, to predict the effects on beaver functional responses when feeding in forest environments of increasing complexity. The optimality model predicted that adaptive size selection by beavers should reduce rates of sapling consumption at high resource densities but have little effect at low resource densities, producing a type-II functional response. In contrast, adaptive diet selection in forests with several species of prey should lead to reduced consumption rates of saplings at low resource densities but have little effect at high densities, producing a type-III functional response. Observed functional responses by beavers in controlled feeding trials with complex communities of saplings varying in size and/or species composition were qualitatively consistent with predictions.

FUAD, TARA D. and MARK R. WALBRIDGE. George Mason University, Fairfax, VA, 22030, USA. Phosphorous retention in freshwater wetland soils--effects of hydrologic regime and watershed land use.

We compared phosphorous (P) sorption capacities in temporarily and seasonally flooded non-tidal palustrine forested wetland and adjacent upland soils, in eight watersheds in Caroline County, VA, containing varying degrees of agricultural and forest cover. P sorption capacities were significantly greater in wetland vs. upland soils, but were not significantly different in temporarily vs. seasonally flooded wetland soils. P sorption capacities were also significantly greater in surface (0-20 cm) vs. subsurface (20-50 cm) wetland soils. Trends in P sorption capacity are discussed in terms of P pool sizes, concentrations of non-crystalline and crystalline Al and Fe, and soil texture and organic matter content. Because wetland soils show a greater capacity for phosphate removal than surrounding upland soils, these wetlands may play an important role in removing nonpoint source inputs of phosphate in agricultural watersheds.

FUENTES, MARCELINO. Utah State University, Logan, UT, 84322, USA. Infructescence structure and fruit removal by birds in Pistacia terebinthus.

Pistacia terebinthus produces crowded infructescences with up to hundreds of final-sized fruits. Fruits are red when unripe and turn bluish green when they ripen. Most final-sized fruits never ripen (their seeds do not contain viable embryos) but do not abscise. My purpose is to analyze the effect of these fruits on fruit removal by birds. Greenfinches (which destroy seeds of both unripe and ripe fruits) usually perch near the proximal end of the infructescences and feed on the fruits they can reach from there. The larger an infructescence the higher the proportion of fruits that are inaccessible and escape predation. In this way the production of surplus fruits may reduce seed predation by birds. On the other hand, the presence of unripe fruits has both a positive and a negative effect on the rate of ripe fruit

removal by avian seed dispersers (which strongly prefer ripe to unripe fruits), because of increased conspicuousness of the infructescences and reduced accessibility of ripe fruits.

FUHLENDORF, SAMUEL D., FRED E. SMEINS and EDWARD J. RYKIEL. Texas A&M University, College Station, TX. 77843-2126, USA. Influence of scale on vegetation dynamics of a semi-arid grassland community.

The hypothesis by Wiens (1989) and Levin (1992) that scale influences interpretations of community dynamics was tested on an ungrazed perennial grassland. Basal area of Hilaria belangeri was measured periodically from 1948 to 1992 in 36 permanent quadrats within two 16 ha ungrazed exclosures. Differences in scale were determined by examining the dynamics of basal areas within each exclosure (exclosure scale) and dynamics of individual quadrats (quadrat scale). Data supports the hypothesis that dynamics at the large (exclosure) scale is apparently driven by large scale variables, such as climate and release from grazing, and is characterized by low between and high within variation, high predictability, and movement toward an equilibrial state. The stochastic response of individual quadrats is most likely driven by biotic interactions as indicated by high variation between quadrats, and low predictability. At the scale of individual quadrats there is no indication of any stable states and chaotic behavior could occur.

FULTON, M.R. and HSIN-I WU. Texas A&M University, College Station, TX, 77843, USA. Life Before Self-Thinning; Implications of the Growth-Survivorship Equation.

We show a simple derivation of the growth-survivorship equation, which quantifies how growth rate constrains survival to a given size in size-structured populations. A single parameter quantifies the demographic risk associated with small size and indicates the sensitivity of survivorship to changes in growing conditions. The equation applies where individuals are too small or too widely scattered for interference to be a significant factor. We show how the equation may be applied to adult tree recruitment rates and sapling density, providing a parsimonious account of the burst of recruitment associated with gap formation in closed-canopy forests. This approach inverts the usual thinking in ecology about the relationship of density and growth rates. Density is usually assumed to control growth rate through interference between plants. However, when the growth-survivorship equation applies, growth rate controls density through changes in the rate of escape from vulnerable small size.

GAFNY, S., N. NIBBELINK, A. TREBITZ, A. MUNOZ DEL RIO, C. STORLIE, D. SLOEY & S. CARPENTER. University of Wisconsin & Department of Natural Resources, Madison, WI, USA. Is bluegill growth associated with excessive milfoil growth in south-central Wisconsin lakes?

Bluegill and largemouth bass growth rates may be adversely affected by extensive growth of Eurasian water milfoil. In Fish Lake, a lake infested with milfoil, bluegills stay in the vegetated area to avoid predation and remain small due to high densities and limited food resources while bass grow slowly because they lack access to prey. We tested the hypothesis of a connection between macrophyte community structure and poor bluegill growth. We surveyed 36 lakes in south-central Wisconsin for fish and macrophytes and compared bluegill growth and macrophyte community structure in the different lakes. We then related these variables with those of Fish Lake. In all the lakes dominated by milfoil bluegill growth was low and not significantly different from Fish Lake. However, in two other lakes with high milfoil density, bluegill growth was significantly higher. Our data support a possible connection between stunted bluegill populations and excessive milfoil but other factors such as the physical structure of the macrophyte beds must also be considered.

GAITHER, JAMES C. JR. University of California, Davis, CA 95616 USA. Between-patch variation in the abundance and survivorship of fruit infesting insects on wild blueberry (Vaccinium spp.) in Alaska.

In Southeast Alaska Vaccinium spp. occur throughout a mosaic of forest patch conditions ranging from treefall gaps to closed forest. Consequently, fruit infesting herbivores (Lotisma trigonana (Lepidoptera: Copromorphidae) and Melastola resinicolor (Hymenoptera: Tenthredinidae)) confront dramatic between-patch variation in biotic and abiotic conditions. I tested the hypothesis that the between-patch abundance and survivorship of the insects is positively correlated with the abundance of their primary food, blueberry fruit. The data indicate that the insects are most abundant in patches of intermediate fruit abundance, and that some, but not all, measures of survivorship are positively correlated with high insect abundance in the intermediate patch.

GALLO, KIRSTEN L. and RAY W. DRENNER. Texas Christian University, Fort Worth, TX, 76129, USA. Ecological interactions between carp, macrophytes and water column: An experimental pond study.

We investigated the main and interaction effects of common carp (Cyprinis carpio) and fertilizer on macrophytes in a 23-pond experiment of factorial design in which the presence

and absence of carp were cross-classified with the presence and absence of fertilizer (10:34:0 N:P:K). Carp were stocked in December 1991 and the macrophytes were sampled in July and August 1993. The presence of carp reduced the biomass of bushy pondweed (Najas guadalupensis) and the number of macrophyte species per pond. No significant fertilizer effects or carp X fertilizer interaction effects were detected on the macrophytes. Turbidity in carp ponds decreased as a function of the biomass of Eurasian watermilfoil (Myriophyllum spicatum L.) suggesting that milfoil may regulate the effects of carp on the water column.

GAMON, JOHN A. California State University, Los Angeles, 90032, USA. Spatial and temporal patterns of photosynthetic activity determined by reflectance at 531 nm.

Reflectance at 531 nm (R_{531}) is an indicator of the relative concentrations of the xanthophyll cycle pigments. Because these pigments are involved in photosynthetic light regulation, R_{531} provides a useful tool for studying photosynthetic regulatory processes. Kinetic studies involving simultaneous measurement of gas exchange, chlorophyll fluorescence and spectral reflectance of individual leaves indicate a good correlation between R_{531} and non-radiative energy dissipation calculated from fluorescence parameters. These results indicate a close functional connection between R_{531} and dissipation of excess light energy, supporting the use of R_{531} as a measure of photosynthetic light-use efficiency. This rapid optical indicator of photosynthetic function can be used to track the spatial and temporal distribution of photosynthetic activity in intact canopies.

GARONO, RALPH J., RICHARD L. KIESLING and GEORGE M. STAFF. Texas Natural Resource Conservation Commission, Austin, TX 78711. Landscape analysis of Texas aquatic invertebrate communities: a prerequisite for biodiversity conservation.

Texas stream and wetland invertebrate collection records were compiled to compare regional and landscape patterns in aquatic invertebrate diversity (H) and species richness (s). Areas of high diversity and species richness were compared with the locations of public and private nature preserves. In Texas combined areal extent of these preserves is less than 3% of the total land area. Preserves were larger and occurred more frequently in the eastern third of the state, but stream invertebrate communities tended to be more diverse and had a greater species richness in western Texas ($1.9 \leq H \leq 5.0$ & $23.7 \leq s \leq 58.8$) and central Texas ($2.4 \leq H \leq 5.1$ & $42.2 \leq s \leq 48.9$) compared to eastern Texas ($1.9 \leq H \leq 4.7$ & $31.0 \leq s \leq 45.2$). In contrast, results from the preliminary analysis of wetland insect communities showed eastern and western sites to be equally diverse. Although coastal wetlands occupy less than 1% of the land area of Texas (compared to almost 4% by inland wetlands) preservation efforts seem to be centered on coastal wetlands which are most threatened by urban development. Studies of biodiversity at regional and landscape scales contribute to sound management plans and regulatory practices. Areas of high biodiversity can be targeted for future preservation efforts and used to establish regional water quality reference sites.

GARRETT, K. A., and P. M. DIXON. Savannah River Ecology Laboratory, University of Georgia, Aiken, SC, 29801, USA. Evaluation of statistical techniques for measuring temporal change in community composition.

We evaluate multivariate techniques to detect temporal change in species composition in real and simulated communities. We describe existing techniques, including detrended correspondence analysis (DECORANA) and canonical correspondence analysis (CANOCO), and develop a new technique that avoids some of the problems associated with second axes in indirect ordination. The approaches are compared based on the types and magnitudes of change they could detect using data from montane meadows and bottomland hardwood forests. In addition, composition changes such as might be produced through climate change were simulated using simple competition models to determine when such changes could be distinguished from typical successional changes.

GARRISON, MARY K. and JULIE S. DENSLOW. Tulane University, New Orleans, LA, 70118, USA. Model of the invasion of Sapium sebiferum into a Louisiana bottomland hardwood forest.

We developed a population stage projection model to predict the invasion rate of the exotic Sapium sebiferum into secondary and gap-structured, old growth Louisiana bottomland hardwood forest. Seed production was estimated from reproductive forest grown trees. Germination of planted seeds was monitored for one year and viability tested on recovered, ungerminated seeds. Transplanted seedlings were monitored for one year to determine seedling growth and survival in different forest environments. Plants sampled in belt transects were used to estimate stage class densities. Growth and survivorship were estimated from growth ring analyses of these plants. Results showed that individuals were capable of germination and survival in both gaps and understory, but those not occurring in gaps appeared senescent after five years of age. The model predicts greater invasion rates in old growth forest based on a larger proportion of area occurring in gaps.

GASTON, KEVIN J. The Natural History Museum, London SW7 5BD, UK. What is rarity?

Concepts of rarity pervade the ecological literature. Many cannot be reconciled, based as they are on a variety of different variables and combinations of variables, and treating rarity both as continuous and discontinuous. Some prejudge causes, and others can seldom in practice be applied. Abundance and range size can be viewed as the best consensus parameters of rarity, although both can be measured in a sufficient diversity of ways as to render many comparisons difficult. Accepting a definition of rarity based on these two variables focusses attention on the extent to which they should be viewed as inter-dependent, and the nature of any interaction. Inter-specific abundance-range size relationships have often been documented, and a variety of mechanisms have been proferred for their causes and dynamics.

GAWLIK, DALE E., R. DOUGLAS SLACK, JAMES A. THOMAS, and DOUGLAS N. HARPOLE. Texas A&M University, College Station, TX, 77843, USA. Temporal trends of a bird community: a matter of scale.

Because biological patterns are at least partly dependent on the scale (i.e., grain and extent) of the investigation, new patterns may emerge as either grain or extent are changed. We compared long-term trends of a colonial waterbird community across 3 scales (e.g., community, assemblage, species) by holding extent constant and varying grain size. At the community scale, none of the indices we examined showed a significant change over the 18-year period. However, analyses at the assemblage scale indicated considerable within-community change. One assemblage decreased in abundance, 1 assemblage increased, and 1 assemblage remained constant. Analyses at the species scale indicated that 2 species decreased in abundance, 3 increased, and 13 showed no significant change. Our results suggest that the assemblage scale is fine-grained enough to detect long-term trends but coarse enough to allow for generalizations across the entire bird community. This trend is consistent with the notion that as grain size is increased, a larger proportion of the total variation is contained in a single grain thus resulting in less between-grain variation.

GEARHART, N.L., P.J. SMALLIDGE, J.D. CASTELLO, and D.J. LEOPOLD. SUNY-College of Environmental Science and Forestry, Syracuse, NY, 13210. Landscape factors influencing disease of white ash in central New York.

The incidence of ash yellows disease in white ash (Fraxinus americana L.) is a function of host/vector interactions and may be influenced by where the host occurs in the landscape. This study was designed to investigate the incidence of ash yellows mycoplasmalike organisms (MLOs) and manifestation of disease symptoms in relation to specific stand and landscape variables in central New York white ash-dominated stands. Disease symptoms, stand features (e.g. stem density, stand age, size-class structure) and landscape features (e.g. slope, stem distance to edge of stand) were recorded. Spatial data were manipulated with a raster GIS. Phloem samples were extracted from white ash in 20 randomly selected stands and screened for the pathogen using the DAPI fluorescence test. Preliminary evidence suggests stand and landscape level parameters, particularly stand density, white ash importance value, and proximity to low-structure cover type, influence infection and symptom expression by the disease in central New York.

GERHARDT, TROY D., JAMES K. DETLING, and N. THOMPSON HOBBS. Colorado State University and Colorado Division of Wildlife, Fort Collins, CO, 80523, USA. Interactive effects of mowing, fire and primary production on patch selection by large herbivores.

We estimated forage removal to assess patch selection by herbivores in a mosaic of mowed and unmowed patches in Wind Cave National Park, SD. These paired patches were used to present herbivores with a tradeoff between forage quantity and quality (foliage in mowed patches is of higher quality). Patches were established along catenas exhibiting gradients in aboveground net primary production (ANPP) and across the burn line of a spring wildfire. Along catenas, grazing was significantly heavier in mowed patches and in areas of high ANPP. The interaction between ANPP and mowing was not significant. In burned landscapes, fire history and mowing interacted to influence patch selection. In unburned areas, grazing was significantly heavier in mowed patches, but in burned areas, grazing did not differ between patch types.

GIBSON, DAVID J., JOSEPH S. ELY, and PAUL B. LOONEY. Southern Illinois University, Carbondale, IL, 62901, USA and The University of West Florida, Pensacola, FL, 32514, USA. Primary succession on dredge spoil deposited on a northwest Florida coastal barrier island.

Plant species were monitored in permanent plots (60 m^2) colonizing dredge spoil deposited in August 1990 on the seaward edge of Perdido Key, a barrier island off NW Florida. The first colonizing species, *Cakile constricta*, was dominant during the first year of succession. By Fall 1993, 21 species had colonized the dredge spoil with *Uniola paniculata* as the dominant species in years 2 and 3. Although the total number of species on the dredge spoil continued to increase, the number per permanent plot fluctuated between 1 and 3. Jaccard's Index values indicate a high compositional similarity (mean JI = 69%) between the communities on the dredge spoil and those on unimpacted areas of the barrier island. However, Coefficent of Community values are low (mean CC = 41%) indicating that these early successional communities are still very different from more mature communities typical of coastal dune barrier islands.

GILINSKY, NORMAN L. Department of Geological Sciences, Virginia Polytechnic Institute and State University, Blacksburg, VA, 24061-0420, USA. The 600 Myr. decline of global background origination and extinction intensities: possible ecological correlates and causes.

The 600 Myr. decline of global background extinction intensity, discovered by Raup and Sepkoski, is just one aspect of a long-term decline of both origination and extinction intensities. Both declines were caused by the systematic loss of specific fossil orders: those whose constituent families had high, correlated, probabilities of origination and extinction. High probabilities led to ordinal extinction because the familial diversity paths of high-probability orders were inherently unstable; thus they frequently crashed to zero diversity, from which there was no return. This model for the 600 Myr. decline of global origination and extinction intensities is a kind of statistical, or probabalistic, explanation that treats whole taxonomic groups (orders) as entities and the extinction of such groups as "causes" (of even larger-scale global declines). But this style of explanation is incomplete because it falls short of explaining the causes of the probabilities of origination and extinction themselves. Ecological theory predicts that ecological specialization, behavioral complexity, propensity for population fragmentation, and other factors, are causally linked to high probabilities of speciation and extinction. Conversely, ecological generality, stereotypical behavior, and population contiguity are causally linked to low probabilities of speciation and extinction. It remains to be seen whether the decline of background origination and extinction intensities can in fact be explained in terms of these known ecological causes, but it is clear that ecological principles based on observations over short intervals of time can be a fruitful starting point in efforts to solve the paleobiologist's long-term problems.

GILLHAM, MARLA L., DAVID A. PERRY, NANCY E. GRULKE, and WILLIAM E. WINNER. Oregon State University, Corvallis OR, 97330. Growth and allocation of Douglas-fir seedlings in response to CO_2, temperature, and nitrogen.

Douglas-fir seedlings were grown, from cold-stratified seed, for 32 weeks in controlled-environment chambers. This factorial experiment had two levels each of atmospheric CO_2 (350 and 700 ppm), soil temperature (13 and 17°C), and soil nitrogen (soils from 1200-m-elevation in the western Cascade Mountains of Oregon contained roughly two times as much carbon and nitrogen than soils from 900-m-elevation). Each whole plot (chamber) treatment (CO_2 x temperature) was replicated three times. Photosynthetic photon flux density and soil temperature (at 15-cm-depth) were determined for each seedling/pot, and were analyzed as covariates. Doubled atmospheric CO_2 resulted in greater biomass of seedlings grown in higher N-content soils, and +4°C soil temperature increased biomass of seedlings grown in both soils, at both levels of CO_2. Root-to-shoot ratios were greatest for seedlings grown in lower N-content soils for all treatments except +CO_2 x +T, where they were equal. Doubled CO_2 increased C-allocation belowground for trees grown in both soil types and at both temperatures. Corresponding data include seedling height and basal caliper, mass of structural compartments, and C, N, and total nonstructural carbohydrate contents of biomass compartments.

GILLIAM, FRANK S. and MARY BETH ADAMS. Marshall University, Huntington, WV, 25755, USA and USDA Forest Service, Parsons, WV, 26287, USA. Soil nitrogen dynamics and nitrogen saturation in a central Appalachian hardwood forest.

Among the current environmental concerns for eastern U.S. forests is the threat of nitrogen (N) saturation, which results from excessive inputs of N associated with acidic deposition. We tested for evidence of N saturation on a watershed of the Fernow Experimental Forest, WV, receiving chronic N additions. Mineral soil was placed in bags and buried every ~30 d for a 1-yr period in each of 7 sample plots for each of the following watersheds: WS7 (23 yr-old even-age "control"); WS4 (mature mixed-age "control"); WS3 (23 yr-old even-age "treatment"). WS3 has received aerial applications of $(NH_4)_2SO_4$ since 1989 at three times ambient inputs of N and S, 54 and 61 kg/ha/yr, respectively. Moist samples of soil from the bags were analyzed for extractable NH_4^+ and NO_3^-. In addition, forest floor material and leaves of an indicator species (*Viola blanda*, which was present on all 21 plots) were taken on each plot, and analyzed for N and other nutrients. Results from the 1993 growing season showed few, if any, differences among watersheds for: 1) N content and C/N ratio of the mineral soil and forest floor; 2) foliar N concentration of *Viola blanda*; and 3) relative proportion of NH_4^+ and NO_3^- produced in the bags. Nitrification was quite high on all watersheds. We conclude that 4 yr of N additions have not created conditions of N saturation on WS3.

GLEASON, MARY G. University of California, Berkeley, CA, 94720, USA. The influence of patch type on post-disturbance recovery of corals in reef environments in French Polynesia.

Studies of coral recolonization have focused on changes in percent cover of corals following major disturbance events with little attention to how the patchy nature of the reef landscape affects recovery. This study identifies three common patch types based on their dominant algal component: areas dominated by crustose algae, filamentous algal turfs in damselfish territories, and areas dominated by a common fleshy algae (Turbinaria ornata). Experimental studies show significant differences in coral recruitment rates among patch types, with highest recruitment inside damselfish territories. Experimental transplants of juvenile Pocillopora corals shows strong effects of patch type on growth and survivorship rates. Growth rates are five times higher inside damselfish territories than in grazed areas. Survivorship rates also varied with patch type, ranging from 96% in damselfish territories to 45% in grazed patches after 5 months. Spatial patterns of coral recolonization across the reef landscape are influenced by rates of removal of young corals by grazers and overgrowth of corals by algae in these patch types.

GLEESON, SCOTT K. and RALPH E. GOOD. University of Kentucky, Lexington, KY, 40506, USA and Division of Pinelands Research, Institute of Marine and Coastal Studies, Rutgers University, New Brunswick, NJ, 08903, USA. Root foraging and limiting factors in the New Jersey Pinelands.

We tested the idea that root proliferation at resource rich sites could be used to assay limiting factors, and applied it in two experiments. The validity of the assay was supported in a regenerating short-leaf pine stand when plant growth response to

fertilizer and root proliferation response to resource supplemented in-growth cores both showed significant response only to nitrogen. Results of two limiting factor experiments, one a comparison of root response in the same site (oak-pine upland) in a wet and dry year, the other a comparison of root response along a water table gradient, both failed to support a multiple factor hypothesis and instead were consistent with a switch from nitrogen to water limitation with decreasing water availability in these sandy, nutrient poor soils. Root responses were rapid (5 weeks), suggesting that this method might allow tracking of both short-term and small-scale changes in limiting factors.

GOGUEN, CHRISTOPHER B. and NANCY E. MATHEWS. Texas Tech University, Lubbock, TX, 79409, USA and Texas Cooperative Fish and Wildlife Research Unit-National Biological Survey, Texas Tech University, Lubbock, TX, 79409, USA.
Cowbird parasitism of Neotropical migrant songbirds in grazed and ungrazed pinyon-juniper woodlands.

Increased abundance and range expansion of the brood-parasitic Brown-headed Cowbird (Molothrus ater) has been implicated as a potential contributor in perceived trends of Neotropical migrant songbird (NTM) decline. Livestock grazing is a widespread land-use, that may have the potential to influence cowbird abundances and distributions. We studied cowbird abundance and parasitism rates in grazed and ungrazed pinyon-juniper woodlands in northeastern New Mexico, 1992-93. Cowbird abundance and parasitism rates of all hosts were similar on grazed and ungrazed sites, however, proximity of ungrazed sites to grazed, and mobility of cowbirds may have influenced our results. Six species were parasitized, 5 of which were NTMs. Host species were either heavily parasitized (3 species; >65% of nests) or rarely parasitized (3 species; <10%). High parasitism rates, and frequent cases of multiple cowbird eggs in nests, suggest cowbird densities have reached saturation levels for principal hosts. We predict rarely parasitized hosts will continue to receive low parasitism pressure if cowbird and principal host densities both remain at current levels. Increased cowbird or reduced principal host densities may result in increases in parasitism pressure on these rarely parasitized hosts. Observed levels of nest mortality due to parasitism suggest this area may be acting as a "sink" for some of the principal host populations.

GOMEZ, PROSERPINA L. State University of New York at Stony Brook, Stony Brook, NY 11794. USA. Plant responses to N fertilization and herbicide application in intercropped systems.

Previous intercropping studies showed yield advantages over monocultures using the Land Equivalent Ratio (LER) as index. Individual plant perfromance has yet to be investigated. In the present study, a factorial experiment using soybean (Glycine max) and corn (Zea mays) as test plants was conducted to look at the responses of the individual crop plants to culture (monocultures, replacement intercropping, additive intercropping), fertilization and herbicide application. Biomass and seed production of the individual corn plants were higher in replacement intercrop. Soybeans performed best in the unfertilized replacement system. However, LER's were significantly highest in the additive intercrop where the individuals' fitness was reduced. Architectural responses were also correlated with the plants' competitive performance. Culture pattern and herbicide application significantly affected most of the architectural components of crop species but these features were not correlated with grain production.

GONZALEZ-FLORES, PEDRO C., J. B. KAUFFMAN, and V. J. JARAMILLO. Oregon State University, Corvallis, OR, 97331-2218,USA and Centro de Ecologia, UNAM, Mexico City, MEXICO. Aboveground Biomass losses associated with slash-and-burn conversion of Tropical Deciduous Forest to pasture at San Mateo, Jalisco, Mexico.

To estimate the aboveground biomass losses of a tropical deciduous forest, converted to pasture through slash-and-burn agriculture in the Pacific coast of Mexico, the load of plant material cut and felled by the local management practice was calculated applying a non-destructive planar intercept technique, before and after plot burns. The slashed vegetation was divided in fuel categories and the percentage of biomass consumption obtained. The average biomass before the burn in nine plots ranged from 43 to 77 Mg/ha. The category of fine woody fuels (less than 7.5 cm in diameter) accounted for 41 to 60% of the load, while the heavy fuels (above 7.5 cm in diameter) amounted for 39 to 64% of the total prefire biomass. The fine fuels were consumed almost completely by the fires, after which 8 to 42% of the heavy fuels remained. The average total biomass consumption varied from 71 to 95%. This slash-and-burn agricultural conversion has important implications for deforestation and carbon losses for this scarcely studied ecosystem.

GONZÁLEZ-MELER, MIQUEL A.[1], MIQUEL RIBAS-CARBÓ [2], XAVIER ARANDA[3], JOAQUIM AZCÓN-BIETO[3], BERT G. DRAKE[1], JAMES JACOB[1], ARTUR PALET[3] AND JAMES N. SIEDOW[2]. [1]Smithsonian Environmental Research Center Edgewater MD-21037, USA. [2]Botany Department, Duke University, Durham, NC 27708, USA. [3]Dept. Biologia Vegetal, Universitat Barcelona, 08028 Barcelona, Spain. Increasing CO_2 concentration inhibits cytochrome c oxidase (cytox) in vitro, cytochrome pathway (cytpath) activity in plant mitochondria and dark respiration in plant tissues.

Dark respiration is inhibited in many plants by exposure to elevated atmospheric CO_2 concentration. The addition of 0.2mM free CO_2 in the reaction medium decreased citpath activity in Pisum sativum and Glycine max mitochondria at pH 7.2, possibly by inhibiting cytox. Under similar conditions, activity of purified cytox from beef heart was also inhibited. Cytox activity extracted from plants grown in elevated CO_2 for 7 years was lower than in those grown in normal ambient. The relationship among these effects and the rate of respiration as well as the role of the alternative pathway in each case will be discussed.

GOODLAND, ROBERT. The World Bank, 1818 H St., N.W., Washington, DC 20433. The Concept of Environmental Sustainability.

The three separate concepts of sustainability -- social, economic, and environmental -- are related closely in parts. This paper focuses on environmental sustainability, rather than on sustainable development. Environmental sustainability is defined by: 1) Output Rule: Waste emissions from a project should be within the assimiliative capacity of the local environment to absorb without unacceptable degradation of its future waste absorptive capacity or other important services. 2) Input Rule: (a) Renewables: harvest rates of renewable resource inputs would be within regenerative capacity of the natural system that generates them; (b) Non-renewables: depletion rates of non-renewable resource inputs should be equal to the rate at which renewable substitutes are developed by human invention and investment. Part of the proceeds from liquidating non-renewables should be allocated to research in pursuit of sustainable substitutes.

GORCHOV, D. L., F. CORNEJO, C. ASCORRA, and M. JARAMILLO. Miami University, Oxford, OH, 45056 USA, Casilla 11, Lima 8, PERU, Museo de Historia Natural, Casilla 140434, Lima 14, PERU, and Universidad Nacional de la Amazonía Peruana, Iquitos, PERU. Dietary overlap among frugivorous birds and bats at Jenaro Herrera, Peruvian Amazon.

We quantified fruit use by birds and bats during a study of tropical forest regeneration after logging. Seeds were obtained from 846 bats (29 spp) and 198 birds (33 spp) mist-netted in primary and secondary habitats over 2.5 yr. We calculated overlap in fruit diet by Pielou's Proportional Similarity (PS) for each pair of frugivore species (11 bats and 7 birds). PS was 0 for 70% of the bird-bat pairs, and < 0.1 for the others. Tachyphonus surinamus had greater overlap with bats than did other birds. While most bat species fed primarily on Cecropia, Piper, or Vismia spp., 6 of the bird species fed primarily on Melastomes. Six fruits were eaten by both bats and birds: Phytolacca rivinoides, Marcgravia sp., Souroubea guianensis, Philodendron cuneatum, Coussapoa villosa, and Havetiopsis flavida. As a group, these shared fruits comprised a minor fraction (<4%) of most bat diets, but a larger fraction (>10%) of most bird diets. Most of the shared fruits fit the bird-dispersal syndrome, suggesting bats may be sampling "bird fruits."

GORDON, DORIA R. The Nature Conservancy, Florida Museum of Natural History, University of Florida, Gainesville, FL, 32611, USA. Influence of non-indigenous plant species on disturbance, resources, and community composition.

While the role of natural and anthropogenic disturbance in facilitating invasion by non-indigenous plant species is well documented, less work has examined the modification of ecosystem properties by invaders that either significantly change resource availability or disturbance regimes or both. These species are likely to threaten achievement of conservation goals because the induced changes alter interactions among species, potentially reducing both species richness and connectance, and creating novel selection pressures. These effects increase the competitive advantage of the non-indigenous species, which is likely to be adapted to the new conditions and may dominate large areas. Native species diversity on the site will often be reduced to facultative ruderals, species with high colonizing ability rather than competitive ability or herbivore resistance, and to species that are tolerant of the new site conditions. Identification of those introduced non-indigenous species that might change resource and disturbance processes would allow the conservation community to focus screening, research, control and regulatory efforts.

GOSZ, JAMES R. and DOUGLAS I. MOORE. University of New Mexico, Albuquerque, NM, 87131, USA. Lightning estimates of precipitation location and quantity during convective storms on the Sevilleta LTER, New Mexico.

Over 70 percent of the total annual precipitation in New Mexico can be produced by convective thunderstorms during the *monsoon* season of June through September. These thunderstorms are accompanied by intense lightning and heavy, localized rainfall. Technology exists for locating cloud-to-ground lightning strikes allowing algorithms between lightning and precipitation depth to determine rainfall distribution for areas in New Mexico. Average precipitation volume per cloud-to-ground lightning strike averaged 36,190 m^3 within a 3 km radius of gauge locations resulting in an average rainfall depth of 1.3 mm per strike. Lightning location, combined with a Geographic Information System (GIS), defined the spatial and temporal resolution of these summer patterns and provided a more detailed estimate of total precipitation and precipitation distribution than was provided by the network of precipitation gauges. This information and satellite sensing of vegetation growth (e.g., greeness index) identified causal mechanisms for temporal and spatial patterns in vegetation dynamics on the Sevilleta Long Term Ecological Research (LTER) site.

GRACE, JAMES B. National Wetlands Research Center, Lafayette, LA, 70506, USA. Structural equation modelling as a tool for converting qualitative ecological principles into quantitative conservation approaches.

A major limitation in the application of general ecological concepts to conservation issues is the need to shift emphasis from qualitative models designed to help us conceptualize system function to quantitative models designed to predict system behavior. Current discussions about the value of predictive approaches to ecology have been polarized on the issue of the

relative importance of 'prediction' versus 'understanding' as primary goals. Structural equation modelling, which combines path analysis structure with factor analysis, is a technique that is well suited to combining conceptual and predictive approaches. In attempting to develop predictive models of plant species richness I have found structural equation modelling to be helpful both conceptually and statistically in applying ecological principles to specific situations.

GRACE, SUSAN L. and WILLIAM J. PLATT. Louisiana State University, Baton Rouge, LA 70803. Neighborhood effects on juveniles in an old-growth longleaf pine stand (Pinus palustris Mill.).

Recent models of interference have proposed that individual plant performance is a response to the proximity and size of local neighbors rather than a response to overall plant density. In this study, the effect of size and distance of longleaf adults on the survival of juveniles was investigated. Juvenile plots were established within an old-growth longleaf pine savanna in which locations and sizes of adult trees were known. Effects of neighbors, measured as the sum of sizes of trees in defined distance and size classes, was related to survival and size of juveniles. The results of this study demonstrate that there is a strong influence of neighbors on early life stages of longleaf. As a consequence, patches of juveniles are initiated as early as the first year of growth in areas where neighbor impacts are minimized (i.e. fewer large trees are present.

GRAHAM, DEVON L. University of Miami, Coral Gables, FL, 33124, USA. Contrasting recruitment strategies in two neotropical understory shrubs, Psychotria suerrensis and P. officinalis

Populations of two rubiaceous shrubs, Psychotria suerrensis and P. officinalis were followed over a three-year period in primary forest on the Atlantic slope of Costa Rica. Both species have high population densities and experience high rates of damage due to falling debris and tree-falls. Psychotria suerrensis is primarily dependent on vegetative reproduction for maintenance of its high population densities. Broken branches root readily, and the species exhibits a highly clumped dispersal pattern. High rates of inflorescence abortion, low seed set and high seedling mortality combine to make vegetative reproduction an important strategy for this species. Psychotria officinalis also experiences high seedling mortality, but has a much higher rate of fruit set. Vegetative reproduction is uncommon and a high degree of spatial clumping is not observed. Both species exhibit extended seed dormancy with germination greatest under light levels characteristic of medium sized gaps. Extensive seed predation by phytophagous wasps increases the value of vegetative reproduction for both species.

GRAUMLICH, LISA J. and RICHARD L. HOLMES. University of Arizona, Tucson, AZ 85721 USA. Response of tree growth to climatic variation and stand dynamics: implications for modeling stand dynamics under varying climatic conditions.

We used tree-ring data to assess the relative importance of regional climate vs stand-level processes in controlling tree growth for seven forest dominants of the mixed conifer forest of the Sierra Nevada. For each species, increment cores were collected from at least 20 canopy dominants at several sites arrayed along elevational gradients extending from lower to upper elevational limits. Species sampled include ponderosa pine (*Pinus ponderosa*), Jeffrey pine (*P. jeffreyi*), sugar pine (*P. lambertina*). white fir (*Abies concolor*), red fir (*A. magnifica*), incense cedar (*Calocedrus decurrens*), and black oak (*Quercus keloggii*). Stand-level processes generate low to medium frequency variation in growth that is not held in common among trees within a site or between sites. Stand-level processes are most important for white and red fir and least important for ponderosa pine. Regional climatic variation generates medium to high frequency variation that is coherent among trees of the same species (and often same genera). Results such as these have utility for parameterizing and validating stand simulation models, especially for use in climatic change scenarios.

GRAVEL, MARC E. and JULIANO, STEVEN A. Illinois State University, Normal, IL, 61790-4120, USA. Effects of laboratory selection due to predation by Toxorhynchites rutilus on size at and time to metamorphosis of the tree hole mosquito Aedes triseriatus.

We tested the hypothesis that size at and metamorphosis of Aedes triseriatus would be reduced, and time to metamorphosis altered by laboratory selection by the predatory mosquito Toxorhynchites rutilus. Larvae of A. triseriatus from two populations and their hybrids were subjected to predation over two laboratory generations. Control lines were reared over two laboratory generations under the same conditions with densities of control lines reduced to match those of the lines subjected to predation. Randomly chosen individuals from replicate lines were reared in isolation before and after each generation of selection to determine mass at and time to metamorphosis for both males and females. Preliminary analyses show that lines subjected to selection by predation did not have significantly lower mass at metamorphosis than control lines. Time to metamorphosis did not differ significantly between predation and control lines. The lack of responses to selection by predation was independent of population and sex. These results suggest that predation by this predator does not rapidly select for smaller size at metamorphosis. The effects of predation on phenotypic plasiticy and on behavior of larvae will be discussed.

GRAVES, JAMES H., ROBERT K. PEET, and PETER S. WHITE. University of North Carolina, Chapel Hill, NC, 27599, USA. Resource availability and the outcome of competition between woody and herbaceous plants of the forest floor.

Herbs may be important regulators of forest composition through competition with tree seedlings. Woody plants, which have large investments of carbon in stems, can be expected to lose in competition with herbs where soil resource supply is high and low light limits carbon supply. Processes that increase light or reduce soil resource supply should increase survival rates of tree seedlings. To test this hypothesis, tree seedling and seed establishment were observed in experimental resource and light treatments in mesic cove forest in North Carolina. As predicted, herb reduction, canopy reduction, and to a limited extent resource reduction all increased seedling survivorship. However, survivorship of the large-seeded Quercus rubra was little affected by herbs. Herbs in single-tree canopy gaps can prevent the establishment of Liriodendron, a less shade tolerant species. A second cohort of trees observed in a much drier year showed that herb regulation of establishment is sensitive to current-year moisture regime.

GRAY, ANDREW N., and THOMAS A. SPIES. Oregon State University, Corvallis, OR 97331 and Pacific Northwest Research Station, USDA Forest Service, Corvallis, OR 97331. Tree seedling establishment in forest canopy gaps: microsite modification of gap size effects.

Do tree species establish differentially in the heterogeneous micro-environments caused by canopy gaps? We studied conifer seedling establishment in experimental gaps in old-growth and mature Douglas-fir forests in the Cascade Range of the Pacific Northwest, USA. Seeds of shade-intolerant Douglas-fir (*Pseudotsuga menziesii*) and shade-tolerant western hemlock (*Tsuga heterophylla*) and Pacific silver fir (*Abies amabilis*) were sown in a variety of plot types in gaps of 0, 10, 20, and 50 m diameter. Seedling establishment from natural seed rain was compared with the controlled studies. Relative to *Abies* and *Tsuga*, survival of *Pseudotsuga* was higher in exposed areas of large gaps and lower in small gaps. Survival for all species was highest on log substrates at all microsites, but growth was greatest on forest floor plots. Shade from understory vegetation aided establishment on exposed sites but restricted it in shady areas within gaps. Soil moisture, light intensity, and maximum surface temperatures appear to account for survival patterns. Results suggest that canopy and forest floor heterogeneity control successional patterns in these forests.

GRECO, SUSANNA and DENNIS D. BALDOCCHI. Atmospheric Turbulence and Diffusion Division, National Oceanic and Atmospheric Administration, Oak Ridge, TN, USA, 37831. Long-term and direct measurements of CO_2 and water vapor exchange over a deciduous forest canopy.

Long-term monitoring of CO_2 and water vapor exchange is needed to determine components of the carbon and hydrologic cycles and to provide data for parameterizing and testing assessment models. Responding to this need we initiated a continous field measurement campaign in April 1993 in a deciduous forest growing near Oak Ridge, TN. The micrometerological eddy correlation method was used to measure flux densities of CO_2 and water vapor over the canopy. Periodic measurements were made of stomatal resistence and pre-dawn water potential to characterize the photosyntetic capacity of the canopy. Three factors accounted for a disproportionate amount of seasonal variance in CO_2 flux densities: photon flux densities, leaf area and the occurrence of drought. Positive and increasing magnitudes of carbon gain were observed between April and June as leaves expanded, the canopy closed and daily insolation increased. At midsummer a drought and heat spell were experienced. This period caused CO_2 flux densities to decline. By late summer adequate precipitation and replenishment of soil water resurrected carbon uptake rates until autumnal leaf senescence and leaf fall.

GREENE, MICHAEL C., RANDELL S. MYERS and GARY P. SHAFFER. Southeastern Louisiana University, Hammond, LA 70402, USA. The interacting effects of allogenic and autogenic agents on baldcypress (Taxodium distichum) in the Lake Pontchartrain Basin, Manchac, Louisiana, USA.

In coastal Louisiana, the lack of regeneration of baldcypress/tupelogum swamp has generally been attributed to such factors as land subsidence, sea level rise, sediment deficits due to levee construction, canalization, increased salinities, waterlogging, and storms and hurricanes. Factorial experiments were undertaken to isolate particular cause(s) of this lack. Among the variables considered were herbivory by nutria (Myocastor coypus), nutrient limitation, competition (from entangling vegetation), substrate type, and relative elevation. It was found that success was entirely dependent upon protection from nutria herbivory; unprotected trees suffered 100% mortality. It was also determined that nutrient augmentation and release from competition greatly enhanced the trees' growth rates. In subsequent studies, it was confirmed that relief from flood stress played an important role in allowing trees to become established, as did a topsoil substrate as opposed to one of sand. This study indicates that biological factors were of primary importance in restricting the natural regeneration of baldcypress seedlings while physical factors played a moderating role.

GREENBERG, CATHRYN H.[1], STANLEY H. CROWNOVER[1] and DORIA R. GORDON[2]. [1]USDA For. Serv., P.O. Box 14524, Gainesville, FL 32604, USA and [2] The Nature Conservancy, Fla. Mus. Nat. Hist., University of Florida, Gainesville, FL 32611, USA. Roadside soil substrate: a foothold for community invasion by non-native plants?

We hypothesized that clay and limerock road substrates provide a roadside corridor and foothold for invasion by non-native plants into the nearly pure sands of Florida scrub. We compared plant communities and soils of sand-, clay-, and limerock-clay-based roadsides and

clearcuts. Mean (± SD) species richness did not differ among the four treatments (8.07 ± 2.89 to 11.40 ± 3.26). Like clearcuts, sand-based roadsides (native, disturbed soils) had little clay (0.79% ± 0.21) and pH of 4.85 ± 0.31, and supported few non-native scrub plants. Clay-based roadsides had more clay (5.04% ± 2.03) and pH of 5.38 ± 0.66, but supported numerous non-native or exotic plants. Plant communities of limerock-clay-based roadsides (pH 8.21 ± 0.41) were similar to those of clay-based roads, with some species differences. Greater water- and/or nutrient-holding capacity of clay, pH, or higher runoff from compact clay- or limerock-clay roads may result in observed differences. We suggest that selection pressure may permit some species to invade scrub soils once established along roadsides.

GRESHAM, CHARLES A., REBBECA R. SHARITZ, MICHAEL J. DUEVER AND WILLIAM R. HARMS. Clemson University, Georgetown, SC 29442, USA, Savannah River Ecology Laboratory, Aiken, SC, 29801 USA, The Nature Conservancy, Kissimmee, FL 34759, USA, Forest Service Wetlands Laboratory, Charleston, SC, 29414, USA. Wetland forest structure recovery from Hurricane Hugo.

A network of 50 plots, 20 m by 100 m or 100 m by 100 m were established on the Hobcaw Forest near Georgetown, SC, the Santee Experimental Forest north of Charleston, SC, the Beidler Forest near Holly Hill, SC and the Congaree Swamp National Monument to allow periodic monitoring of forest structure recovery from Hurricane Hugo. These plots are in cypress-tupelo, bottomland hardwood, pine-hardwood, mixed hardwood and longleaf pine communities. Woody stems> 2.5 cm dbh were inventoried and tagged; smaller woody stems were sampled in subplots. In plots with severe canopy loss, a new canopy is developing from basal and bole sprouts of hardwood species; in less damaged plots, the canopy is regrowing from residual stems. These plots and data are available for continued monitoring of disturbance recovery.

GRIFFIN, KEVIN L.[1], WILLIAM E. WINNER[2] and BOYD. R. STRAIN[1]. [1]Duke University, Durham, NC 27708, USA. [2]Oregon State University, Corvallis, OR, 97331, USA. Effects of CO_2 on apparent dark respiration in loblolly and ponderosa pine seedlings grown in sub-optimal, optimal or supra-optimal nitrogen.

Differences in the response of apparent dark respiration to elevated CO_2 and nitrogen were studied in loblolly (*Pinus taeda*) and ponderosa (*P. ponderosa*) pine seedlings. Seedlings of both species were grown for 160 days in two CO_2 partial pressures (35 or 70 Pa) and three levels of soil nitrogen (1, 3.5 or 7 mM NH_4) in sterilized sand culture. Ponderosa pine had higher apparent respiration rates (CO_2 efflux in the dark) than loblolly pine across all CO_2 and nitrogen treatments. Loblolly pine grown in elevated CO_2 had lower apparent respiration rates than seedlings grown in low CO_2. Apparent respiration for ponderosa pine was similar at both CO_2 partial pressures. Apparent respiration increased with nitrogen in both species. The direct effects of ambient CO_2 partial pressure on apparent dark respiration were measured during short-term manipulations (min. to hr.) of the CO_2 environment surrounding isolated leaves or whole seedlings. Short term increases in CO_2 partial pressures consistently resulted in significant decreases in CO_2 efflux across all growth treatments and measurement scales. Leaf level decreases in CO_2 efflux were as large as 90% when CO_2 partial pressures were increased from 0 to 100 Pa. Species level differences in apparent respiration, and its response to nitrogen availability, may influence the potential of these two species to grow and sequester carbon as atmospheric CO_2 increases.

GRIFFITH, CONVERSE and BRUCE L. HAINES. University of Georgia, Athens, GA, 30602, USA. Correlations between soil mineralization rates and leaf nutrient concentrations.

We tested the idea that foliar nutrient concentrations should be positively correlated with nutrient mineralization rates. During the summers of 1991 and 1992 at the Coweeta Hydrologic Laboratory, we incubated soil cores and collected canopy tree leaves from four plots at different elevations within a deciduous forest. We analyzed the soil cores for extractable N, P, Ca^{++}, Mg^{++}, and K^{+}. We collected canopy leaves from Acer rubrum, Carya glabra, Oxydendron arboreum, and Quercus prinus, and analyzed samples for N, P, Ca^{++}, Mg^{++}, and K^{+}. We then carried out a correlation analysis using Pearson's r and Kendall's tau. We found significant, positive correlations between soil and foliar K^{+}, Ca^{++}, and P during 1991 and for soil and foliar Ca^{++}, K^{+}, P, and N during 1992. These results support the idea that trees respond to increased nutrient availability by increasing their use of nutrients.

GRILL, CHRISTOPHER P. and PHILIP H. CROWLEY. University of Kentucky, Lexington, KY, 40506-0225, USA. An optimization model of gender-specific juvenile development in a semelparous animal population.

For many animals, a tradeoff between growth (or development rate) and survival is mediated by juvenile "activity level": both growth and mortality may increase with activity, particularly in the presence of predators. Moreover, this tradeoff may be resolved differently by the two sexes, generating differences in activity level, juvenile stage duration, survival to maturation, size at maturation, and/or fecundity. To predict how these traits respond to the relationships between activity and growth rate, activity and mortality rate, and female size and fecundity, we formulated a deterministic model in which both males and females are assumed to exhibit the activity levels and juvenile-stage durations that maximize fitness. Reproduction by females depends only on their size at maturation, whereas reproduction by males is strictly limited by the availability of females. Activity level and juvenile stage duration of females and maximal fitness are found with a numerical hill-climbing algorithm; then the optimal male activity level yielding the same maximal fitness is found numerically, and the other variables are directly calculated. Results to date indicate considerable sensitivity to all three of the above-noted relationships, especially female fecundity vs size: a higher peak or steeper slope on the fecundity curve leads to greater activity, faster development, and a more male-biased sex-ratio at maturation.

GRIMM, NANCY B., KEVIN C. PETRONE, and STUART G. FISHER. Arizona State University, Tempe, AZ, 85287-1501, USA. Nitrogen fixation and temporal succession of cyanobacteria in a nitrogen-limited Sonoran Desert stream.

Few measurements of nitrogen fixation exist for streams. Because cyanobacteria can be abundant in desert streams, N_2 fixation is probably significant in these N-limited ecosystems. Acetylene reduction by epilithic assemblages and *Anabaena* sp. mats was measured approximately monthly from summer 1992 through summer 1993. Cyanobacterial assemblages were incubated *in situ* in 4-L recirculating chambers containing acetylene, and biomass-specific ethylene production was measured during daylight hours and at night, allowing estimation of daily rates. A molar ratio of ethylene produced to N_2 fixed of 3 was used to generate estimates that could be compared with published values. Daily rates were applied to 1992 and 1993 data on cyanobacterial biomass to obtain areal N_2 fixation estimates. Because of its high biomass-specific N_2 fixation and extensive distribution, *Anabaena* was the most important fixer in Sycamore Creek. Cyanobacteria were absent or rare during winter and spring, thus most of the annual N_2 fixation occurred during summer and autumn. The annual rate of nitrogen fixation for the study year was very high compared with other streams, and moderately high compared with other ecosystems. Applying assemblage- and biomass-specific rates to known seasonal and successional patterns of cyanobacterial biomass in other years suggests that year-to-year variation in nitrogen fixation depends upon the number and temporal distribution of flood events.

GROFFMAN, PETER M. and GAY C. HANSON. Institute of Ecosystem Studies, Box AB, Millbrook, NY 12545, USA. Geomorphic controls on microbial processes in freshwater wetlands.

Many studies have examined the influence of site water and nutrient resources on the structure and function of upland ecosystems. We suggest that microbial processes in wetlands will vary with site resources since these resources influence plant productivity and litter quality and thus the flow of carbon (C) and nitrogen (N) to microbial populations. We measured pools of potentially and readily mineralizable C and N, microbial biomass C and N and denitrification in red maple wetlands developed on parent materials of different fertility associated with different geomorphic features in Rhode Island. Pools of labile C and N (microbial biomass, readily mineralizable) and denitrification were higher on the more fertile parent materials while pools of recalcitrant C and N were higher on the low fertility parent materials. These results support the idea that the influence of site resources on ecosystem properties resonates from the plant community to the microbial community. Focusing on variation in fertility among different geomorphic features is a useful approach to addressing landscape and regional-scale variation in microbial processes.

GROPP, ROBERT E. and LINDA L. WALLACE. University of Oklahoma, Norman, OK, 73019, USA. A Comparison of the physiology and productivity of *Panicum virgatum* (Poaceae) grown hydroponically and in soil: Implications for hydroponic studies.

Hydroponic studies are often employed to study the rate of nutrient or pollutant uptake by plants. This study was conducted to determine if there is any difference in the physiological parameters of plants grown hydroponically or in soil saturated with water. Ramets of the C_4 grass, *Panicum virgatum*, were grown in either hydroponic chambers or soil saturated with water. Photosynthetic rate, transpiration, stomatal conductance, tillering, plant height, shoot and root productivity were measured. No physiological differences ($P > 0.05$) were found between soil and hydroponically grown plants. While whole plant biomass and root biomass were not significantly different ($P > 0.05$), there was a treatment effect on shoot biomass ($P < 0.05$). It thus appears that, with respect to physiological parameters, hydroponic studies are an effective research tool for examining plant response to stress. Therefore, we used hydroponic plants to determine rates of nutrient uptake following clipping.

GROSHOLZ, EDWIN D. and GREGORY M. RUIZ. University of California, Davis, CA, 95616, USA and Smithsonian Environmental Research Center, Edgewater, MD, 21037, USA. The potential multi-trophic effects of the recently introduced European green crab, *Carcinus maenas*, in central California embayments.

Ecologists continue to debate whether changes in the abundance of organisms at one trophic level will have cascading effects at other trophic levels. We are investigating the impact of predation by the European green crab, *Carcinus maenas*, recently introduced to coastal embayments in central California, on the population dynamics at two different trophic levels: 1) benthic invertebrates directly consumed by *Carcinus* and 2) shorebirds that rely on benthic invertebrates as prey. Our approach combines descriptive field sampling, short-term laboratory and field experiments, and long-term data on the abundances of both invertebrates and shorebirds (10 yr prior to the invasion of green crabs) in Bodega Harbor, Bodega Bay, CA. In summer, small (15-40mm) *Carcinus* are abundant in the intertidal zone, where they can severely reduce densities of small bivalves (*Transennella* spp.) and crustaceans (*Corophium* sp., *Cumella vulgaris*, *Leptochelia dubia*) in the upper few cm of sandflat habitats. Our long-term data at Bodega Harbor documents declines in shorebird abundance coincident with a previous catastrophic decline in abundance of these same species of their benthic invertebrate prey. We predict that *Carcinus* can impact both invertebrate and shorebird abundances in coastal embayments of western North America.

GROSS, HOWARD P., WAYNE A. WURTSBAUGH, CHRIS LUECKE, and PHAEDRA E. BUDY. Utah State University, Logan, UT, 84321, USA. The implications of lake fertilization shading effects on a deep chlorophyll layer maintained by plunging inflows.

Lake fertilization is being considered to increase the productivity of lakes which will be stocked with endangered Snake River sockeye salmon (*Oncorhynchus nerka*) in the Sawtooth Valley of Idaho.

Large-scale mesocosm (340 m^3) experiments in 1993 showed primary productivity could be increased with N and P additions. Surface fertilization, however, decreased the amount of light reaching the deep chlorophyll layer (DCL), which peaked near the compensation point. The DCL is responsible for > 50% of water column productivity. Experimental DCL shading at levels which would be expected by lake fertilization caused a decrease in chlorophyll a. Plunging inflows deprived the epilimnion of most of the fluvial nutrient inputs during the growing season, delivering them to the DCL and contributing to its maintenance. Thus, surface addition of nutrients during fertilization could cause under-utilization of plunging inflow nutrients.

GROSS[1], JOHN E., COLLEEN ZANK[2], N.THOMPSON HOBBS[1], DONALD E. SPALINGER[3], LISA A. SHIPLEY[3], AND BRUCE A. WUNDER[1]. [1]Colorado State Univ., Ft. Collins, CO 80523, USA, [2]Johannesburg, South Africa, [3]Texas A&M Univ., Uvalde, TX, 98801, USA. Rules for moving between apparent resources: How good is good enough?

Many studies have examined the rules of thumb that animals use for maximizing returns while seeking obscure or cryptic prey. Virtually no attention has been directed towards the alternate situation -- the rules an animal should use to move between apparent but spatially dispersed resource items. We developed simulation models to evaluate a spectrum of potential movement strategies. These ranged from a completely random walk to strategies that minimized the distance for the next n moves (for n = 1 to 15). We also conducted foraging trials by presenting hand-assembled plant patches (approx. 4000 m^2) to bighorn sheep. We compared the observed distributions of move distances to our simulations. For larger species, a random walk is clearly not realistic, resulting in absurdly inefficient searches. On the other hand, a path resulting from simply moving between nearest-neighbors generates move distances surprisingly close to those from numerically intensive optimal solutions, and it closely matched our observations of bighorn sheep. We found that complex algorithms provide little benefit over simple rules under most distributions of plants.

GROSS, M.F., M.A. HARDISKY, P.L. WOLF and V. KLEMAS. Georgian Court College, Lakewood, NJ, 08701, USA, University of Scranton, Scranton, PA, 18510, USA, Lebanon Valley College, Annville, PA, 17003, USA, and University of Delaware, Newark, DE, 19716, USA. A survey of plant biomass, methane emissions, and pore water methane in four midAtlantic wetlands.

We measured pore water methane, methane flux, and biomass of six species of macrophytes in four wetlands. Pore water methane and methane flux were dependent on site and on water table position. Where the substrate contained little macroorganic matter, there were positive correlations between plant biomass, methane flux and pore water methane, which can be explained by plants supplying methanogenic substrates and a pathway for methane emissions. At a site rich in soil macroorganic matter and sampled during peak biomass, biomass and pore water methane were negatively correlated, apparently because plant transport or methane oxidation prevented soil methane accumulation. At two sites, methane consumption (up to 377 mg m^{-2} d^{-1}) corresponded to drops in the water table. Although vegetation can influence pore water methane and methane flux, variations in soil properties and water table can obscure the effects of plants.

GROSSMAN, DENNIS H. AND KATHLEEN LEMON GOODIN. The Nature Conservancy, Arlington, VA, 22209, USA. Terrestrial Community Types of the United States: Patterns of Rarity and Threats.

The Nature Conservancy, in collaboration with the Biodiversity Information Network (BIN), has compiled existing data on rare terrestrial community types across the conterminous United States. Each of these types have been cross-referenced to the Conservancy's National Community Classification System. The conservation status of these communities is being determined according to their relative rarity and threats. National and regional overviews will be presented on the following: 1) the proportion of all terrestrial community types that are rare or threatened; 2) community types that are naturally rare as opposed to those whose ranges have declined through anthropogenic activity; 3) the particular classes of anthropogenic disturbance that have had the greatest impact on communities; 4) the physiognomic patterns of community rarity (e.g., woodlands, grasslands, etc.); and 5) the geographic patterns of rarity associated with zones of high anthropogenic impact (e.g., midwest cornbelt, western riparian zones, Mississippi River bottomlands, eastern maritime regions, etc.).

GUNDERSON, CARLA A., RICHARD J. NORBY, TIMOTHY J. TSCHAPLINSKI, AND STAN D. WULLSCHLEGER. Oak Ridge National Laboratory, Oak Ridge, TN 37831-6034. Coppicing of yellow-poplars does not enhance the growth response to elevated CO_2.

Rising atmospheric [CO_2] has the potential to enhance growth, photosynthesis, and carbon sequestration in trees. Increased growth is not always observed, however, perhaps because of limitations imposed by nutrient or water availability, or by inadequate sink strength. To investigate these mechanisms, we studied coppice regrowth in decapitated yellow-poplar saplings (*Liriodendron tulipifera*) growing (both before and after decapitation) under 3 levels of CO_2 enrichment in open-top field chambers. Coppice growth is typically rapid, providing a large sink for carbon, in part because large residual root systems increase the availability of nutrients and water. Coppice plants exhibited a physiological reinvigoration-- photosynthetic rates and photosynthetic pigment concentrations were higher than in leaves of intact plants. The relative effect of CO_2 enrichment, however, was similar in coppice and intact trees-- photosynthetic rates were 20-60% higher and pigment concentrations were lower in leaves exposed to higher [CO_2]. There was no increase in aboveground growth in elevated [CO_2] in either coppice or intact trees. These results suggest that the limitations restricting CO_2-induced growth enhancement in this species are not released by shoot decapitation.

GUO, QINFENG and JAMES H. BROWN. The University of New Mexico, Albuquerque, NM 87131, USA. A constraint line characterizes effects of competition on survivorship of desert annuals.

We report empirical evidence from northern Chihuahuan Desert showing complex relationships between survivorship and initial (usually seedling) density in desert annuals. Survivorship was generally negatively related to initial density but the relationship did not exhibit a simple linear or curvilinear form. Instead, the data points filled the space under a smooth curve, with survivorship exhibiting enormous variation at low densities (where factors other than resource limitation and competition can cause mortality) but uniformly low values at high densities. We hypothesize that resource limitation as a function of density sets a very deterministic upper bound (constraint line) on survivorship. This constraint line can be described by the function $S = ae^{-bD}$ (where S is survivorship; a and b are constant parameters that vary with specific species; D is original density). Further, the effect of density on survivorship has the same shape, regardless of whether the competing plants are conspecific, other annuals, or perennials. We suggest that the approach of defining a constraint space is a useful way to understand ecological complexity.

GUSTAFSON, ERIC J. and THOMAS R. CROW. North Central Forest Experiment Station, W. Lafayette, IN, 47907, USA and North Central Forest Experiment Station, Rhinelander, WI, 54501, USA. The effects of alternative management strategies on forest spatial pattern in the Hoosier National Forest.

Two different management strategies were proposed in the Forest Plan (1985) and the revised Forest Plan (1991) for the Hoosier National Forest (Indiana). The 1985 plan emphasized even-age management, while the revised plan called for primarily uneven-age management. A timber harvest allocation model, used to simulate timber harvesting decisions typically made by National Forest managers, produces landscape patterns reflecting the "look and feel" of managed landscapes. The model was used to simulate 150 years of management using the strategies represented by the two plans, with the resulting patterns of forest openings over time compared to each other and to a "no-harvest" scenario. Based on indices of the spatial pattern, the 1985 plan produced less forest interior and more forest edge than the 1991 plan. The 1985 plan continued trends of the period 1948-1988 toward increased forest fragmentation. This was true for each pattern index, except in areas where timber harvest had been minimal in recent decades. Vulnerability of forest birds to cowbird brood parasitism was predicted to be greater under the 1985 plan than the 1991 plan. The 1991 plan generally showed a reversal of the forest fragmentation trends seen between 1948-1988. The "no-harvest" scenario increased forest interior, reduced forest edge, and reduced the diversity of successional habitats.

GUTSELL, S.L. and E.A. JOHNSON. Dept. of Biological Sciences and Kananaskis Field Stations, University of Calgary, Calgary, AB, T2N 1N4, CANADA. The mechanisms of fire scar formation.

Two key observations lead to our understanding of how fire scars form on trees. First, as a fire passes by a tree, its flame length increases on the leeward side of the tree. Second, the cambium is killed in a triangular shape, encompassing approximately half the circumference at the base of the tree and becoming narrower with height. The increase in leeward flame height is due to the formation of two adjacent vortices on the leeward side of the tree. Vortices form on the leeward side of a tree when the Reynold's number (a function of wind speed, tree diameter and kinematic viscosity) is greater than 40. The vortices do not draw the flame upwards, but in fact, they suppress the turbulence in the diffusion flame by their centripetal motion. The flame height increases because the flow of fuel becomes greater relative to the mixing of fuel with air, resulting in an increased length along which combustion will occur. Cambial death at the base of the tree occurs between the two points of separation of the vortices from the tree.

GWO, CHARLES J., ROBERT E. HODSON, HAROLD J. MOROWITZ[1], WILLIAM J. PAYNE and RICHARD G. WIEGERT. Univ. of Georgia, Athens, GA, 30602, USA and [1]George Mason Univ., Fairfax, VA, 22030, USA. Toward a thermodynamic niche theory: the kinetic and energetic analysis on growth of Klebsiella pneumoniae along the pH niche axis.

To gain insight into how physical and chemical Niche variables affect the growth characteristics of an organism, a kinetic and energetic analysis of the effect of media pH on the growth rate and yield was done. Klebsiella pneumoniae was grown in batch culture in a defined mineral salt solution with glucose as limiting nutrient and sole carbon and energy source. Growth yield and growth rate were monitored between pH 4 and 9, over which range this organism was capable of completely utilizing the glucose. Both rate and yield peaked at pH 7, at which point the bacteria exhibited highest specific growth rate (0.9 per hour) while maintaining a 58% efficiency of energy conservation in biomass synthesis. Both rate and yield drop precipitously beyond pH 5 and pH 8 and approach zero around pH 4 and pH 9. At these pH niche boundaries, the organism lost its competitiveness on two fronts: the ability to acquire available energy and the efficient utilization of such energy for biomass synthesis. Mathematical simulations were done for cultures in which K. pneumoniae competed with two hypothetical bacterial species with maxima at pH 8.9 and pH 4.2. It was assumed that these two populations had the same growth rate and yield at their maxima as K. pneumoniae at pH 7. The simulations using equal starting populations of the two species show that, after 5 generations of competition, K. pneumoniae is able to acquire 17.3% and 7.9% of the total glucose at pH 8.9 and 4.2 respectively, and manages to produce 4.6% and 3.9% of the final biomass in each case.

HADLEY, JULIAN L. Harvard Forest, Harvard University, Petersham, MA, 01366, USA. Effects of elevation, slope aspect, and longitude on red spruce needle mortality during a year of severe winter damage.

Winter needle mortality was estimated in 177 red spruce stands in New York State, New England, and southern Quebec in spring 1993. Only current-year foliage was killed on most trees. Needle mortality increased with elevation in 7 of 9 regions sampled ($p = 0.0001$ to 0.07), although not in the Adirondack region of New York, where injury was instead greater on southerly slopes ($p = 0.009$). In New York and western New England, red spruce was sampled

across several degrees of latitude with no significant effect on needle mortality ($p > 0.1$). Given the hypothesis that needles are killed primarily by extreme cold, the lack of a latitudinal effect was surprising in view of lower minimum temperatures recorded at weather stations further north. In contrast, longitude affected needle mortality ($p < 0.0001$), with more current-year needles killed in northern New York and Vermont (≈50% mortality) compared to northeastern New Hampshire and Maine (<30% mean mortality). Acadia National Park did not fit the longitudinal pattern, with over 40% average current-year needle mortality in the stands sampled. These results will be discussed in relation to climatic data, air pollutant deposition, red spruce cold tolerance, bud mortality, and red spruce decline.

HAFER, B.L. and S. OAKLEY. National Biological Survey-Cooperative Park Studies Unit, The University of Tennessee, Knoxville, TN, 37996 USA, and North Carolina Natural Heritage Program, Raleigh, NC, 27611. Occurrence of Bent Avens in calcium-rich soils on the Grandfather Mountain massif of North Carolina.

The uneven distribution of rare plant species among the watershed drainages of the Grandfather Mountain massif may be linked to unique and contrasting root zone soil chemical conditions. Soil samples were collected and analyzed from two watersheds with extremely dense populations of Bent Avens and from two drainages entirely lacking populations, but which otherwise display similar habitat parameters. A strong correlation of Bent Avens population occurrence and size with local watershed root zone chemical parameters was observed, including a combination of high levels of total calcium, high cation exchange capacity, and very high base saturation. pH and base saturation decrease sharply at ~1460-1490 m elevation within the ecotonal transition between hardwood to Spruce-fir communities. Although elevation-associated decreases in buffering and nutrient content are considerable, root zone chemical conditions were consistently more favorable at all elevations in watersheds containing Bent Avens. Future soils sampling throughout the narrow range of these species is needed to clarify the possibly limiting role of soil chemistry in the physiology and distribution of endemic southern Appalachian plant species.

HAINDS, M.J., R.J. MITCHELL, L.R. BORING and B.J. PALIK. Joseph Jones Ecological Research Center, Newton GA 31770. Temporal and spatial dynamics of legume populations in a frequently burned longleaf pine/wiregrass savanna.

Longleaf pine savannas are dependent on frequent fires. Associated with these fires is a loss of N through volatilization; however, frequent fires also have been suggested to encourage legume populations. These populations may serve as significant N inputs. Yet no study has quantified population dynamics of legumes across time and space for these communities. In this study, legume populations were sampled each month for a year throughout a hydric to xeric gradient in undisturbed longleaf pine wiregrass savannas. These areas had been subjected to frequent dormant season burning for more than a quarter of a century. Approximately 50 species of legumes were encountered with the diversity of legumes declining as the hydric or xeric extremes of the gradients were approached. Also these populations were variable in time, with the greatest diversity occurring in the spring and summer. The relationship between site factors and legume abundance will be explored using multivariate techniques.

HAIRSTON, NELSON G. JR. and STEPHEN ELLNER. Cornell University, Ithaca, NY, 14853, USA and North Carolina State University, Raleigh, NC, 27695, USA. **Responses to natural and artificial selection: Field and lab realized heritabilities in a copepod population.**

Two wild populations of the freshwater copepod *Diaptomus sanguineus* are active in winter when zooplanktivorous fish are quiescent, and diapause in summer when the fish are active. For these copepods, interannual fluctuations in fish predation are known to change the mean timing of onset of diapause. Timing of diapause comes earlier in years following early and intense fish predation and later in years following late and relaxed predation. Here we estimate realized heritabilities of diapause timing in the field for both populations, based on changes in the trait distribution and calculations of selection intensity. Intensity is derived from fitness functions founded on experimental estimates of copepod susceptibility to predation and the timing and intensity of predation in individual years. We compare these field heritabilities with a laboratory estimate of heritability from parent-offspring comparisons of diapause timing in copepods taken from one of the two natural populations. We also consider the effect of hatching of copepods from prolonged diapause on the field heritability estimates.

HAKONSON, T.E., A.W. ALLDREDGE, T.B. KIRCHNER, T. MCLENDON, AND E.F. REDENTE. Colorado State University, Fort Collins, CO, 80523, USA. Development of ecological risk assessment procedures for Los Alamos National Laboratory, New Mexico.

The Center for Ecological Risk Assessment and Management (ERAM) at Colorado State University is developing prototype ecological risk assessment procedures for Los Alamos National Laboratory using a three-step approach: 1) develop a conceptual model of contaminant effects on species, lifeforms, and ecological processes, 2) construct and initialize screening-level models, and 3) construct and initialize a predictive pathway model. We have developed the conceptual and screening-level models for depleted uranium effects on pinyon-juniper woodland and have initialized the model using data in the literature. We are expanding these models to include ponderosa pine woodland and are developing the predictive pathway model to include additional

contaminants, ecological processes (succession and decomposition), and responses of species important ecologically, economically, or socially. Uncertainty and sensitivity analyses, clear documentation of procedures and assumptions, and formal peer review are emphasized.

HAMRICK, J. L. AND M. J. W. GODT. University of Georgia, Athens, GA, 30602, USA. Genetic diversity in southeastern endemic plant species.

The flora of the southeastern United States includes more than 200 species endemic to the region, many of which are listed as either threatened or endangered. A thorough understanding of the level and distribution of genetic variation for such species is essential for their effective management and/or restoration. Reviews of the plant allozyme literature have demonstrated that endemic species maintain less genetic diversity than widespread species with similar traits but that their distribution of genetic diversity within and among populations is similar. Three case studies based on allozyme surveys of genetic diversity in several plant species endemic to the southeastern U.S. are reviewed. These studies demonstrate that when knowledge of the systematics, biogeography and population ecology of a species or population are known there is some predictability to the levels and distribution of genetic diversity. On the other hand, exceptions are relatively common indicating that it is necessary to have empirical data before appropriate plans for the conservation of genetic diversity can be developed for individual species.

HAN, KAIPING and DAVID E. LINCOLN. University of South Carolina, Columbia, SC, 29208, USA. The impact of plasticity and maternal effect on the evolution of leaf resin production in Diplacus aurantiacus

Our previous study of leaf resin production in Diplacus aurantiacus has shown a large environmental and maternal effects on the variation of resin production. Our objective in this study was to examine the impact of plasticity and maternal effects on the evolution of leaf resin production in D. aurantiacus by observing the genetic variation in plasticity of resin production using cloned genotypes (parents) under field and chamber conditions, comparing phenotypic correlations of resin content with growth traits under these two environmental conditions, and distinguishing the possible basis of the maternal effects on resin production using parents and half-sib progeny. A significant G X E interaction ($P<0.0001$) in leaf resin production was found and phenotypic correlation between resin content and growth rate also exhibited plasticity. In addition, the resin content of dam half-sib families grown in the chamber had a closer relationship with their maternal parents in the field ($r^2=0.42$, $P=0.059$) than in the chamber ($r^2=0.15$, $P=0.34$), suggesting an environmentally based maternal effect on the secondary chemicals. We suggest that the maternal environmental effect may act as a contributor to plasticity of resin production and, while it may not diminish the appearance of genotype by environment interaction, the heritable variation of plasticity of resin production may be confounded.

HANKS, LAWRENCE M., and ROBERT F. DENNO. University of Maryland, College Park, MD, 20742, USA. Local adaptation to host plants in a sedentary insect.

We investigated adaptation of the armored scale insect Pseudaulacaspis pentagona (Targioni-Tozzetti) to individual mulberry trees (Morus alba L.) in Maryland, USA. Local adaptation was tested by transferring eggs within and between trees and by measuring the subsequent survivorship of developing scales. Survivorship of P. pentagona was significantly higher when raised on their natal host tree compared to rearings on novel trees. This finding is consistent with local adaptation of scale populations to individual host trees. However, we found evidence for differences in local adaptation of scale populations only between populations on distantly separated mulberry trees. There was no evidence for genetic differentiation of scale populations on neighboring trees, suggesting that gene flow inhibited local adaptation. While local adaptation may fine tune populations of this herbivore to individual host phenotypes, it is unlikely to play a general role in their distribution on host plants. The patchy distribution of P. pentagona in Maryland is best explained by the combined influences of natural enemies and plant water relations.

HANSKI, ILKKA and MIKKO KUUSSAARI. University of Helsinki, Helsinki, FINLAND. Butterfly metapopulation dynamics.

The notion of metapopulation persistence in fragmented landscapes has received much attention in population and conservation biology in recent years. We review the metapopulation concept and especially its application to the dynamics of butterflies. As an example we describe the metapopulation dynamics of the Glanville fritillary Melitaea cinxia, an endangered European checkerspot butterfly, in a network of 1502 discrete habitat patches in SW Finland. We demonstrate that this system satisfies four necessary conditions for metapopulation persistence (habitat patches support local breeding populations; no population is large enough to assure long-term survival; habitat patches are not too isolated to prevent recolonization; and local dynamics are sufficiently asynchronous to make the simultaneous extinction of all local populations unlikely). We also demonstrate that patterns of patch occupancy are consistent with theoretical predictions. We summarize the results of other metapopulation studies on butterflies and discuss the general use of the metapopulation concept in the study and conservation of specialized, rare and endangered species of insects.

HANSON, PAUL J., TIMOTHY J. TSCHAPLINSKI, DANIEL B. STEWART and RICHARD J. NORBY. Environmental Sciences Division, Oak Ridge National Laboratory, Oak Ridge, TN, 37831-6034, USA. Water use of three hardwood species under variable CO_2 and soil water conditions.

The impacts of elevated CO_2 and cyclic water stress on water use of American sycamore (*Platanus occidentalis* L.), sweetgum (*Liquidambar styraciflua* L.) and sugar maple (*Acer saccharum* Marsh.) were evaluated. One-year-old seedlings were planted in 8-L pots and grown in four open-top chambers containing either ambient or ambient +300 μmol mol^{-1} CO_2. Soil moisture regimes were nested within each chamber. Well-watered plants were watered daily and water-stressed plants were exposed to drought cycles. Differences in plant leaf area and conductance between species altered the rate of water use, such that sycamore plants experienced 11 drought cycles whereas sweetgum and maple only had 5. Mean soil matric potentials at the depth of the drought cycles were -1.5, -0.7, and -0.5 MPa for sycamore, sweetgum, and maple, respectively. Leaf-level gas exchange measures agreed with direct gravimetric observations and showed increased water-use efficiency when grown under elevated CO_2. Conversely, water use per plant was typically not reduced under elevated CO_2 because of increased leaf area production. Drought reduced total water use per plant and leaf, but did not preclude the CO_2 effects on water use.

HARCOMBE, P.A.& C.X. LIU. Rice University, Houston, TX, 77251 USA Can current vegetation be used to infer presettlement patterns?

In southeast Texas, longleaf pine regeneration is usually associated with frequent fire. Increases in the hardwood component of upland forests following logging and fire suppression has led to the idea of widespread successional conversion of longleaf pine forest to oak-pine forest. Strong quantitative relationships of extant vegetation patterns to site conditions and landforms led us to argue that some of the oak-pine forest is not successional, but is stable, i.e. that with some exceptions extant vegetation can be a valid indicator of presettlement vegetation. Partial tests of this hypothesis involve monitoring of demographic processes in an oak-pine forest, measurement of effects of fire in different vegetation types, and tests for grass phytolith presence (indicative of past pine savanna vegetation). Preliminary results show that longleaf might persist for long times in the absence of fire, that fires tend to have little effect where hardwood canopies are dense, but that some hardwood sites showed evidence of prior occupancy by savanna grasses.

HARGIE, KIRSTIN A. University of Mississippi, University, MS, 38677, USA. Visual and tactile predation of epibiont infected zooplankton.

A series of short-term experiments tested if the presence of epibiotic *Colacium sp.*, *Characium sp.*, and peritrich ciliates increases the susceptibility of zooplankton to visual predators, and reduces susceptibility to tactile predators. The visual and tactile predators used were *Gambusia affinis* and *Chaoborus sp.* Water was colored with dyes to match background chlorophyll, eliminating epibiont-environmental contrast. Zooplankton were stained with Bismarck Brown to obscure the epibiont-zooplankton contrast. Visual predation was found to decrease the prevalence of phototrophic epibiont laden zooplankton. This suggests that epibiont pigmentation increases the conspicuousness of zooplankton to visual predation.

HARGROVE, WILLIAM W., ROBERT H. GARDNER, MONICA G. TURNER, and WILLIAM H. ROMME, Oak Ridge National Lab, P.O. Box 2008, Oak Ridge, TN 37830-6038, and Fort Lewis College, Durango, CO 81301. Fire-induced changes in the Yellowstone landscape simulated under alternative future climate trends.

Future long-term (ca. 100 year) trends in fire frequency and burn patterns were investigated in the subalpine plateau of Yellowstone National Park, USA, using EMBYR, a probabilistic, spatially-explicit fire simulation model. The central subalpine plateau (85 km x 82 km) was represented as a raster map with 50 m x 50 m cells of 5 fuel types. Markov probabilities developed from fire scar and tree core data were used to simulate regrowth and succession of fuel. Historical daily sequences of weather, including wind speed, wind direction, and percent moisture in fine and heavy fuels, were used to classify fire years into synoptic types (e.g. "wet" or "dry"). Weather for future scenarios was obtained by randomly drawing years with replacement from within one such synoptic type. Spatial locations for ignitions were drawn from the total population of historical ignition locations. Changes in abundance of fuel types through time and amount of edge between fuel types were used to monitor landscape structure.

HARLEY, PETER, STEVE ARCHER and ALEX GUENTHER. National Center for Atmospheric Research, Boulder, CO 80307, USA and Texas A & M University, College Station, TX, 77843, USA. Effects of growth irradiance, nitrogen nutrition and watering regime on photosynthesis, leaf conductance and isoprene emission in leaves of Post Oak, *Quercus stellata*.

Seedlings of Post Oak (*Quercus stellata*), the dominant woody species of oak savannas of east-central Texas, were grown outside in College Station, TX from April to November 1993. Plants were randomly placed in one cell of a 3 x 2 x 2 factorial experiment, employing 3 nitrogen

fertilization regimes (25, 100 and 225 ppm NH_4NO_3), 2 light levels (70% and 20% of full sun) and 2 watering regimes (to maintain 80-100% or 30-50% of field capacity). In November, net photosynthesis, leaf conductance and leaf isoprene emission rates at 30°C and PPFD=1000 μmol m^{-2} s^{-1} were determined for two mature leaves on each of four plants from eight growth treatments and data were analyzed statistically. For plants grown under the lower watering regime, photosynthesis and isoprene emission increased with both increasing PPFD and nitrogen (effects significant at $p<0.01$). For plants grown at 70% full sun, effects of nitrogen treatment on photosynthesis, conductance and isoprene emission were significant ($p<0.001$) while effects of watering treatment were not significant ($p<0.2$). Although watering treatment did not lead to significant differences between treatments, in a short-term drying experiment conducted on four plants, isoprene emissions increased through the drying period in previously well-watered plants, but decreased in previously droughted plants. Measurements were also made on two leaves to determine the effects of varying PPFD and temperature on rates of isoprene emission.

HARPER, STEVEN J. and GEORGE O. BATZLI. University of Illinois, Urbana, IL, 61801, USA. Effects of three extrinsic factors on the agonistic encounter rates of prairie voles.

We investigated the effects of three manipulated environmental variables (food quality, predation, and interspecific competition) on the agonistic encounter rates between individual prairie voles in enclosed populations. Populations were established and monitored for 24 weeks in each of three years and agonistic encounter rates within and between age-sex classes were estimated. Agonistic encounter rates between individuals are a function of the probability of encountering an opponent and the level of aggression elicited by the encounter. Probability of encounter was estimated by monitoring the number of active runways (via transects), timing and frequency of activity along a runway (via infrared sensors), and number of voles using a runway (via passive integrated transponder tags). Levels of agression were estimated by staging dyadic encounters between voles in a neutral arena. Results will be discussed in relation to dispersal rates as predicted by a multifactorial hypothesis of population dynamics.

HARPER, TRAVIS M. and SCOTT K. GLEESON. University of Kentucky, Lexington, KY, 40506, USA. Growth, allocation and N/C response to gradients of density and nitrogen supply.

The reciprocal-yield relationship is generally believed to reflect the effects on plant growth of competition by resource depletion. What resources are involved is less well understood. We investigated this issue by growing *Sorghum bicolor* in a factorial design at seven densities and five nitrogen supply levels in sand culture. The plants responded to the gradients both by modifying the shape of the density-yield curve and by shifts in carbon and nitrogen allocation. As nitrogen supply decreased, curves became more linear and root allocation and tissue nitrogen decreased. Increasing density strongly reduced per plant biomass in all but the lowest nitrogen treatment. Although growth saturates strongly with nitrogen only at the lowest densities, root allocation increases with density only at the lowest nitrogen levels. We infer from these responses that typical reciprocal-yield relationships are a result of shoot competition rather than root competition.

HARRELL, PETER, A.[1], LAURA L. BOURGEAU-CHAVEZ[2], ERIC S. KASISCHKE[2], and NORMAN L. CHRISTENSEN[1]. [1]Duke University, Durham NC, 27708-0328, USA, and [2]ERIM, P.O. Box 134001, Ann Arbor MI, 48113-4001, USA. Sensitivity of ERS-1 and JERS-1 radar data to biophysical parameters in Alaskan boreal forest.

Thirty-two boreal forest sites were identified and sampled in the central region of Alaska to evaluate the sensitivity of the C-band ERS-1 and the L-band JERS-1 radar platforms to site biophysical properties. Previous research has shown a significant radar backscatter response to biomass in Duke Forest. We hypothesized that differences in biomass, biomass distribution, and site moisture conditions would correlate to variability in backscatter intensity in these boreal forests as well. The sites selected represent black spruce (Picea mariana) and white spruce (Picea glauca) stands in a post-fire chronosequence. Black spruce biomass ranged from less than 1 to 5.6 kg/m^2 and white spruce from 8.8 to 21.5 kg/m^2. Results indicate both ERS-1 and JERS-1 backscatter is responsive to biomass, density and height, though other factors, most likely surface moisture conditions, are often a stronger influence. Examination of a subset of sites which all fall within a single image provide good correlations and a temporal sequence of imagery for these sites from April to August indicate the importance of surface moisture conditions, though results must be interpreted with caution as the dynamic range is often less than 3 dB.

HARRIS, PATRICIA M. and MICHAEL J. VANNI. Miami University, Oxford, OH 45056, USA. Varying the time scale of nutrient addition in a pond: effects on phytoplankton and zooplankton communities.

Whether nutrients are added to phytoplankton gradually or in a sharp pulse can affect algal responses to the addition, because algal taxa differ in their abilities to use brief pulses of nutrients and to store nutrients. The time scale of N and P addition is known to affect algal response in continuous culture, but its effect in natural communities is poorly known. In an oligotrophic pond, w enclosed a natural phytoplankton assemblage in 1000 L experimental bags which then received a total of 100 μg N/L and 8 μg P/L either in a single pulse or gradually over 2 weeks. Control bags had no N or P added. Because algal response also varies with grazing, the three nutrient treatments were crossed with three zooplankton treatments: rotifers only, rotifers + Bosmina, and rotifers + Bosmina + predatory Chaoborus larvae. Increase in phytoplankton biomass was initially highest in "pulse" bags but persisted longest (after N and P addition ended) in the "gradual" bags. Bags with Chaoborus had the lowest phytoplankton biomass, and the N and P added to these bags apparently ended up in Chaoborus rather than in phytoplankton or zooplankton. Algal community structure differed between "pulse" and "gradual" treatments. Rotifer community structure was affected by nutrient treatment on only a few dates, and other zooplankton were unaffected. Nutrient and zooplankton effects were additive. We conclude that time scale of N and P addition did significantly affect this limnetic community, but effects did not extend much beyond the phytoplankton.

HARRISON, SUSAN P. Division of Environmental Studies, U. C. Davis, Davis, CA 95616. Toward a theory of beta diversity.

Beta diversity is the among-locality, or "turnover", component of total regional (gamma) diversity. It may result either from ecological dissimilarity among localities, or from limitations on the dispersal of component species. If dispersal limitation is a major cause of beta diversity, then 1) beta diversity should be highest among poorly dispersing species; 2) it should be higher in insular than continuous habitats; 3) it should generally increase with distance. Analysis of numerous data sets from islands, terrestrial habitat isolates, and continuous habitats generally disproves these three predictions. This suggests that limited dispersal plays only a minor role in determining species ranges, except at very large goegraphic scales (such as between continents).

HARRISON, SUSAN and NAOMI CAPPUCCINO. University of California--Davis, Davis, CA, 95616 USA and Université du Québec à Montréal, Montréal, Québec, H3C 3P8, CANADA. Testing for population regulation with density-perturbation experiments.

We review the use of experimental manipulations of population density to test for the existence and causes of regulation. Relatively few such studies have been performed, but they typically show clearer evidence for regulation than do the far more abundant census and life-table studies. Potentially regulating density dependence is nearly always exerted by the lower trophic level (food quality as well as quantity), rather than by predators or parasitoids. Unfortunately, many studies finding density dependence lack critical information that would allow us to infer regulation. We discuss the "ideal" experimental design for detecting regulation and examine the difficult issue of when temporal density dependence may be inferred from the results of spatial manipulations of density.

HARTT[1], LAURA, TODD A. CROWL[1], and ROBERT T. DILLON, JR.[2], [1]Utah State University, Logan, UT, 84322-5210 and [2]College of Charleston, Charleston, SC 29424-0001. The effects of mating history on anti-predation behavior in the freshwater snail, Physa heterostropha.

Evolutionary ecologists traditionally view phenotypic variation as essential for long-term population persistence. Small, isolated populations are susceptible to reductions in genotypic diversity, a major component of phenotypic variation, which may result in a lower mean fitness. Although we have many examples of inbreeding depression relative to discrete physiological and/or reproductive traits, relatively little is known about the effects of lower genetic variability on behavioral traits such as predator avoidance. Freshwater snails are known to exhibit an anti-predation response in the form of "crawling-out" in the presence of snail-foraging crayfish. We hypothesize that under constant environmental conditions, historically inbred snail populations would lack variation in crawl-out behavior. Furthermore, if predator avoidance is a trait susceptible to inbreeding depression, we might also expect an direct relationship between mean crawl-out response and genetic variability. We discuss our laboratory results showing individual and between mating-system variation in snail response to crayfish in the context of mating-system theory.

HASKELL, DAVID G. Cornell University, Ithaca NY, 14953, USA. Foraging and learning: Models and experiments with area-restricted searches.

Many animals and plants perform area-restricted searches (ARS's) after finding food, yet we currently have little understanding of the adaptive significance of this behavior. I used a simulation model to predict optimal ARS strategies for predators faced with different spatial distributions of food. The model predicted that predators should learn how long and wiggly an ARS to do based on their prior experience of the arrangement of prey. I tested the model's predictions with four ferrets (Mustela putorius furo) that foraged for prey items in an arena. As predicted, the ferrets learned how large and wiggly an ARS to perform. Clustered prey items led to short, wiggly searches; more spread out prey items led to longer, less wiggly searches. When trained with two prey items with different spatial arrangements, the ferrets simultaneously learned two types of ARS. This study shows that ARS behavior can be investigated as an optimality problem, and that animals are capable of learning to modify their ARS patterns to best exploit different spatial arrangements of prey.

HATFIELD, COLLEEN A. and ALAN R. JOHNSON. University of New Mexico, Albuquerque, NM 87131, USA. Modelling riparian plant dynamics at the scale of the drainage basin.

As organisms restricted to a subset of the environment such as streams or the adjacent riparian area explore potential habitat space, they encounter a gradient of available resources. This gradient of resources is governed in part by the size of the stream and the distribution of elevations within the drainage basin. Theoretical studies of simulated networks show that, in the long term, the configuration of the

drainage network influences how a species moves through the drainage network. An individual-based, spatially explicit model is presented that explores the implications of the theoretical studies in empirical drainage. This allows exploration of how and to what extent the configuration and geometry of real stream networks, at the scale of the drainage basin, influences dispersal and establishment dynamics of selected riparian woody vegetation. Life history features of the selected species are modelled as probabilistic functions and overlain onto a lattice representation of actual stream networks derived from Digital Elevation Models. The model allows exploration of questions, at the scale of the drainage basin, related to dynamics of recovery from disturbance, gene flow, potential for genetic isolation and spread of invading organisms within stream networks.

HAVENS, K.E. South Florida Water Management District, West Palm Beach, FL, 33416-4680, USA
Predator-Prey Interactions in the Lake Okeechobee Food Web.

A multi-agency investigation of the Lake Okeechobee ecosystem was performed in 1987-92. Information on species composition and predator diets was used to produce sub-webs for the littoral and pelagic components of the community. At present, the webs are coarse-scale, and reflect linkages between major groups of organisms: wading birds, fish, macroinvertebrates, zooplankton and phytoplankton. Additional categories (not taxonomically resolved) are periphyton, bacterioplankton and protozoans. These are important diet items for many predators. In all, over 500 biological species were identified, including 13 birds, 40 fish, 97 macroinvertebrates, 63 zooplankton and > 300 phytoplankton. Yield-effort curves indicate a very complete species census. The littoral web is most complex. Omnivory is common in both sub-webs, and among both vertebrate and invertebrate predators. Nearly all predators exploit prey from two or more trophic guilds. Although species-species trophic linkages have not yet been established, the total number of links in the web can be predicted ($L = 0.1S^2$) from results of previous studies. It may exceed 25,000.

HAY, MARK, TIM SCHMITT, and NIELS LINDQUIST. UNC Inst. of Marine Sciences, Morehead City, NC 28557, USA. Multiple functions of plant secondary metabolites will constrain chemically-mediated coevolution.

Although chemically-mediated coevolution between plants and herbivores is thought to be common, such coevolution will depend on selection altering the chemical defenses of the plant following the evolution of resistance by herbivores. Such a reciprocal response will be constrained if compounds play multiple roles that are ecologically important. We show that the seaweed *Dictyota menstrualis* produces secondary metabolites that are broadly defensive against both herbivores and competitors. Individual diterpenes from *Dictyota* deter feeding by fishes, urchins, and amphipods, but also prevent fouling organisms from settling on *Dictyota* even though they contact the alga as often as they contact preferred hosts. Although certain herbivores are resistant to these metabolites, it is unclear that feeding by these herbivores will result in a reciprocal response from the plant. We suggest (1) that coevolved interactions are less common than is generally thought, (2) that chemically-mediated coevolution may be rare because secondary metabolites commonly have multiple functions, and (3) that many interactions appearing to be coevolved result from fortuitous and opportunistic preadaptations.

HAYDEN, BRUCE P., JOHN H. PORTER, and GUOFAN SHAO. University of Virginia, Charlottesville, VA 22903, USA. Impacts of tide amplitude and timing variation on remote sensing of emergent wetlands.

The high productivity and physical structure of coastal wetlands make them important to the functioning of coastal marine systems, either as contributors of biomass or by serving as nursery areas and refuges. Coastal wetlands can pose special problems for remote-sensing because inundation of vegetation caused by tides occurs both spatially (between sites within a single image) and temporally (between images). We assessed the effects of spatial and temporal differences in tides on the spectral characteristics of Thematic Mapper images of the Chesapeake Bay and Virginia Coast Reserve. Using land cover data layers produced by the Coastwatch Change Analysis Program of NOAA and pairs of Thematic Mapper images differing in tidal stage, we compared spectral shifts between images for areas covered by emergent wetlands. A full range of tidal phases are present in the Chesapeake Bay at any one time, but the differences in tidal stage throughout the Bay were usually less than 40 cm. Spectral changes in Thematic Mapper imagery resulting from moderate tidal flooding of wetlands (41 cm) were comparable to those observed for many upland cover classes which were not subject to tidal flooding.

HE, XI. Center for Limnology, University of Wisconsin, Madison, WI, 53706, USA.
Behavior of 3-species food web models: Its relationships to structure, interaction strength and interaction types.

The behavior of food web models can be described by measures of the growth of relative error per iteration of simulations. One such measure is the first Lyapunov exponents (λ_1), which ranges from $\lambda_1<0$ for stable points, to $\lambda_1=0$ for limit cycles, to $\lambda_1>0$ for chaos. I examined how structure, interaction strength and interaction types affect the behavior of 3-species food web models. When food web structure is dominated by competition or omnivory, the strength of species interactions are extreme, or predator-prey functional responses are ratio dependent, food web behavior is likely to be stable ($\lambda_1\leq 0$). In contract, food webs dominated by predation, intermediate strength interactions and density-dependent functional responses are likely to exhibit chaotic behavior.

HEADWORTH, JENIFER L. and MICHAEL J. VANNI. Miami Univ., Oxford OH 45056 USA. Ecosystem level impacts of an exotic species: Herbivory and nutrient cycling effects of zebra mussels.

Zebra mussels (Dreissena polymorpha) can affect phytoplankton by both consumption and nutrient recycling, potentially affecting entire food webs. We investigated how invasion by zebra mussels may affect phytoplankton by making lab measurements of algal consumption and nutrient cycling in water samples from 3 mussel-free Ohio lakes. Algal biomass was reduced 81% in Acton Lake water, 84% in Sharon Lake water and only 18% in Miami Whitewater Lake water. P excretion rate was 83 µg/g/hr, 36 µg/g/hr and 56 µg/g/hr in the 3 lakes respectively, and varied seasonally in Acton Lake. N excretion by mussels averaged 392 µg/g/hr. N:P ratios averaged 6.5 which may favor blue-green taxa. Phytoplankton were also isolated in nutrient permeable chambers and exposed to nutrient recycling by mussels but not to consumption. Algal biomass increased by 2-5x, depending on temperature, when exposed only to nutrients recycled by the mussels. These results indicate that zebra mussels can have substantial effects on phytoplankton through direct consumption and recycling of N and P, and could greatly alter a lake ecosystem when they invade.

HEALY, JOSEPH L., S.O. LINK* and R.A. BLACK. Washington State University, Pullman, WA 99163 and *Pacific Northwest Laboratory, Richland, WA 99352, USA. Competition for water between deep- and shallow-rooted grasses.

Competition between root systems of neighboring plants may be altered by seasonal variation in precipitation and soil moisture. Competitive effects of a deep-rooted, perennial grass, Pseudoroegneria spicata, on a shallow-rooted, perennial grass, Poa sandbergii, were monitored over two growing seasons by isolating the root system of P. sandbergii individuals within PVC tubes and comparing plant and soil characteristics to controls. When isolated for the entire growing season, P. sandbergii continued vegetative growth three weeks longer and late season soil water content was significantly greater than controls. Differences in soil water content were greatest between 30 and 50cm, below P. sandbergii's typical rooting depth. Flowering phenology was unchanged. When plants were isolated late in the season, treated plants showed more negative predawn xylem pressure potential the morning after isolation. Compared to controls, soil water content was reduced the day after tube insertion. These immediate effects on plant and soil water status may be due to removal of water supplied nightly by hydraulic lift. Research was funded by the US Department of Energy under contract DE-AC06-76RLO 1830.

HEARD, STEPHEN B. University of British Columbia, Vancouver, B.C., CANADA, V6T 1Z4. Effects of varying search and travel costs on clutch size decisions by mushroom-breeding flies.

Decaying mushrooms are the larval food for flies from a number of families. Adult females distribute their eggs among available mushrooms. Clutch size decisions by these females are likely to involve tradeoffs between conflicting pressures. As a female lays fewer, larger clutches, she should face increasing costs of sib competition among her offspring. However, as a female lays more, smaller clutches, she must visit more oviposition sites and should incur increasing costs of search and travel. If clutch size is a compromise between these two costs, higher search and travel costs should prompt females to lay fewer but larger egg clutches. I tested this hypothesis in field experiments with mushroom fly populations in Newfoundland and British Columbia. I allowed mushroom flies to oviposit on grids of supermarket mushroom baits (Agaricus bisporus). I varied the distance separating baits in a grid from 5 to 200 cm. Larval aggregation on the grids increased with grid spacing, as expected if clutch size responds to search and travel costs. Such a response may have important implications for population and community dynamics of consumers using variable, patchy resources.

HEDDEN, R.L., T.S. FREDERICKSEN, and S.A. WILLIAMS. Clemson University, Clemson SC, 29634, USA and Baruch Forest Science Institute, Georgetown, SC 29442. Dependence of ring-porous xylem tree species on recently-formed xylem vessels.

Deciduous tree species with ring-porous xylem anatomy are thought to be highly-dependent on recently-formed vessels for maintenance of water flow to the crown. However, the wide diameter vessels of ring-porous trees are prone to cavitation and become ineffective conducting elements after only one or two growing seasons. We tested the degree of dependence on recently formed rings of four ring-porous tree species on the Coastal Plain of South Carolina. The latest one-to-two rings of xylem were removed from several individuals of turkey oak (Quercus laevis Walt.), mockernut hickory (Carya tomentosa Poir. Nutt.), and green ash (Fraxinus pennsylvanica Marsh.). In the following weeks, midday xylem water potentials and rates of stomatal conductance and transpiration were measured on the treated trees and compared to measurements made on nearby paired untreated controls. Treated trees had significantly higher xylem water potentials two and four weeks after treatment compared to control trees for all species. Stomatal conductance and transpiration rates were lower for treated trees compared to controls indicating that stomatal closure limited moisture loss. Stomatal closure, combined with water flow through older late-wood vessels, prevented mortality of ring-porous trees despite loss of wide-diameter vessels in outer rings.

HEDIN, LARS O.[1], JUAN J. ARMESTO[2], and ARTHUR H. JOHNSON[3]. [1]Cornell University, Ithaca, NY 14853, USA, [2]Universidad de Chile, Santiago, Chile, and [3]Univ. of Pennsylvania, Philadelphia, PA 19104, USA. Patterns of nutrient loss from unpolluted, old-growth temperate forests.

Old-growth forests have been conceptually important for theories on how nutrient cycles change during plant succession. However, studies of nutrient cycles in old-growth temperate forests which are not subject to atmospheric deposition (e.g., by

nitrogen, sulfur, base cations and acids) are rare. We report on patterns of hydrologic nutrient loss from old-growth temperate forests in southern Chile, which are free of air pollution and have remained floristically stable throughout the Holocene. For the majority of elements, our results support predictions from current biogeochemical theory: that biotic control on element loss should be minimal in old-growth forest ecosystems. However, patterns of nitrogen loss were markedly different from other studies, suggesting that current theories may be biased by anthropogenic effects. Our results suggest that long-term patterns of cycling and loss of nitrogen are constrained by different mechanisms than are generally thought to dominate in temperate old-growth forests.

HEISLER, DIANA A. University of Kansas, Lawrence, KS 66045, USA. Costa Rican Woodpecker abundances and habitat use in a fragmented landscape.

Costa Rican woodpeckers vary in their dependence on primary tropical forest versus disturbed areas. As a phylogenetically coherent yet behaviorally diverse group of organisms, they are ideal for studying the impacts of habitat fragmentation on animal populations. I censused woodpeckers in and around La Amistad Biosphere Reserve, Costa Rica, mapped the location of each individual, and entered the data in a geographic information system (GIS). For each of five woodpecker species (Campephilus guatemalensis, Dryocopus lineatus, Melanerpes chrysauchen, M. rubricapillus, Piculus rubiginosus,), preferred habitat was characterized using the categories primary forest, selectively logged forest, open pasture, and forest edge. The two largest woodpecker species, C. guatemalensis and D. lineatus, were absent from areas in or adjacent to small forest patches. Melanerpes rubricapillus, the most abundant species, occurred more frequently in pasture, near forest edges than in interior forest or pasture. The GIS environment permits simulation of long-term changes in woodpecker abundance that may result from changes in habitat availability.

HEMMING, JOCELYN D. C. and RICHARD L. LINDROTH. University of Wisconsin, Madison, WI, 53706, USA. Changes in the carbon-nutrient balance of aspen: Effects on gypsy moths and forest tent caterpillars.

We investigated the effects of altering the carbon-nutrient balance of aspen (Populus tremuloides) on the performance of gypsy moths (Lymantria dispar) (GM) and forest tent caterpillars (Malacosoma disstria) (FTC). GM and FTC were fed leaves from aspen trees grown under 2 levels of light and 3 levels of fertilizer. In general, larval performance followed patterns predicted by the carbon-nutrient balance theory, although the magnitude of the differences was small. FTC and GM 2nd instars were smaller when fed leaves from trees grown in high light, but only FTC were significantly affected by fertilizer status of the trees. Stadium duration increased and growth rates decreased for 4th instar FTC eating leaves from trees grown under high light. These differences were exacerbated when the trees were not fertilized. 4th instar GM did not exhibit significant differences in growth rates. However, food conversion efficiencies were significantly reduced for GM feeding on leaves from high light trees. Results will be interpreted in terms of differences in foliar chemistry.

HENDRIX, P.F., M.A. CALLAHAM AND L. KIRN. University of Georgia, Athens, Ga, 30602, USA and U.S. Forest Service, Bristol, FL, 32321, USA. Ecological relationships and effects of harvesting on native earthworm communities in Apalachicola National Forest.

Earthworm assemblages dominated by nearctic Diplocardia mississippiensis are prevalent in native longleaf pine/wiregrass ecosystems in northern Florida. This study examines their habitat and feeding relationships, response to earthworm harvesting, and effects of harvesting on soil nutrients that may limit ecosystem productivity. Earthworm sampling was conducted using a soil vibration technique in paired harvested and unharvested plots at three forest sites. Specimens were collected for identification, count and biomass measurements and, together with plant and soil samples, for elemental and stable isotope analysis. C-13 and N-15 data suggest that D. mississippiensis are generalist, geophagic feeders, deriving nutrition from microbially-processed soil organic matter. Results indicate reductions in earthworm densities and in soil cation concentrations in harvested plots. Earthworm harvesting may export the equivalent of 7% of total soil P standing stocks.

HENDRIX, S. D., L. RIGNEY, and R. W. CRUDEN. Department of Biological Sciences, University of Iowa, Iowa City, IA, 52242, USA. Effects of patch size on reproduction in Amorpha canescens

In Iowa, small roadside remnants and a few large state preserves constitute all that remains of the tallgrass prairie ecosystem. To date, few studies have analyzed and compared viability of prairie forbs along roadsides and on preserves. In this study, we use roadside remnants and state preserves in Dickinson County to examine the effects of number of flowering stems in a patch on reproduction in Amorpha canescens. Correlation analysis indicates that as the number of flowering stems in a patch increases, total flower number, number of fruits produced, and number of raceme branches per flowering stem increases. However, large patch size does not insure reproductive success on preserves. In state preserves, some patches have high reproductive success, but others do not. These differences are attributed to variation in levels of flower feeding herbivores and seed predators. Our results suggest that large, multiple patches of A. canescens on preserves are necessary to insure long term viability.

HENEBRY, GEOFFREY M. and THELMA KRUG. Kansas State Univeristy, Manhattan, KS, 66506, USA and Instituto Nacional de Pesquisas Espaciais, São José dos Campos, SP, 12227-010, Brasil. Landscape trajectories in a disturbance-driven ecosystem: observing spatio-temporal variability induced by seasonal flooding in the Pantanal, Brasil.

The Pantanal is the largest wetland habitat on the planet: an immense alluvial plain formed during the Holocene, it covers 139,000 km^2 in Brasilian states of Mato Grosso and Mato Grosso do Sul. Subject to extensive seasonal flooding by the Rio Paraguai and its tributaries, the Pantanal is an ecotonal landscape, a complex mosaic of shallow lakes, periodically inundated grasslands, and corridors of gallery forests, which together form a threatened haven of vertebrate biodiversity. Our study characterizes the spatio-temporal variability within an intensively studied area, Fazenda Bodoquena, a large commercial cattle ranch located in the southern Pantanal. Subsets from 15 Landsat TM quarter-scenes from 3 years (1985, 1989-90, and 1992) were analyzed using measures of spatial heterogeneity, spatial dependence, and spectral intensity. From the time series of these measures, landscape trajectories were constructed yielding spatio-temporal-spectral signatures that correspond to different levels of inundation, vegetation, and land use. The method enables quantification of complex landscape change and thus is appropriate for environmental monitoring.

HENRY, V. G. AND C. F. LUCASH. U. S. Fish and Wildlife Service, Asheville, NC 28806. Reestablishment of the red wolf into the Southern Appalachians.

In 1973, the U. S. Fish and Wildlife Service initiated an intensive recovery program for the critically endangered red wolf (Canis rufus). The remaining wild wolves were captured and placed in a captive breeding program. From 14 founder wolves, the captive population had increased sufficiently by the early 1980's to begin attempting wild restorations. In 1987, following intense public education efforts, the first reintroduction took place in eastern North Carolina. In 1991, a second reintroduction was initiated in the Great Smoky Mountains National Park (Park), in an attempt to restore the red wolf to the Southern Appalachians landscape. The recovery goal is 550 animals, with 330 in captivity and 220 in at least three wild populations. At the close of 1993, the captive population numbered 181 at 31 breeding facilities, and the wild population numbered 45-59, with 38-52 in eastern North Carolina and seven in the Park.

HERMAN, R.P. and KERRI PROVENCIO. Dept. of Biology, New Mexico State University, Las Cruces, NM, 88003, USA. Does the resource island hypothesis predict the distribution of heterotrophic bacteria in Chihuahuan Desert soil?

The resource island hypothesis states that desert shrublands have a heterogeneous distribution of soil resources with the shrubs serving as islands of fertility, while desert grasslands show an even distribution of soil resources. Extending the hypothesis predicts a heterogeneous distribution of soil bacteria following resources, heterogeneous in shrublands and even in grasslands. This study enumerated soil heterotrophic bacteria using the most probable number method during the period April- December 1993. Soil samples were collected from the 5-10 cm depth zone at plants and in inter-plant spaces in bajada and playa grasslands, as well as mesquite, creosote and tar bush shrublands. There was no consistent significant difference between at-plant and inter-plant heterotrophic bacterial numbers in either grassland. Creosote shrubland showed the greatest difference between at-plant and inter-plant bacterial numbers while mesquite and tarbush shrub lands showed less well defined differences. The distribution of heterotrophic bacterial populations found in this study is consistent with the shrub island hypothesis.

HERZIG, ANN L. and RICHARD B. ROOT. Cornell University, Ithaca, NY 14853, USA. The influence of long-distance dispersal on landscape-scale population patterns of a goldenrod leaf beetle

The goldenrod herbivore, Trirhabda virgata (Coleoptera: Chrysomelidae), has a discrete, preovipositional dispersal phase during which it is capable of flying long distances (commonly flying ≥0.7km). To examine how regional abundance patterns of Trirhabda are influenced by long-distance dispersal of beetles among sites, we monitored changes in beetle densities before and after dispersal at widely scattered sites (2 to 75 km between sites) over seven years in central New York. Previous results from small-scale experiments indicated that emigration was density-dependent and that immigrating females preferred undefoliated over defoliated host patches. High mortality associated with dispersal lowered regional abundance in years when beetles were abundant due to density-dependent emigration. During years when beetle densities were low, the population became more evenly distributed among sites after dispersal as predicted. During regional population peaks the immigration pattern was unpredictable, suggesting that beetles were unable to select preferred sites over large distances.

HESS, GEORGE. N.C. State University, Raleigh, NC, 27695, USA. Modeling disease in metapopulations: Implications for conservation.

Is increasing the movement of individuals among subpopulations always a good idea? Many metapopulation models suggest that increasing movement among subpopulations will reduce the chances of metapopulation extinction. Epidemiological models suggest that increased movement among subpopulations enhances the spread of disease and can trigger an epidemic. Under what conditions might disease pose a threat to conservation efforts? To approach these questions I incorporate elements of mathematical epidemiology into

deterministic metapopulation models. Results suggest that some movement among subpopulations may prevent metapopulation extinction. However, too much movement may allow disease to successfully invade, causing epidemic cycles and precipitous drops in metapopulation size. Diseases of intermediate severity are likely to have the largest effect. Very severe diseases burn out in the infected subpopulation; mild diseases are likely to become established, but have little effect. Highly contagious diseases become established more easily than less contagious diseases, and at lower movement rates. These results have implications for conservation techniques that increase movement among subpopulations, including conservation corridors and wildlife translocation programs. It may be necessary to regulate the movement rate, keeping it below levels at which disease can invade the metapopulation.

HESTER, LAUREL L. University of Michigan, Ann Arbor, MI, 48109, USA. Diet analysis of two sympatric Murides: Mastomys huberti and Arvicanthis niloticus.

This study was undertaken in order to better describe the ecology of two species of syntopic Murides in West Africa (Mastomys huberti and Arvicanthis niloticus), and any possible competition between them. Diet is an essential component of an animal's ecology, and has been used in the past to test niche partition theory. Therefore, a stomach content analysis of these two species' diets was performed over a 6 month period. The importance of fruit in Arvicanthis niloticus' diet, the alternating frequency of insect consumption, and other dietary differences suggest some niche partitioning between Arvicanthis niloticus and Mastomys huberti. However, other non-dietary means of niche partitioning may be more important to these species. Significant month to month variation in both species' diets underlines the importance of long term ecological studies.

HEWITT, CHAD L., GARY R. HUXEL and JAMES A. DRAKE. University of Tennessee, Knoxville, TN, 37996, USA. Assembly dynamics: extinction events across multiple scales.

Biological systems are often approached as if they were structured by short-term temporal processes (i.e., ecological time) operating simultaneously over global spatial scales. It has recently become clear that the present structure of communities/ecosystems are contingent on both short-term and long-term (historical) processes. Similarly, it has been recognized that communities do not exist in isolation but rather are spatially linked systems (meta-communities) in which dynamics at all spatial scales are the result of interactions between local and regional mechanisms. We have modelled the process of community assembly (thus incorporating both short- and long-term temporal processes) in a spatially extended fashion, specifically focusing on the dynamics of species extinction and community collapse. The frequency of extinctions of various sizes fits on a $1/f^{w}$ (flicker) curve. On such a curve there are many small extinction events (e.g., 1-2 species or patches) and few correspondingly large extinction events. Many complex systems exhibit similar spatial and temporal trends, which suggest a link between the structure of diverse physical and biological systems--nature self-organizes.

HIBBARD, KATHY A. and STEVEN R. ARCHER. Texas A&M University, College Station, TX, 77843, USA. Nitrogen dynamics in herbaceous and woody landscape elements in a subtropical savanna ecosystem.

Southern Texas landscapes have been historically characterized as *Prosopis-Acacia-Andropogon-Setaria* grassland savannas. However, increases in woody plant biomass and density over the past century have transformed many areas into thorn-scrub savanna parkland and woodlands dominated by the arborescent legume, *Prosopis glandulosa*. To determine how these historic increases in woody plant abundance has influenced the nitrogen cycle, we quantified monthly (1992-93) litterfall and net nitrogen mineralization (N_{min}) in contrasting vegetation elements arrayed along a toposequence (1-3% slope). Annual N_{min} was highest in shrub -dominated habitats (205-355 μg/g/y) and lowest in herbaceous zones of uplands (163 μg/g/y). Among wooded elements, rates were highest in upland shrub clusters (355) and groves (278) and lowest in closed-canopy woodlands of intermittent drainages (205). Annual foliar litter input was greatest in woodlands ($406 g/m^2$), followed by upland groves ($330 g/m^2$) and discrete clusters ($273 g/m^2$). Peak litterfall ($118 g/m^2$) occurred in November, coincident with seasonal peaks in N_{min} (59μg/g/day) for upland woody vegetation. Secondary peaks in litterfall and N_{min} ($69 g/m^2$; 52μg/g/day) occurred in August, following unusually high rainfall in July and August . Regulation of N_{min} by soil texture, soil C and N, and litterfall will be investigated using multiple regression and used in a biogeochemical ecosystem model (CENTURY) linked to a spatially referenced successional model to determine how vegetation change along the toposequence influences landscape-level biogeochemistry.

HILGARTNER, WILLIAM B. The Johns Hopkins University, Baltimore, MD, 21218, USA. Habitat response to anthropogenic change: a 2000 year history of a freshwater tidal wetland.

A paleoecological approach was used to reconstruct the spatial pattern of habitats over a time period >1000 years within a freshwater tidal wetland in the upper Chesapeake Bay, Maryland. Plant macrofossils from cores extracted along an elevational gradient show minor changes in dominant species and community composition over a period of 1500 years. Autogenic succession and changes due to natural disturbance including fire and hurricanes, identified from pollen and charcoal records, were minimal to non-existent during this time. The dominant factor in initiating habitat change has been high sediment accretion rates resulting from colonial land clearance beginning 260 years ago, and alteration in the hydrologic regime from road construction during the past 50 years. Once change was initiated. succession varied among sites. Between 1730 and 1860, sites closest to the upland shifted rapidly from submerged aquatic to riparian floodplain forest, while those farthest from the upland shifted from submerged aquatic to low marsh. In 1940, road and dam

construction contributed to changing the outer low marsh to a high marsh, while in 1970, a portion of riparian forest that had persisted for several hundred years shifted to a shrub marsh after road construction created a flood basin.

HINOTE, HUBERT and JOHN D. PEINE. SAMAB, Gatlinburg, TN, 37738, USA and USDI-National Biological Survey, Knoxville, TN, 37910, USA. Framework for integrated resources management: Southern Appalachian Man and the Biosphere Cooperative.

This cooperative is the first regional biosphere program established in the United States. Created in 1988, the program's basic objective is to provide solutions to resources management and economic development problems in the region through cooperation and collaboration among eight federal agencies, state governments, and non-governmental organizations. SAMAB membership meets regularly to discuss opportunities for collaborative projects that minimize overlap and maximize use of scarce resources while focusing on research needs of the region and ways to achieve truly sustainable development. Because SAMAB membership consists of regional land managers and decision makers, along with scientists and other concerned parties, SAMAB provides a unique mechanism to implement an integrated approach to ecosystem management in a region of significant ecological resources.

HOAGLAND, BRUCE W. and SCOTT L. COLLINS. Department of Botany and Microbiology, University of Oklahoma, Norman, OK, 73019, USA. Distribution and abundance of plant species within and among playas on the Southern High Plains.

We examined patterns of plant species distribution and abundance within and among playa basins in the Southern High Plains. Playas are deflation basins that soil and soil moisture gradients that differ from surrounding upland vegetation. Plant species composition was sampled in 40 playas during the summers of 1992 and 1993. At the regional scale, DCA ordination indicated that playa vegetation ranged from sites dominated by grasses, such as *Agropyron smithii*, to disturbed playas with numerous forb species. Species abundance was weakly but positively correlated with regional distribution. The weak correlation may be attributable to species such as *Oenothera canescens* and *Lippia cuneifolia* which were widely distributed but had low average abundance values. Overall, species distribution was unimodal at the regional scale. No species occurred in every playa and only two species occurred in >85% of the playas. At the local scale, TWINSPAN classification identified 4-6 vegetation zones within playas. Patterns of species distribution were also unimodal at this scale, which may result form the apparent zonation in playas. Although playas from distinct habitat patches within the shortgrass prairie region, a high degree of compositional heterogeneity exists within and between playas in response to disturbance and surrounding land use.

HOBBIE, SARAH E. University of California, Berkeley, CA, 94720, USA. Plant species' effects are larger than those of increased temperature on microbial activity in tussock tundra litter-soil microcosms.

I determined the effects of increased temperature and interspecific variation in litter quality and allocation on microbial activity in litter and soil microcosms for 6 tussock tundra species. I incubated litter of *Carex bigelowii*, *Eriophorum vaginatum*, *Betula nana*, *Ledum palustre*, *Vaccinium vitis-idaea*, *Hylocomium splendens* or *Sphagnum balticum* with tundra soil at 4 and 10°C. For the vascular species, I held the total amount of litter constant, but included root, stem, and leaf litter in proportion to their annual production in each species' incubations. I measured soil and litter respiration, litter weight loss, and soil solution inorganic and litter nitrogen (N) dynamics over 21 weeks. Temperature increased respiration, decomposition, and soil net N mineralization, and decreased litter N immobilization. Respiration and decomposition were fastest in those microcosms containing sedge litter and slowest in those containing *Betula nana* or moss litter. Although respiration rates reflected differences in litter carbon (C) quality, decomposition rates did not correlate with initial litter C:N ratio. *Sphagnum* and *Vaccinium* litter immobilized the most and *Carex* and *Hylocomium* the least N. Soil net N mineralization patterns only partially reflected litter N immobilization patterns. In general, species' effects on microbial activity were larger than temperature effects, suggesting that changes in community composition associated with climate change will have important consequences for C and N cycling.

HOBBS[1], N. THOMPSON, and JOHN E. GROSS[2]. [1] Mammals Research, Colorado Division of Wildlife, 317 W. Prospect, Ft. Collins, CO 80526, USA [2] Natural Resource Ecology Laboratory, Colorado State Univ., Ft. Collins, CO 80523, USA. Predicting impacts of landscape change on biotic diversity: Dynamic multispecies models.

Efforts to preserve biological diversity have emphasized conservation of individual species. Although such efforts are often necessary, they are not sufficient for the long term preservation of a diverse fauna. Here, we develop a multispecies approach for predicting the long term impacts of changes in land-cover on vertebrates. The approach uses mathematical relationships between life history characteristics and body mass to predict risks of extinction based on metapopulation theory. These risks are then aggregated to assess higher-order impacts on vertebrate communities resulting from natural and anthropogenic environmental change. Predictions are sensitive to poorly understood relationships controlling the scaling of dispersal and the scaling of density-independent influences on population growth. We develop the idea that simple, general models driven by existing data provide an immediate alternative to more complicated models requiring detailed inventory to support decisions on land management.

HOFFMANN, ANNETTE and AARON ENGLISH. Pacific Northwest Laboratory, Richland, WA 99352, USA and AScI Corp. McLean, VA 22101, USA. Choosing traits for testing differences between groups of animals.

Tests of differences between groups of animals should be based on the most discriminating trait. A discriminating trait is one where the difference between groups is large, but the difference among animals within a group is small so there is a clear group distinction. As part of a plan to increase the natural production of salmon in a Pacific Northwest river, "wild-like" hatchery

fish will be compared to truly wild fish. A literature search of 10 traits was conducted and the traits were ranked by their discriminating power. Traits are not necessarily measured in comparable units. Therefore, coefficients of variation (a unitless quantity) were used to measure and compare inter-group and intra-group variability among different traits. We found measures of survival and morphometrics to be the most highly ranked. The list of ranked traits is a valuable management tool for guiding comparative research. By using the most discriminating traits for the comparison, the most sensitive test of success can be constructed.

HOHMANN, MATTHEW G. AND DONALD B. MILES. Ohio University, Athens, OH 45701, USA. An analysis of scale and spatio-temporal variation of regional avian population trends.

Recent population declines in migrant songbirds have been reported by local, regional and continental scale analyses. Inappropriate comparisons of population trends from disparate and arbitrarily defined spatio-temporal scales have led to contention over the existence and extent of these declines. Accurate estimates of population trend must be calculated at regional scales defined by the spatial structure of local changes in abundance. We determined these regional scales and analyzed the spatio-temporal relationship of patterns of population trend and relative abundance for 25 avian species classified into four ecological groups. Trends were estimated from USFWS BBS data using a route regression technique for five staggered ten-year time periods. Kriging of route trends produced regional patterns of population trend and relative abundance. Heterogeneity of these patterns was quantified with fractal, diversity and contagion indices. These indices and the percent overlap of trend and abundance classes were used to assess the similarity of patterns within and among species groups. Preliminary results indicate that regions of decline are associated with areas of low abundance and coincide for species within a group.

HOLL, KAREN D. Virginia Polytechnic Institute and State University, Blacksburg, Virginia 24061, USA. The influence of nectar resources on butterfly communities in a reclaimed ecosystem.

Butterfly communities are influenced by a suite of habitat variables that must be considered when aiming to restore these communities. The goals of this research were to quantify the nectar resources provided by reclaimed coal surface mines and to examine the role nectar resources play in determining butterfly community composition on these sites. Butterfly communities and nectar resources were sampled on 23 reclaimed and hardwood sites during the 1992 and 1993 field seasons. Recently reclaimed sites provide an average of 300 times the nectar abundance of the surrounding hardwoods, and nectar abundance decreases with time since reclamation ($r=-0.65$). Nectar abundance is highly correlated with butterfly abundance ($r=0.72$) and species richness ($r=0.66$) when summed over the entire flight season. However, in only a few sites are butterfly and nectar variables correlated during the flight season. These results suggest that, although many butterfly species move in response to nectar availability, nectar is not a limiting resource. While the presence of most adult butterflies is strongly influenced by nectar abundance, the vast majority of temperate butterfly species is able to utilize nectar from a wide variety of plant species. Therefore, adult butterfly communities appear to have limited utility as indicators of revegetation success.

HOLLAND, MICHELE, MARK A. MCGINLEY, AND SHIVCHARN S. DHILLION. Texas Tech University, Lubbock, TX, 79409, USA. Animal disturbances, environmental heterogeneity, and herbaceous plant dispersion.

Communities of sand shinnery oak, a low-growing clonal shrub, are found on deep sandy soils in New Mexico, Texas, and Oklahoma. This study compares patterns of spatial environmental heterogeneity and herbaceous plant dispersion in regions of this community that were and were not grazed by cattle. Patch disturbances produced by small animals (e.g., rabbits, gophers, heteromyid rodents, and ants) and the activity of cattle both remove the oak leaf litter layer and open sites for seedling establishment. Bare spaces produced by small animal disturbances are patchily dispersed. However, when cattle are present, their effect is more ubiquitous so that there is an increase in the amount of bare ground, which tends to be spread throughout the habitat. Thus, if the distribution and abundance of bare space is an important factor influencing the herbaceous plant community, then we predict that herbaceous plants should be less abundant and more patchily dispersed in ungrazed regions. The density of herbaceous plants was almost twice as high in grazed regions (4.69 indiv./m^2) than in ungrazed regions (2.51 indiv./m^2). Herbaceous plants species showed clumped distributions more often in the ungrazed region than in the grazed region. Thus, different disturbance histories can affect the spatial patterns of environmental variables, which in turn influences the dispersion and density of herbaceous plants.

HOLLINGSWORTH, JAMES M.(1), KATHRYN M. FLYNN(1), DANIEL A. BROWN(1), B. GRAEME LOCKABY(1), and WILLIAM H. MCKEE, JR.(2). (1)Auburn University, AL 36849, USA and (2)USDA Forest Service, Charleston, SC 29414, USA. Ecology of hydric soils: Influence of flooding and oxidation-reduction potential on decomposition and litter-decomposing microorganisms.

Relationships between flooding, oxidation-reduction potential (redox), and decomposition processes are not well defined. The primary focus of this study is to investigate the effects of redox variation on the degradation of carbon fractions in decomposing leaf litter. Using microcosms, each of six hydric soils were placed in an outdoor environment under precipitation barriers. Hydric soils included are poorly drained Ultisols, Alfisols, and Spodisols, a shallow peat, and two deep peats from the Francis Marion National Forest near Charleston, SC. Litter-bags were placed on the microcosm surface and each maintained in either a drained or continuously flooded condition. Redox will be monitored and mass loss from litter samples is being used as an indicator of Phase I decomposition. The primary C fractions (organic solubles, holocellulose, and lignin) within litter samples are being characterized and used as an estimate of Phase II decomposition. In addition, populations of the fungus Trichoderma colonizing litter bag samples are being monitored in an effort to identify influences of flooding and redox on microbial populations important in decomposition processes.

HOLLWEG, KAREN S. North American Association for Environmental Education, Washington, DC, 20037, USA. Ecology in education workshops as strategies for involving ecologists with educators to improve K-12 ecology education.

The Ecological Society of America sponsored regional workshops in the Southeast (1992) and Rocky Mountain states (1993) with NSF funding. Teams of ecologists and educators received updates about pre-college science education reforms, assessed the status of K-12 ecology education in their states and created action plans for improvement. Participant feedback indicated that the most valuable outcomes were the opportunities for ecologists and educators to work together, get to know one another, and break stereotypical preconceptions. A variety of efforts have resulted ranging from identification of additional ecologists interested in working with teachers, to curriculum development initiatives and workshops for teachers. Ecologists and educators are doing more to improve ecology education, but on-going support is essential if such efforts are to be sustained.

HOLMES, MICHAEL T. AND ELAINE R. INGHAM. Oregon State University, Dept. of Botany and Plant Pathology, Corvallis, Oregon, 97331-2902, USA. The Effects of Genetically Engineered Microorganisms on Soil Foodwebs.

By studying the effects of a genetically engineered strain of Klebsiella planticola on other soil organisms in soil microcosms, the risks involved with GEMs may be better understood. The addition of GEMs to soil microcosms were demonstrated to produce adverse effects to plant growth and food web structure. When K. planticola was added to soil, significant decreases were measured in plant shoot and root biomass of Triticum aescivum. The production of metabolites by K. planticola resulted in chlorotic plant symptoms. Additional effects caused by K. planticola on plants were a decrease in VA mycorrhizal colonization. The addition of K. planticola to soil microcosms resulted in significant changes in the soil food web structure. Bacteria-feeding and plant parasitic nematodes significantly increased with the addition of K. planticola into soil microcosms. The survival and observed effects of the GEM were shown to vary with physical, chemical and biological properties of soil treatments.

HOLMGREN, M., M.A. HUSTON, J. QUILES and S. WARNER. Environmental Sciences Division, Oak Ridge National Laboratory, Oak Ridge, TN 37831-6038, USA. Spatial distribution of understory plants along gradients of water and light availability.

We measured the percent cover, stem densities, and heights of understory plant species in 72 3 x 3m plots on a southeast-facing slope of mature mixed oak forest. The 80 x 240 m site is intensively instrumented for monitoring soil water content using the Time Domain Reflectometry method as part of the Throughfall Displacement Experiment on Walker Branch Watershed. We estimated canopy openness in each of the plots using hemispherical photographs. The goal of the research was to determine if the spatial distribution of understory community structure was consistent with hypothesized limitations imposed by water availability on plant responses to light. We measured the natural patterns of size, abundance, and survival of seedlings of fourteen tree species under a range of light and soil water availability. Seedling densities ranged from 4 individuals per meter square under dry, low light conditions, to 27 per meter square under the high light, high moisture conditions. Red maple comprised about two thirds of the total number of seedlings. Several distinct types of responses can be identified from three-dimensional graphs of size, abundance, or survival in relation to light and water.

HOLT, ROBERT D. University of Kansas, Lawrence, KS, 66045 USA. Senescence and the evolutionary conservatism of species niches.

The evolutionary theory of senescence rests on the simple -- but profound -- observation that the force of selection declines with age. This decline reflects two facts: 1) in a stable population, stable age structure is biased toward younger age classes, and 2) younger age classes have relatively high reproductive values. Senescence occurs because of either 1) a biased accumulation of deleterious mutations acting at later age classes (the mutation theory of senescence), or 2) tradeoffs between gene effects early and late in life (the antagonistic pleiotropy theory). Here, I sketch a parallel theory for the evolutionary conservatism of species' niches in spatially heterogeneous environments. Dispersal can couple sites within a species' niche -- sources -- to sites outside the niche -- sinks. Models for spatial dynamics are a class of "stage-structured" population models where "stage" = "habitat". Because the stable patch distribution tends to be biased towards sources, and individuals in sources have higher fitness, selection is weighted against adaptation to sinks. The ideas presented extend Holt-Gaines (Evol. Ecol. 6:433-447, 1992) to meld together several heretofore distinct topics in ecology and evolution: source-sink dynamics; niche stasis; the evolutionary stability of species' borders.

HOLYOAK, MARCEL. Center for Evolutionary Ecology and Behaviour, T.H. Morgan School of Biological Sciences, University of Kentucky, Lexington, KY 40506-0225, USA. The effect of sampling method and scale on detection of spatial and temporal density dependence.

This paper aims to give practical advice on how the scale and pattern of sampling (in space and time) influence the detection of both spatial and temporal density dependence. The study was carried out using numerical simulations of a host parasitoid model with explicit spatial structure to generate time series for subsequent analysis. We can sample initial abundance and mortality in the same generation to look for spatial density dependence, or we can collect a single abundance per generation to make a time series to look for temporal density dependence. When samples from separate patches are aggregated (*e.g.* by taking the mean), the sampling pattern has a large effect on whether we are likely to find both temporal and spatial density dependence. Then samples which are more correlated, which usually come from close together, are most likely to show spatial or temporal density dependence. However, if abundances from separate patches are used as individual data points in tests of spatial density dependence, then tests are not influenced by the pattern of sampling.

HOM, CAROLE L. and ROBERT G. JAEGER. University of California, Davis, CA, 95616, USA and University of Southwestern Louisiana, Lafayette, LA, 70504, USA. Modelling territorial behavior in male Red-Backed salamanders.

Social interactions in red-backed salamanders (Plethodon cinereus) are complex and often depend upon the sex and reproductive status of individuals. In populations at Mt. Lake, Virginia, males outnumber gravid females by ca. 2:1. Field observations of male P. cinereus suggest that males allow non-gravid females access to their territories for foraging, whereas they defend their territories against intrusion by males. We used a game-theoretic analysis of models of male fitness to examine conditions that would favor the evolution of this "permissive" behavior. Under a series of increasingly realistic behavioral assumptions, we found that the critical factor in the evolution of male permissive behavior is female preference for permissive males. If non-gravid females are more likely to return to mate with a male that allows access to his territory, then permissive behavior is likely to evolve. Further, the evolution of permissive behavior is facilitated when energetic losses due to territory defense exceed those due to allowing females to forage.

HOOGE, PHILIP N. and SPENCER J. TAGGART, National Biological Survey, Glacier Bay Field Station, Gustavus, AK 99826, USA. Home range and movement patterns of pacific halibut (Hippoglossus stenolepis): There's no place like home.

The movements and distribution of Pacific halibut (Hippoglossus stenolepis) in Glacier Bay National Park were determined using ultrasonic telemetry. Long-life transmitters (approximately 18 months) were selected in order to investigate intra- and inter-year movement patterns. Transmitters were initially attached externally (N=29), but were later inplanted internally (N=5) due to premature tag loss. Many halibut, especially larger individuals, exhibit a home range and site fidelity. Home range size was small, in almost all cases less than 0.5 km^2. In addition, attachment of transmitters on individuals captured within 100 meters of each other revealed that home ranges were non-overlapping, suggesting territoriality. Of the five individuals for which tag retention between years was possible, four were found in the subsequent year on or close to their home ranges of the previous year. Smaller halibut and some larger individuals did not exhibit continual site fidelity, instead moving over larger areas in a random fashion before returning to their home range, shifting that home range to another area, or leaving the study area. Transmitter ranges were short (< 1.0 nautical mile), and the movement patterns of those individuals moving larger distances were difficult to detect, yet the data indicate that significant proportions of the population do exhibit both inter- and intra-year site fidelity. These results suggest that halibut exhibit much more attachment to particular areas than previously thought, and that these movement patterns need to be taken into account in the management of this species.

HOOK, PAUL B. AND INGRID C. BURKE. Colorado State University, Fort Collins, CO, 80523, USA. Landscape and individual plant scale patterns of carbon, nitrogen, and nitrogen mineralization in shortgrass steppe.

Geomorphic processes, effects of individual plants, and seasonal variation in weather are thought to be important controls of soil carbon and nitrogen dynamics in semiarid grasslands, but their relative importance and interactions are not known. We quantified C and N pools and monitored seasonal patterns of N mineralization in 8 paired upland and lowland plots in shortgrass steppe. Plots represented diverse geomorphic settings, with lowlands ranging from minor swales to alluvial surfaces of ephemeral streams. Total C and N and mineralizable C in the top 15 cm of soil varied relatively little among upland sites but were 2-3 times greater in the 3 alluvial lowlands than on adjacent uplands; C and N in non-alluvial lowlands ranged from no greater to 1.8 X greater than adjacent uplands, with no clear pattern related to landscape position. Soil C and N pools were consistently greater under than between bunchgrass plants, and these differences were generally similar to or greater than topographic differences. Neither large nor small scale spatial patterns of N mineralization were as clear as C and N pool results. For most of the landscape studied, topographic variation in C & N appears to be less consistent than microscale heterogeneity related to patterns of plant cover, probably because runoff and associated material transport is limited.

HOOPER, DAVID U. and PETER M. VITOUSEK. Stanford University, Stanford, CA 94305-5020, USA. What's diversity got to do, got to do with it? Nutrient cycling in a California serpentine grassland.

Does diversity in functional characteristics of plants influence the cycling of nutrients, either in terms of soil transformations or losses from the system? In restored plots of California serpentine grassland, we observed no differences in N leaching losses among treatments using plants of four distinct phenological types (early and late season annuals, perennial bunchgrasses, and N-fixers) alone and in more diverse combinations. The only exceptions were significantly higher losses from bare plots and plots composed solely of N-fixing species. Annual aboveground productivity and litterfall varied widely among treatments, however (90-260 $g \cdot m^{-2}$). Though competitive effects of early season annuals influenced productivity of other phenological groups in the wet mid-winter phase of the growing season, they did not reduce late season annual biomass by the end of the season, indicating complementary resource use. Gross N mineralization rates of the more diverse treatments without N-fixers (1.07-1.35 $ugN \cdot g\ soil^{-1} \cdot day^{-1}$) did not differ significantly from the less diverse treatments without N-fixers (0.77-1.48 $ugN \cdot g\ soil^{-1} \cdot day^{-1}$). Because phenological diversity does not affect N losses or turnover in this system, but does increase accumulation in above-ground plant biomass, other factors such as soil microbial biomass may play important roles in nutrient retention in less diverse sites.

HOPPER, KEVIN R., and PHILIP H. CROWLEY. University of Kentucky, Lexington, KY, 40506, USA. Density-dependent and relative size-dependent effects of cannibalism on growth and survival in larval dragonflies (Epitheca cynosura).

Tradeoffs between growth benefits and avoidance of intraspecific predation (cannibalism) characterize ontogeny within cannibalistic populations. Among developing dragonfly larvae hatched in close proximity, these tradeoffs may be density-dependent and, moreover, may hinge upon size

asymmetry between potential cannibal and victim. We present two laboratory experiments that explore these possibilities in larvae of the dragonfly Epitheca cynosura. The first experiment addressed the effects of size on the frequency of cannibalism. The design included all pair-wise combinations of second through fourth instar larvae, the presence or absence of food, and whether or not cannibalism was possible. Tests of independence indicate that cannibalism rates increase with relative size advantage. The second experiment included eight treatment combinations based on two levels each of initial density, hatching synchrony, and food availability. Analysis of variance revealed greater density-dependent mortality with asynchronous than with synchronous hatching of larvae. Larvae initially at high density consistently grew larger than did those initially at low density. Although the higher food level produced larger mean larval sizes, ANOVA detected no significant food effect on survival. These responses are consistent with the density-dependent and relative size-dependent mechanism of cannibalism. Thus, cannibalism may (1) contribute to population regulation by imposing greater mortality at higher densities and (2) increase emergence synchrony by exerting heavy size-specific mortality on smaller larvae throughout development.

HORN, SALLY P. and LISA A. NORTHROP. University of Tennessee, Knoxville, TN, 37996, USA.
Precolumbian agriculture, fires, and forests in the Reventazón watershed, Costa Rica.

As part of a study of prehistoric human disturbance of rainforests in Costa Rica, we recovered and analyzed sediment cores from two adjacent lakes in the Río Reventazón drainage: Laguna Bonilla (380 m) and Laguna Bonillita (450 m). A reconnaissance archaeological survey in the 1960s revealed burial mounds and petroglyphs near the lakes, but the sites were regarded as only temporary habitation sites. Our paleoecological data show that the area around the lakes was permanently inhabited for thousands of years. Land was cleared and burned for maize agriculture, possibly as early as 4800 yr BP. This date is based on AMS-dating of small organic fragments in the Bonilla core; if correct it indicates that maize was grown here more than 2000 years earlier than suggested by lithic and ceramic artifacts from this and other areas of the Central Atlantic region. Fluctuating percentages of pollen of Cecropia and other weedy taxa suggest continual human and natural disturbance of lakeside communities.

HORTON, THOMAS R.[1], V. THOMAS PARKER[2] and THOMAS D. BRUNS[1]. [1]University of California, Berkeley, CA, 94720 USA. [2]San Francisco State University, San Francisco, CA, 94132, USA. Molecular verification that *Pseudotsuga menziesii* and *Arctostaphylos glandulosa* associate with the same fungal species in field collected mycorrhizae.

It has been suggested that invasion of *Pseudotsuga menziesii* into stands of *Arctostaphylos glandulosa* chaparral is facilitated by ectomycorrhizal fungi. Prior work on pure culture synthesis and observations of fruiting patterns demonstrate the potential for these two species to utilize the same fungal symbionts. However direct demonstration of shared symbionts in natural settings has been impeded because of an inability to identify fungi directly from mycorrhizal root tips. We circumvent this problem through the use molecular techniques. Our results demonstrate that when roots of mature *Arctostaphylos glandulosa* and *Pseudotsuga menziesii* seedlings are in close proximity, several fungal symbionts will associate with both plants. These results support the possibility that the existing hyphal network associated with *Arctostaphylos glandulosa* mycorrhizae contributes to the establishment of *Pseudotsuga menziesii*.

HORVITZ, CAROL C. AND JOHN B. PASCARELLA. University of Miami, Coral Gables, Florida 33124.
Sensitivity analysis for plants in hurricane-prone forests: matrix models analysis.

Sensitivity analysis in matrix models of population dynamics has been used in conservation as a way to identify and target critical life history stages for a given species in a particular environment, but not for dynamic environments. To examine the importance of temporal variation produced by hurricanes on the long-term population success of an understory shrub, Ardisia escallonoides, in a Florida tropical hardwood hammock, we built a matrix model of patch dynamics and population dynamics. Data on hurricane frequency and related levels of canopy disturbance were combined with some demographic data on the plants to parameterize the model, a 56 x 56 matrix, including 7 different levels of canopy disturbance and 8 different stage classes for the plant. The sensitivity of the overall population growth rate (the dominant eigenvalue) to demographic events within each of the temporal variants of the environment was calculated to determine whether the demographic events in the hurricane years were critical.

HOWE, MICHAEL J. and ROBERT G. WETZEL. The University of Alabama, Tuscaloosa, AL 35487-0344, USA. Population dynamics and seasonal growth and biomass patterns of an emergent rush (*Juncus effusus* L.) in a subtemperate Alabama wetland.

Seasonal changes in the population dynamics, biomass, and growth rates of the emergent rush *Juncus effusus* L. were evaluated over an annual period. Extant and emerging individual photosynthetic stems (culms) were labelled and their growth dynamics quantified. Lengths of live (chlorophyllous) portions and basal diameters of individual ramets were determined at weekly intervals and converted to biomass (AFDM) by regression ($r^2 = 0.97$) of surface areas to mass. Shoots emerged continuously at all times of the year, but the number of ramets increased from ca. 12,000 culms m^{-2} in June to ca. 20,000 culms m^{-2} in December. Individual culms in November-December, however, were 41-52% smaller in size than culms in June. Between plot variation in instantaneous above-ground biomass ranged from 1,733 $\pm$ 84 g AFDM m^{-2} to 3,147 $\pm$ 215 g AFDM m^{-2}, but within plot variation (SD/mean) varied seasonally by only 5 to 7%. Maximum growth of individual new culms (< 10 cm height) ranged from a maximum ($\pm$ SD) of 6.4 $\pm$ 2.0 mg day^{-1} in June to 1.1 $\pm$ 0.3 mg day^{-1} in November. Because of the continuous recruitment and gradual culm senescence, numerous multiple cohorts occur on an annual basis.

HUBBELL, STEPHEN P., ROBIN B. FOSTER and RICHARD CONDIT. Princeton University, Princeton, NJ 08544 USA; Museum of Natural History, Chicago, IL 60605 USA and STRI, APO-AA 34002-0098, Miami, FL. Gap disturbances: do they promote local diversity in the mature-phase tree community of tropical forests?

This paper describes the fates of juveniles of mature-phase tree species in more than 600 gaps in the 50 ha plot on Barro Colorado Island, Panama over a 12 year period. Changes in the relative abundance of mature-phase species during the building phase of gap regrowth are analyzed. The results show that in the data aggregated over all gaps, relative abundances of tree species in the mature-phase community changed very little. While pioneer species and late secondary heliophilic species do depend on gaps, these results raise questions about the efficacy of gaps in promoting the maintenance of mature-phase tree diversity in tropical forests. However, a caveat to this conclusion is the possibility that nonrandomly distributed gaps can generate density and frequency dependent population growth in patchily distributed tree species. This theoretical possibility has yet to be examined and will be reported in the paper when the results are known.

HUBER-SANNWALD, ELISABETH, DAVID A. PYKE, and MARTYN M. CALDWELL, Utah State University, Logan, UT, 84322-5230, USA, and Oregon State University, Corvallis, OR, 97331, USA. Growth responses of two competing perennial grasses under uniform and patchy nutrient environments.

Growth behavior and biomass allocation of two perennial grasses (Pseudoroegneria spicata,Agropyron desertorum) were compared under different competition and nutrient treatments. In a pot study we assessed the competitive ability of 2 plants under uniform and patchy nutrient application in monocultures and mixtures. Tiller production differed significantly between the species and two competition treatments. A. des. had greater tiller production when grown in monoculture, Ps. spi. when grown in mixture. Root and shoot biomass differed significantly between species and nutrient treatments. A. des. produced more root and shoot biomass under uniform nutrient application. Ps. spi. invested more biomass into roots under patchy conditions. Shoot biomass did not change with nutrient treatment. Despite the lower tiller production of Ag. des. in mixture, its shoot biomass was greater than that of Ps. spi. For Ag. des., tiller density did not change, whereas for Ps. spi. it changed under specific environmental conditions. These species reacted differently to intra- and interspecific competition as well as to the patterns of nutrient distribution. Thus, multiple variables need to be considered for predictions on competitive ability of species.

HUBERTY, LISA E. and KATHERINE L. GROSS. Michigan State University, Kellogg Biological Station, Hickory Corners, MI, 49060, USA. A graphical and statistical method for evaluating the impact of experimental treatments or environmental perturbations on species hierarchies.

The effects of the timing of nitrogen additions on community structure and the species hierarchy were examined in a 2nd-year old-field plant community, where variation in life histories created variation in the growth phenologies of the plant species. Community biomass doubled in response to nitrogen additions, and the ability to respond declined with additions made after mid-June. Nitrogen additions reduced biomass evenness and diversity, but not species richness. The dominant, Conyza canadensis, accounted for 51% of community biomass when no nitrogen was added, and 60-69% of community biomass when nitrogen was added. This dominant responded disproportionately to the subordinate plant community at each time of nitrogen addition. A graphical and statistical method will be introduced to evaluate the impact of experimental treatments or environmental perturbations on the hierarchy of species. The graphical analysis showed that the biomass hierarchy of species was relatively insensitive to the timing of nitrogen applications. However, the biomass of several individual species was sensitive to the timing of nitrogen applications. It appears that the dominant exerts a strong effect on the performance of subordinate plant species, and the ranking of species performance in this community. These results will be contrasted with a study in which removal of the dominant species created more variation in the hierarchy of species biomass.

HUCKINS, CASEY J.F. Kellogg Biological Station, Michigan State University, Hickory Corners, MI, 49060, USA. Interactions between native and introduced congeners in a sunfish guild.

An introduced species in Michigan provides an opportunity to examine coexistence of ecologically similar species. Pumpkinseed (Lepomis gibbosus) and redear (L. microlophus) sunfish have historically separate geographic ranges. These congeners are both molluscivores as adults, however redear appear to be more specialized based on electromyographic and morphological analysis of the pharyngeal jaw apparatus. Analysis of diets and relative snail crushing performance further indicate the greater specialization of redears. In lakes with artificial sympatry, created by a redear stocking program, within lake comparisons of growth rates show redears grow faster than pumpkinseeds. Also, growth rates of pumpkinseeds in lakes with introduced redears are lower than those without redears. This relationship, combined with a decrease in catch-per-unit-effort of pumpkinseeds in lakes following redear introduction, suggest a strong negative interaction between redear and pumpkinseed sunfish. The extent to which relative trophic specialization is the mechanism driving this pattern is not clear.

HUDDLE, JULIE A. and STEPHEN G. PALLARDY. School of Natural Resources, University of Missouri, Columbia, MO, 65211, USA. Survivorship of maple and oak seedlings after prescribed fire at three seasons and three fuel loadings and of potted seedlings after stem and soil heating.

To determine the effect of fire on survivorship of oak and maple, two experiments were conducted. First, planted seedlings were burned in three seasons under three different fuel loadings. Second, fire was simulated by application of a heated aluminum block to potted seedlings for ten minutes. Survivorship of Quercus rubra exceeded that of Acer rubrum and Quercus alba in all

prescribed burn plots. These differences in survivorship were significant between Q. rubra and A. rubrum in all April burn plots and between Q. rubra and Q. alba in both April and May low fuel plots. In the second experiment, order of survivorship was Q. rubra > Q. alba ≥ A. rubrum > A. saccharum. All A. saccharum and most A. rubrum and Q. alba survived the heating treatment by sprouting; in contrast, Q. rubra survived by both stem survival and sprouting.

HUENNEKE, LAURA FOSTER, New Mexico State University, Las Cruces, NM, 88003, USA. Plant community structure in Chihauahuan Desert ecosystems of New Mexico: results of grassland conversion to shrub-dominated communities.

Aboveground biomass of all plant species has been measured 3 times per year since 1989 in 15 sites at the Jornada Long-Term Ecological Research site in southern New Mexico. The sites include 3 examples each of *Larrea* shrublands, *Prosopis* dune systems, *Flourensia* shrub flats, *Bouteloua eriopoda* grasslands, and grassy playas. Results from nearly 5 years of sampling suggest that any single sample date will underestimate seriously the total species richness of any site. Not all interannual variation in species composition is due to differences in annual species. The 5 ecosystem types differ significantly in species richness, with grasslands containing the highest species numbers (50 - 70 per site) and *Prosopis*-dominated systems the lowest (20 - 35). Diversity and evenness analyses confirm substantial and consistent differences in community structure among ecosystem types. Relative productivities of species (system function) do not always reflect relative abundances (system structure). The conversion of *Bouteloua* grasslands to shrub-dominated systems in this century has resulted in an impoverishment of the flora.

HUME, H.G. and O.L. LOUCKS. Miami University, Institute of Environmental Sciences and Department of Zoology, Oxford, OH 45056, USA. Housing patterns, technology, and regulation as controls for protecting biological diversity in the Big Darby Creek Bioreserve, Ohio.

The loss of natural landscapes to urban sprawl was once driven by high density "tract" development, but more recently is dominated by conversion of rural land to low density "estates." Some specific impacts on ecology, biodiversity and sustainability are different, but many others are quite negative and remain unchanged. Innovations in housing development design, construction technology, and new approaches to development regulation offer new options for mitigating human impacts and achieving sustainability of ecosystems in close proximity to metropolitan centers. The Big Darby Creek, near Columbus, Ohio, a bioreserve of The Nature Conservancy, and a state scenic river, provides the study focus. The outcomes of three types of residential development and regulation are compared and evaluated -- utilizing GIS and modeling techniques -- for their effect on hydrologic regime, nutrient flows, sediment yield and stream biodiversity, all surrogates or indicators of ecosystem health.

HUMPHREY, L. DAVID and DAVID A. PYKE. Utah State University, Logan, UT, 84322, USA and NBS Cooperative Research and Technology Unit, Corvallis, OR, 97331, USA. Response of tiller numbers and biomass in competitive mixtures of caespitose and rhizomatous perennial grasses.

Tiller production of rhizomatous Elymus lanceolatus ssp. lanceolatus and caespitose E. l. ssp. wawawaiensis was studied to determine its effect on biomass and competitive ability. Biomass and tiller numbers were assessed for two-species mixtures over a range of densities of each taxon, two years and intervals over the growing season. Biomass and tiller numbers of ssp. lanceolatus, the better competitor, declined greatly from 1990 to 1991, when resources were depleted; ssp. wawawaiensis differed with less decrease in biomass and increase in tiller numbers. Taxa differed in phenology of tiller production: all tillers of ssp. wawawaiensis emerged in fall, and tillers of ssp. lanceolatus emerged in fall and spring. In 1990, ssp. lanceolatus better exploited open resources by greater growth, rhizomatous spread and greater tiller production. Although ssp. wawawaiensis's lower tiller production in 1990 and slower growth implies stress tolerant traits, its greater fall tiller production may allow it to quickly exploit seasonally variable conditions.

HUNGATE, BRUCE A.[1], ELISABETH A. HOLLAND[2], JOSEP CANADELL[1], HAILIN ZHONG[1], and F. S. CHAPIN III[1]. [1]University of California, Berkeley, CA, 94720, USA, and [2]National Center for Atmospheric Research, Boulder, CO, 80307, USA. Elevated Atmospheric CO_2 Increases Microbial Nitrogen-demand, but Plants Outcompete Microbes for Inorganic N.

Soil microbial biomass C increased after 3 months of exposure to elevated atmospheric CO_2 in serpentine and sandstone annual grasslands, but microbial biomass N did not change. We suggest that C:N ratio is plastic within the soil microbial community, shifting in response to the relative availability of C and N. The observed increase in C:N ratio indicates decreased C- and increased N-limitation of microbes, consistent with the increase in microbial N-immobilization we found for the same samples in laboratory incubations. When both plants and microbes were given equal access to 15NH4 in the field, however, plant uptake increased under elevated CO_2, but microbial immobilization did not change. This suggests that elevated CO_2 increases plant N-demand more strongly than microbial N-demand.

HUNSAKER, CAROLYN and ROBERT O'NEILL. Oak Ridge National Laboratory, Oak Ridge, TN, 37831-6038, USA. **Understanding factors that influence pattern metrics for monitoring landscapes.**

Since landscape pattern is relatively easy to measure with remote sensing techniques, it should be an effective tool for monitoring ecological condition. The way in which landscape pattern is measured is a function of many attributes, but three are especially important--data resolution or grain, geographic extent, and number of land-cover types. For 13 ecoregions in the United States we examined the behavior of landscape pattern metrics (dominance, contagion, shape complexity, and proportion of possible edge types) when the number of land-cover types is aggregated from 14 to 7. Data resolution was kept constant at 1 km^2. Behavior of metrics includes range of values, ecoregion with highest and lowest values, and orthogonality or co-linearity. The values of the metrics decrease, as expected, as the number of land-cover types increase, except for shape complexity which increased. The ecoregions with the highest and lowest values for a metric often were not the same for different numbers of cover types. These results will help with the design of landscape monitoring for regional assessments.

HUNTER, ALISON F. University of British Columbia, Vancouver, BC, V6T 1Z4, Canada. Flightless forest Macrolepidoptera: outbreaks, phenology and phylogeny.

Phylogeny-based comparative methods were used to examine the correlation between reduced wings and ecological traits of temperate forest Macrolepidoptera. Non-phylogenetic comparisons show that reduced wings are associated with spring feeding, overwintering as eggs, placing eggs in a single egg mass, high host breadth, high fecundity, and outbreaking population dynamics. Phylogenetic analysis revealed that reduced wings have evolved only in spring-feeding lineages. Reduced wings are slightly more likely to evolve in species that overwinter as an egg than in other stages. Egg clustering was not related to the appearance of reduced wings. There is little indication of an effect of host breadth or fecundity, but the data are limited, particularly for fecundity. Wing reduction and population outbreaks are correlated, but how this correlation arises is not clear; a possible scenario is outlined. Although the data set considered here contains 33 species with reduced wings in the Lymantriidae and Geometridae, there were just 7 independent origins of this trait, so the phylogenetic tests have low sample sizes.

HUNTER, JOHN C. University of California, Davis, CA, 95616, USA. The litter layer as a barrier to seedling emergence in California's mixed evergreen forests.

California's mixed evergreen forests are dominated by broadleaf sclerophyllous trees. This study's results indicate that the litter layer of such forests forms a partial barrier to the emergence of seedlings of Pseudotsuga menziesii and Arbutus menziesii, which are the smaller seeded species of these forests. In 0.5 sq. m plots from seven stands (n = 28), the litter layer ranged from 0-7.5 cm deep (ave. 2.8 cm) and covered 90% of the surface. In an experiment with Arbutus, no seedlings emerged from 7.5 cm deep litter, and fewer emerged from 3 cm deep litter (13%) than from the no litter control (81%). In an experiment with Pseudotsuga, almost no seedlings emerged from 7.5 cm deep litter (0.7%), and fewer seedlings emerged from 3 cm deep litter (12%) than from the no litter control (19%). When litter was shredded into pieces smaller than 1 sq. cm and placed 3 cm deep, more Pseudotsuga seedlings emerged (42%) than in the no litter control (19%).

HUNTER, MARK D. and JACK C. SCHULTZ. Université Laval, Ste-Foy, Québec G1K 7P4, CANADA and Pennsylvania State University, University Park, PA 16802, USA. Impacts of disease on insect herbivore populations: need we know more?

The quality of host plant foliage can influence the susceptibility of insect herbivores to their pathogens. The gypsy moth, Lymantria dispar, for example, is less susceptible to infection by a nuclear polyhedrosis virus on some host species than on others. Differences in foliage quality among forest stands and even among leaves within individual trees influence the infection of gypsy moth larvae by virus. Moreover, a literature search shows that infection of insect herbivores by pathogens has proven to be host plant-dependent in almost every case where foliage quality has been considered. We conclude that population models of insect disease that do not consider spatial and temporal heterogeneity in host plant quality are unlikely to represent accurately host or pathogen dynamics. We suggest that, particularly for polyphagous pest species, models should include parameters that describe spatial variation in foliage quality as well as the distributions of the pathogen and insect host.

HUNTINGTON, THOMAS G. U.S. Geological Survey, Atlanta, GA, 30360, USA. A Comparison of environmental factors in southern pine beetle infested and uninfested loblolly pine forests in the Georgia Coastal Plain.

Infestations of southern pine beetle in loblolly pine forests of the extreme northwestern Coastal Plain of Georgia have been unprecedented in their persistence and not explained by climatic, silvicultural, or other known factors. An assessment has begun to determine whether atmospheric acidic deposition, ambient concentrations of sulfur dioxide and ozone, or soil chemical properties are associated with the incidence of beetle infestation. Preliminary results after 1 year of measuring acidic deposition in throughfall at infested and uninfested locations do not support the hypothesis that infested areas are currently receiving higher rates of acidic deposition. Measurements of ambient concentrations of sulfur dioxide were within the normal background levels expected for rural Georgia. Ozone concentrations frequently exceeded 50 to 60 ppb for several hours during growing season days and may be a contributing stress but there is insufficient data to detect any association between infestation and ozone concentrations. Soil samples were collected within 28 infested and 28 adjacent uninfested forest stands at 0-20, 20-60, and 60-100 cm depth strata. Unbuffered 1 N ammonium chloride was used to extract the samples to determine cation exchange capacity (CEC) and base saturation. There were no significant differences in base saturation between infested and uninfested forest stands and the mean base saturation for all soils was 54%. CEC was significantly lower in infested stands below 20 cm soil depth averaging 1.82 and 2.3 $cmol_c\ kg^{-1}$ for infested and uninfested soils respectively.

HUNTLY, NANCY and PETER CHESSON. Idaho State University, Pocatello, ID, 83209, USA and Australia National University, Canberra, Australia. Differential germination responses of desert annual plants to spatially and temporally varying environmental conditions.

Fluctuations in weather conditions that affect germination of plants can be an important mechanism affecting coexistence and diversity. We show that the major species of winter annual plants (Eriogonum abertianum, Eriastrum diffusum, Descurainea pinnata, Spermopelis echinata, Haplopappus gracilis, Baileya multiradiata, Cryptantha micrantha) in our Chihuahuan desert study area differ significantly in germination among years, among times within a year, and among microhabitats. Experiments show that these germination patterns are responsive to temperature and water availability; thus they vary with weather conditions among and within years. The experiments also show that plant competition is strong and is influenced by germination timing and water availability. Our data show both among-year and within-year storage effects that can contribute significantly to coexistence of these desert annual plants.

HUTCHINSON, TODD F. and JOHN L. VANKAT. Miami University, Oxford, OH 45056, USA. Invasion by Lonicera maackii in Ohio forests: community invasibility and tree regeneration.

The Asian exotic Lonicera maackii has become the dominant shrub in many forests in southwest Ohio and in some other locations of the eastern U. S. Lonicera maackii has been widely used as an ornamental, and in our area was first planted approximately 30 years ago. Our research focused on the invasibility of forest communities and possible effects of L. maackii on tree seedling abundance. One hundred forest stands of differing canopy cover were surveyed near Oxford, OH to determine L. maackii cover, tree canopy cover and composition, and tree seedling density. We found that L. maackii cover was inversely related to tree basal area and canopy cover, indicating that mid-successional and disturbed forests are more invasible than late-successional forests and suggesting that light intensity is important in L. maackii abundance. Lonicera maackii cover was also found to be inversely related to tree seedling density, implying that L. maackii alters tree regeneration.

HYATT, LAURA A. University of Pennsylvania, Philadelphia, PA 19104, USA. Seed bank dynamics : spatial variation in sources of loss and gain.

Conventionally, seed bank studies have concentrated on censusing techniques, examining the potential contribution of seed banks to community structure. However, we know very little about the sources of gain and loss to seed banks, and the historical reasons for spatial heterogeneity in seed bank composition. To study spatial variation in seed bank dynamics, seed rain was collected in trays of sterilized soil inside and outside patches of blackberry (*Rubus allegheniensis*), the dominant species in a 4 year old 2 hectare forest disturbance. Half the soil from each tray was brought into the greenhouse while half stayed in the field. This permitted comparisons of seed rain with losses due to germination in the field in the following year. Total seed numbers did not differ with respect to vegetation patch type, but more species were deposited in blackberry patches. The three most common seed bank species made up a larger proportion of all seeds in the open sites. There was also a trend for less common species to germinate more readily in the open. These short term dynamics result in greater retention of less common species in soils beneath blackberry. Thus vegetation heterogeneity in space and time can affect seed bank dynamics and its contribution to future community structure.

INGHAM, ELAINE R. Oregon State University, Corvallis, OR 97331-2902 USA. Controlling Factors in Conifer Forest Soils: Soil Foodweb Organisms or the Vegetative Community?

Do soil organisms control plant establishment or are organisms in soil merely the consequence of the vegetative community? Which develops first, plants or soil organisms? In the Pacific Northwest, conifers cannot establish in soil where the decomposer biomass is dominated by bacteria. Soils must be dominated by fungal biomass or re-generation of conifers may not occur. Mycorrhizal fungal species can be depleted in forest soils and reduce the survival and reproductive success of many species of plants. The presence of fungal or bacterial pathogens, or root-feeding nematodes in soil may preclude the survival of plant species whose distribution has been predicted to change with global climate change. Without attention to biotic as well as abiotic factors controlling plant distribution, many species will not survive. Evidence also indicates that changes in single species of bacteria, fungi, protozoa, nematode, microarthropod or earthworm can result in changed plant species abundance. For example, invasions of earthworms into relatively pristine conifer forests in North America could have devastating effects on nutrient cycling through alteration of soil foodweb communities. These interactions offer opportunities to test the stability and successional responses of ecosystems with complex foodwebs.

INOUYE, DAVID W. Dept. of Zoology, University of MD, College Park, MD 20742, and Rocky Mtn. Biological Laboratory, Crested Butte, CO 81224. Life history variation in *Frasera speciosa* (Gentianaceae): Is longer and bigger better?

Frasera speciosa is a long-lived herbaceous perennial monocarp characteristic of montane meadows of the Rocky Mountains. Previous work showed that plants in a high-elevation (3,750 m) alpine population flower at estimated ages ranging from 27

- 56 years, and that flower stalk height is correlated with size of the basal rosette achieved before flowering. In this study an explanation was sought for the wide range of sizes (and probably ages) at which plants reproduced. Individual plants were followed for up to 19 years, until they flowered in 1992. Flower stalks were measured, flowers were counted, and fruit samples collected in order to estimate ovule production and seed set. In 1993 a careful search was conducted for seedlings produced by each of the flower stalks (seed dispersal is very limited). Flower stalk height, number of flowers on the stalk, number of ovules, number of seeds, and number of seedlings are all significantly correlated with the number of leaves in the basal rosette in 1991. There is some suggestion in the data of a decrease in seed set and number of seedlings with increasing size, which might explain the upper limit of size (age) before flowering.

INOUYE, RICHARD S. and DAVID TILMAN. Idaho State University, Pocatello, ID, 83209, USA and University of Minnesota, St. Paul, MN, 55108. Convergence and divergence of old-field plant communities along experimental nitrogen gradients: patterns after 11 years.

We tested the hypothesis that plots with similar supply rates for a limiting resource should have similar plant species composition. Plots that received different levels of nitrogen became less similar; the degree of difference between plots depended on both the absolute and relative difference in added nitrogen. Where a species that became dominant was initially widespread, convergence was rapid and consistent among plots. In contrast, more heterogeneous and species-rich vegetation tended to converge more slowly, with less predictable trajectories. In many cases, relatively short-term (3-5 year) results were not consistent with the results after 11 years. Our data clearly illustrate the roles that initial species composition and establishment can play in determining short-term responses to experimental manipulations, and the need for long-term experimental manipulations.

IRELAND, P. L. and G. N. CAMERON. University of Houston, Houston, TX 77204 USA. Effect of fire ants on the arthropod community and fitness of plants in the upper Texas coastal prairie community.

Populations of red imported fire ant, *Solenopsis invicta*, reach densities >1,000 mounds/ha in coastal prairie in Texas, but effects on native flora and fauna are poorly understood. Fire ants are entomophagous and negatively impact native ants. A 2 yr press experiment investigated effects of fire ant removal on arthropods and annual plants of the upper Texas coastal prairie. To test the prediction that fire ants positively affect plant fitness by preying on herbivorous insects, experimental plots at the University of Houston Coastal Center were treated with Logic®, an insect growth regulator specifically formulated to kill fire ants. Fire ants were reduced by 80% on treated plots; native ants were not affected by this treatment. Preliminary analyses revealed that fitness of the annual herb, *Rudbeckia hirta*, measured as number of seeds and seed mass, was not affected by fire ant removal. However, abundance of some insect groups (e.g., lacebugs, flea beetles) and spiders changed on treatment plots, but species diversity was not altered. Thus, fire ants modify species makeup of the coastal prairie insect community, but appear to have minor effects on overall diversity.

ISHII-EITEMAN, MARCIA J. Cornell University, Ithaca, NY 14853, USA. Influence of plant density and dispersion on egg parasitism of green rice leafhoppers in Thailand.

Transplanted rice fields have a low density of uniformly spaced plants, while broadcast-seeded fields have a high density of irregularly dispersed plants. From 1989 to 1991 I tested the effects of seeding practice on the abundance of the leafhopper, Nephotettix virescens, and on the parasitism rates of Paracentrobia and Gonatocerus in Thailand. Hopper densities were greatest in broadcast fields early in the season, but later were higher in transplanted fields ($p<0.001$). Paracentrobia was an early immigrant to newly planted rice fields despite extremely low host densities, and parasitized more eggs when plants were uniformly dispersed particularly mid-season, regardless of tiller density ($p<0.02$). Parasitism by Gonatocerus, which replaced Paracentrobia as the dominant parasitoid mid-way through the rice season ($p<0.001$), was influenced by neither plant dispersion nor tiller density, but responded positively to host abundance ($p=0.008$). Together the parasitoids provide important natural control of the leafhopper, but the ecological factors influencing parasitism differ markedly between the two.

IVERSON, LOUIS R. Northeast Forest Experiment Station, US Forest Service, 359 Main Road, Delaware, OH, 43015, USA. The Illinois Plant Information Network: an information database for regional analysis of vascular plant biodiversity.

The Illinois Plant Information Network (ILPIN), a species-based database under development since 1983 at the Illinois Natural History Survey, has been a useful database for assessing botanical diversity in Illinois. All known vascular plant taxa (over 3,200) are included. It includes county distributions (totalling nearly 90,000) for each taxon and information on the taxonomy, ecology, biology, and ecodistribution of each. Summary maps and tables on the Illinois flora can thus be easily generated, such as number of taxa by county or subsets thereof (number of threatened and endangered species, number of exotics, number of native, forest-associated species, etc). Via geographic information system overlay analysis and

statistics, the database also can yield information on the regional ecological factors associated with the flora. As examples, 1,581 taxa are associated with forests, and the Southern Unglaciated natural division has the highest concentration of rare taxa.

KANDL, KAREN L. University of Georgia, Athens, GA, 30605 and Savannah River Ecology Laboratory, Aiken, SC, 29802, USA. Inbreeding, family, and genotype affect environmental tolerance of mosquitofish.

Both environmental stress and inbreeding can affect the survival of organisms, but the simultaneous effects of environmental stress and inbreeding have not been clearly demonstrated. This study measured the effects of inbreeding on tolerance to salinity stress, as well as the influence of family, and multi-locus and single-locus genetic effects. Mosquitofish (Gambusia holbrooki) having inbreeding coefficients of F=0, 0.125, and 0.25 were exposed to an acute salinity stress (14.3 ppt) for 96 hours. Survival time was measured in hours, and Proc LIFEREG in SAS was used for survival analysis. Both inbreeding class and family were significant in determining survival time of mosquitofish in salinity stress. Several single-locus genotypes also had significant effects on survival, and these contributed to a marginally significant effect of multi-locus heterozygosity. These data demonstrate that an organism's breeding, family, or genetic history may influence survival in changing or stressful environments. In organisms with moderate inbreeding coefficients, family effects were more important than inbreeding effects in determining survival. Short-term experiments under stressful conditions may be useful in elucidating long-term consequences of inbreeding.

KARBAN, RICHARD. University of California, Davis, CA 95616, USA.
Fine-scale adaptation of weakly dispersing thrips to individual host plant clones.

Populations of the herbivorous thrips, Apterothrips apteris were affected strongly by their individual host plants, Erigeron glaucus. Some host individuals consistently supported high densities while others were consistently free. Thrips from a particular host individual were more successful on that "home" host than on other nearby neighbors. The plant traits that influence thrips populations are heritable and affected by both maternal and paternal influences. Limited movement of thrips was associated with local adaptation. Clean plants placed in the field received only 1.47 immigrants during a year. Most immigrants were able to reproduce. Limited movement appeared to be more important as a barrier to colonization than was demographic success following arrival at a new host plant.

KARRON, JEFFREY D. University of Wisconsin, Milwaukee, WI, 53201, USA. Mating systems and patterns of genetic variation in different types of rare species.

Rabinowitz described three distinct forms of rarity: 1) localized endemics have small geographical ranges; 2) habitat specialists are only found in one or a few habitat types; and 3) sparse species occur at low local density throughout their range. Evolutionary theory suggests that these forms of rarity may differ with respect to patterns of genetic variation and mating systems. For example, due to the effects of genetic drift in small populations, localized endemics and habitat specialists tend to exhibit significantly lower levels of polymorphism than are found in closely related widespread congeners. By contrast, many sparse species have large numbers of individuals and exhibit levels of polymorphism comparable to more abundant taxa. Several localized endemics, such as Astragalus linifolius, receive poor or unreliable pollinator service and have higher levels of self-fertility than are found in closely related widespread congeners. Other endemics, however, are self-incompatible and appear to lack alleles for self-fertility. The breeding systems of sparse species have received little study. However, experiments with widespread taxa, such as Mimulus ringens, suggest that population density can dramatically influence outcrossing rates.

KASMER, JOHN M. University of Michigan, Ann Arbor, MI, 48109, USA. Twig growth and abscission in *Populus tremuloides*: responses to different shading treatments.

To determine the role of light in causing twig abscission in natural clones of *Populus tremuloides*, I subjected branches to 4 shading treatments and observed the growth, bud conditions, and fates of the branches and their leaf-bearing twigs over a single growing season. I used a nested design with 8 clones and 3 trees/clone. On each tree, I chose exposed branches (with an average of 7 twigs each) to receive one of the following treatments: green plastic (Gr; to decrease red:far-red ratio), neutral shade (Ne; to alter only the quantity of light), clear plastic (Cl), and an unshaded control. While abscission rates were doubled under Ne and Gr, Ne and Gr had similar rates: thus shade causes abscission, but the red:far-red ratio is not a direct cue. Stunted buds were 1.5x more frequent under Gr than under other treatments, indicating the red:far-red ratio affects development of buds; because twigs with stunted buds are abscised with higher frequency, light quality is an indirect cue to shed shaded twigs. While volume growth of retained twigs was similar in all treatments, the net seasonal growth of branches+twigs was lower under Ne and Gr due to higher abscission rates. Thus, *P. tremuloides* is using a variety of cues to ensure that resources are allocated only to twigs and crown positions that are productive. Such behavior may be critical in maximizing the growth rates of individuals of this and other shade-intolerant species.

KASPARI, M. and VARGO, E. Lawrence Livermore Labs, Livermore CA, 94550, USA and Dept. of Zoology, Univ. of Texas, Austin, 78712, USA. Colony size as a buffer against seasonality: Bergmann's rule in social insects.

In eusocial species, the size of the superorganism is the summed sizes of its component individuals. Bergmann's rule, the cline of decreasing size with decreasing latitude, applies to colony size in ants. Using data from the literature and

our own collections, we show that colony sizes of tropical ant species are on average 1/10th the size of temperate species. The pattern holds for 5 of 6 subfamilies and 15 of 16 genera tested. What causes this trend? Larger colonies of the fire ant, *Solenopsis invicta,* are better able to protect the queen (the colony's reproductive tissue) against food shortage, likely by sacrificing workers (it's somatic tissue). Days of queen survival follows the allometry $M^{0.25}$. We propose that the shorter growing seasons in temperate latitudes cull small-colony species through over-wintering starvation.

KAUFMAN, DONALD W., GLENNIS A. KAUFMAN, and ELMER J. FINCK. Kansas State University, Manhattan, KS, 66506, USA. Patterns of abundance of small mammals in tallgrass prairie.

Small mammals were studied on Konza Prairie to describe long-term temporal patterns of abundance in ungrazed tallgrass prairie. Abundances were estimated from captures along permanent live-trap lines during 1981-1991. Common species, in descending order of abundance, were Peromyscus maniculatus, Reithrodontomys megalotis, Blarina hylophaga, P. leucopus, Microtus ochrogaster, Sigmodon hispidus, Spermophilus tridecemlineatus, and Synaptomys cooperi. Timing and magnitude of high and low abundances varied widely among species. However, both Peromyscus were less variable than Microtus and Synaptomys; Microtus and Synaptomys appeared cyclic with relatively synchronized highs and lows; and autumn abundances of Peromyscus, Reithrodontomys, and Sigmodon were intercorrelated. Finally, patterns of abundance did not correlate consistently with indices of temperature, precipitation, and productivity which suggests that these factors were not simple determinants of temporal patterns of abundance of small, prairie mammals.

KAUFMAN, GLENNIS A., DONALD W. KAUFMAN and ELMER J. FINCK. Kansas State University, Manhattan, KS 66506, USA. Fire effects on small mammal communities in tallgrass prairie.

We initiated a long-term study in burned and unburned tallgrass prairie to examine the effects of fire on communities of rodents and shrews on the Konza Prairie. Small mammal responses were based on census-line data collected from autumn 1981 to spring 1991. Experimental spring fires on ungrazed treatment sites ranged from annual intervals to 20 years between fires. In addition to comparing small mammal communities in burned and unburned prairie, we examined effects of burning (annual vs. periodic fire) and lack of burning (short-term = 2-4 years vs. long-term = 8-20 years since last fire) on communities. The community of small mammals in unburned prairie was richer and more diverse than the community in burned prairie. Further, the community that developed after periodic fire was richer, more diverse and more even than the community that developed after an annual fire. Communities in long-term unburned prairie were richer and more diverse than communities in short-term unburned prairie.

KAUFMAN, M. G., E. D. WALKER, R. W. MERRITT, and M. J. KLUG. Michigan State University, W. K Kellogg Biological Station, Hickory Corners, MI 49060. Larval mosquito feeding and microbial community dynamics in container habitats.

We examined the potential interaction between larval *Aedes triseriatus* and the aquatic microbial community in treehole and artificial container habitats with a microcosm experiment. Containers were seeded with dried beech leaves, stemflow water collected from beech trees, and microbial inocula from beech treeholes. Experimental treatments included the presence or absence of larvae and the addition (or not) of a weekly stemflow event. Microbial dynamics were monitored by direct microscopic counts, plating on general media, monitoring of ion concentrations, and analysis of whole community and isolate fatty acid patterns. The presence of larvae decreased bacterial numbers on leaf material, increased the relative proportion of facultatively anaerobic bacteria in the water column, and inhibited nitrification processes in treatments without stemflow. Principle component analysis of fatty acid patterns further revealed a distinction between microbial communities; eukaryotic fatty acids were reduced in the presence of larvae. PCA of fatty acid patterns also indicated that microbial communities in these habitats are likely to become less predictable with increasing levels of disturbance in the form of larval feeding and stemflow.

KAYE, THOMAS N., KATHY CONNELLY, and KAREN FINLEY. Oregon State University, Corvallis, OR, 97331, USA. Population viability analysis of an endangered plant, *Lomatium bradshawii*, under three prairie burning treatments.

Lomatium bradshawii is an endangered plant species of western Oregon prairies that were burned annually by Native Americans prior to Euro-American settlement. The plants are perennial, reproduce by seed only, and do not maintain a persistent soil seed bank. We used transition matrix models incorporating observed environmental stochasticity to determine the effects of prescribed fires on the viability of two populations. Three fire treatments were used: burned three times in six years (1988-1993), twice in six years, and not burned (control). Burning tended to improve fruit production and subsequent seedling recruitment, and lower mortality of seedlings and small vegetative plants. In addition, fire increased the equilibrium population growth rate (λ) of both populations from 0.943 and 0.928 (respectively for each population) without burning, to 1.110 and 0.976 when burned in two years, to 1.190 and 1.014 when burned three times. The risk of extinction declined sharply with increased fire frequency, from 100% without fire at both populations, to 100% and 52% when burned twice, to 0% when both populations were burned three times. Fire is an effective tool for maintaining viable populations of this endangered species. Our results suggest that in the absence of fire, even large populations will eventually decline to extinction.

KEARSLEY, LISA H., LAWRENCE E. STEVENS AND JOHN C. SCHMIDT. Grand Canyon National Park, Grand Canyon, AZ 86023 and Utah State University, Logan Utah 84322. Riparian plant diversity in the Grand Canyon: disturbance, productivity and geomorphic influences.

The dynamic equilibrium hypothesis (DEH, Huston 1979) predicts that productivity and disturbance interactively affect the diversity of sessile organisms. We test DEH predictions using primary productivity, flow-related disturbance intensity and riparian plant species density (S, number of species/m^2) in eight 0.5 km-long GIS study reaches of the regulated Colorado River in the Grand Canyon. S is non-linearly correlated with both primary productivity and disturbance intensity, and these patterns are mediated by within-site geomorphic differences. S is positively correlated with grain size ($F=11.320$, $p < 0.001$). Lowest diversity occurs in moderately disturbed, low productivity sand bar platforms, while highest diversity occurs in highly disturbed, highly productive fluvial marshes. Support for EDH predictions in highly productive, pristine springs indicates that regulated river corridor plant diversity reflects influences of both pre-dam and post-dam flood frequencies.

KEARSLEY, MICHAEL J.C., LAWRENCE E. STEVENS, and TINA J. AYERS. Northern Arizona University, Flagstaff, AZ, 86011, USA, and Grand Canyon National Park, Grand Canyon, AZ, 86023, USA. Interim flow effects on fluvial marsh plant communities in Grand Canyon.

We examined the effects of an altered flow regime on the development of fluvial marshes in the dam-regulated Colorado River in Grand Canyon. Nine marshes were studied using more than 1600 1 m^2 plots in strip transects and grids. Ordination of the assemblages with a subsample of 300 plots defined 8 distinct groups based on growth form and habit. During two years of "interim flows," reduced daily fluctuations and slower ramping rates in water releases resulted in reductions in inundation frequency, deposition of fine soils, bank scouring and periodic removal of accumulated litter. Concurrently there has been a loss of species diversity and a shift from wet (*Typha / Scirpus / Juncus*) to drier (*Salix / Equisetum / Cynodon*) marsh plant assemblages in higher elevation areas, and a downslope displacement of the wet marsh species towards the river. Thus, management practices variously emphasizing productivity, diversity, stability, and target species are in conflict.

KEIFFER, CAROLYN H. and IRWIN A. UNGAR. Ohio University, Department of Environmental and Plant Biology, Athens, OH, 45701, USA. Germination of seeds of five halophyte species under various salinity treatments.

Seeds of five halophytes; *Atriplex prostrata, Hordeum jubatum, Salicornia europaea, Spergularia marina* and *Suaeda calceoliformis* were germinated in 0.0, 1.0, 2.0 and 3.0% NaCl solutions. A 2-way ANOVA followed by Fisher's LSD comparison revealed a significant difference ($P< 0.001$) amongst salinity treatments with germination being inversely proportional to increasing salinity. Of the five species, *H. jubatum* seed had significantly lower germination while *S. calceoliformis* had the greatest percentage of seeds germinating in all salinity treatments. All seeds failing to germinate after 30 days were placed in distilled water to initiate recovery. Results indicated that the least salt tolerant species, *H. jubatum*, had the lowest germination percentages while *A. prastrata* was the least inhibited by exposure to salinity.

KEITT, TIMOTHY H. University of New Mexico, Albuquerque, NM, 87131, USA. Self-organization and Spatial Complexity in Random and Evolved Replicator Networks.

A model in which replicator dynamics were simulated on a spatial lattice of cells is presented. Probabilistic rules determined the outcome of species interactions. Two cases were explored 1) local movement to neighboring cells (diffusion-limited) and 2) non-local movement to randomly chosen cells (homogeneous mixing). In the homogeneous case, simulations started with 254 randomly chosen rules typically collapsed to a single species, whereas in the diffusion-limited case, closed chains of interaction (hypercycles) spontaneously emerged resulting in traveling waves. The emergent spatial patterns resulted in greater species richness than predicted by the linear stability arguments. Simulations where lattices were randomly fragmented also produced anomalous results, with maximum richness observed when 70% of cells were removed. In other simulations, novel rules or strategies were introduced randomly or evolved using genetic algorithms. Under these conditions, the community of strategies built-up eventually finding a set of minimally stable configurations prescribing a hyperbolic relationship between species richness and web connectance. The minimally stable networks resulted from opposing constraints of stability and productivity.

KELLEY, STEVEN E. AND DANIEL A. SIMS. Emory University, Atlanta, GA, 30322, USA. Sun-shade ecotypic differentiation: a role for virus infection?

Sun-shade ecotypic differentiation has been claimed for numerous species. In random samples of two such species, *Anthoxanthum odoratum* and *Plantago lanceolata*, we found that the incidence of viral infection was significantly higher in the shade vs.the sun. We hypothesized that physiological and fitness differences between sun/shade plants may be partly caused by viral infection. To test for ecotypic differentiation, ramets of the two species were sampled from adjacent shade and sun habitats and clonally propagated. Seeds obtained from pollinations within populations were germinated, grown to adult size, and clonally propogated. All material was transplanted into three habitats: field, forest, and shade-structures (built in the field). Half of the plants were then inoculated with one of two viruses: Tobacco Mosaic Vivus (for *Plantago*) and Brome Mosaic Virus (for *Anthoxanthum*). The results showed that viral infection

significantly affected plant fitness, and the magnitude of the effects depended upon the environment in which the plants grew. Further, there was evidence of ecotypic differences. Observed physiological and fitness differences between shade and sun plants are likely to be caused by both genetical differences and viral infections.

KELLY, CAROL A. University of Missouri-St. Louis, St. Louis, MO, 63121, USA. Life history and morphological variation along an elevational gradient in Solidaga macrophylla.

The large leaved goldenrod, Solidago macrophylla, has been considered to consist of two subspecies, one that grows above treeline and one that grows below treeline in the White Mountains of New Hampshire. During 1992 and 1993 I documented variation in morphology, life history, and fitness traits as well as plant defense against three herbivore guilds for 15 populations of S. macrophylla over an elevational gradient. Three morphological traits showed a curve linear relationship with elevation, with largest forms existing at intermediate elevations. Two life history traits exhibited a positive relationship with elevation, while one morphological and two fitness traits exhibited a negative relationship with elevation. While onset of flowering and plant defense exhibited a negative relationship with elevation, the relationship was not as strong or as consistent as for the other traits. No trait showed an abrupt change in phenotype at treeline. Current work focuses on determining the mechanism of and the genetic basis for population variation in fitness along this elevational gradient.

KELLY, COLLEEN K. and R. PEREZ-ISHIWARA. University of North Texas, Denton, TX, 76302-5218 USA and Centro de Ecología, UNAM, AP 70-275, CP 04510, México D. F., México. Breaking up is hard to do: Fragmentation and survivorship in Cuscuta corymbosa.

We report here the first experimental results showing fitness consequences for clonal "exploration for resources," an oft-cited, but never demonstrated, advantage to clonal growth. Our results show that natural breakage can have significant effects on whole-plant architecture and survivorship under field conditions, and that these effects are not predicted from the effect of experimental severance on detached ramets or ramet groups. Experimental severance of between-ramet connections in Cuscuta corymbosa decreased growth up to 60% of that of unmanipulated ramets, but comparison of the effects of breakage on whole plants under natural conditions revealed no association between breakage and either number of ramets or total stem length (biomass accumulation) of same-genotype individuals. Rather, breakage was associated with decreased distances between ramets, and decreased ramet proliferation and survivorship of ramets acropetal to a break; ramets basipetal to a break gave rise to significantly more ramets than otherwise expected. Breakage was negatively associated with whole plant survivorship into the dry season, and it is suggested that the effect of breakage is due to the observed changes in architecture on resource colonization ability.

KELLY, ROBIN H. and INGRID C. BURKE. Colorado State University, Fort Collins, CO 80523, USA. The role of roots in soil organic matter formation and maintenance in a shortgrass steppe ecosystem.

The role of roots in soil organic matter formation and recovery is an important and poorly understood component of disturbance dynamics in the shortgrass steppe. We conducted field and laboratory studies on the role of roots in soil organic matter (SOM) dynamics using Western Harvester ant (*Pogonomyrex occidentalis*) nests to provide a root input gradient. The nests have a "disk" area that surrounds the central mound and is maintained with no aboveground and few belowground inputs for many (29 - 58) years, with minimal physical disturbance to soil structure. Root biomass decreases from the outside edge to the center of the disk. A nest can be aged by its morphology, allowing us to examine soil organic matter dynamics over gradients of root density and disturbance age. Active soil organic pools, indexed by potentially mineralizable C and N, responded with greater proportionality to both disturbance age and the root gradient than total C and N pools, because they are dependent upon inputs over a short period of time. Results of this study allow us to test the temporal and spatial predictions of current models of SOM formation and maintenance.

KELSO, DONALD P. George Mason University, Fairfax, VA, 22030, USA. Spatial and seasonal variation in fish communities in the tidal freshwater Potomac River.

Trawl collections from 1984-1992 in two tidal embayments and the main river have caught 52,804 individual fishes in 31 species. The abundance of fishes is strongly seasonal, with mean catch per trawl usually below 50 in March, April and November and rising to 150 to 250 during June, July and August. The populations are mostly young of the year juveniles of white perch, blueback herring, bay anchovy, gizzard shad, and alewife. Adult brown bullhead and older juvenile white perch are also abundant. Young of the year white perch are most abundant in the embayments and in late June through July. The blueback herring and alewife are most abundant in the main river and from July through September. The gizzard shad are abundant from July through October and occur most abundantly in the embayments. The anchovy arrive in August and remain through October.

KENDALL, BRUCE E. University of Arizona, Tucson, AZ, 85721, USA. The extinctions of small populations: demographic stochasticity in a nonlinear model.

The prediction that demographic stochasticity dominates population extinction times only at very small population sizes, and is masked by other sources of variation at larger population sizes, is based on analyses of linear continuous time models with

an arbitrarily imposed maximum population size (N). I compare those results with a simple nonlinear discrete time model, with an equilibrium population size (K). The linear model predicts that, under the influence of demographic stochasticity, the mean time to extinction (T) increases exponentially with N; I find the same relation between T and K in the nonlinear model. Environmental stochasticity creates a linear relationship between T and N in the linear model; in the nonlinear model, T is still an exponential function of K, and is virtually indistinguishable from pure demographic stochasticity. Catastrophes induce a logarithmic response of T to N in the linear model; in the nonlinear model, T rises slower than exponentially, but faster than linearly, with K. Thus, in the nonlinear model demographic stochasticity can dominate population variation and extinction rates in the face of environmental variation even at relatively large population sizes.

KENNEDY , M.G. and R.C. BAILEY. Department of Zoology, The University of Western Ontario, London, ON, Canada. N6A 5B7. The effects of placer gold mining effluent on stream invertebrate communities in the Yukon Territory, Canada.

The goal of this research was to quantify the change in benthic macroinvertebrate communities of streams exposed to discharge from placer gold mines. Discharges are typically large amounts of inorganic sediment which have a variety of effects on the downstream ecosystem. Samples were taken in 24 streams near Mayo, Yukon Territory, Canada (63°35'N, 135°35'W), in June and July 1993. Impacted and unimpacted streams, interspersed in three catchment areas, were sampled at a ratio of 1:5. In impacted streams, pH ranged from 4.90 to 7.83, while turbidity ranged from 27 to over 200 NTUs. In unimpacted streams, pH ranged from 5.03 to 8.40, while turbidty ranged from 0.2 to 12 NTUs. Although there were differences between the impacted and unimpacted benthic communities, there was also considerable variation among unimpacted communities. We will assess the ability of habitat descriptors to predict unimpacted community structure, and quantify the deviation of impacted communities from this prediction.

KERN, RUTH ANN, VIRGINIA H. DALE, and JOHN J. BEAUCHAMP. Duke University, Durham, NC 27708, USA and Oak Ridge National Laboratory, Oak Ridge, TN 37830, USA. The effect of elevation, light and water availability on the growth of sierran conifer seedlings.

The composition of many plant communities will be altered with global change, and this will depend on individual species' abilities to reproduce and to survive under new climate conditions. Two experiments are underway to test the hypothesis that seedling demography is affected by the relative drought and shade tolerances of seven co-occurring species of Sierran conifers. The first experiment is being conducted at three sites in Sequoia National Park, California, elevations 1600 m, 1900 m and 2200 m. At each site, closed canopy 'shade' plots and open canopy 'gap' plots are being used. Seedling growth of each species is compared between light levels and elevations. The second experiment also measures seedling growth in low and high natural light levels, but with four levels of water availability at one elevation (1900 m). Microenvironmental monitoring (soil and air temperature, relative humidity, radiation, and soil moisture) of the experimental plots, conductance and water potential of the seedlings, and the rate of water consumption (i.e. transpiration) by surrounding mature trees are also being measured in order to develop a mechanistic model of seedling growth and survival.

KESTER, KAREN M. and LAUREL R. FOX. University of California, Santa Cruz, CA 95064, USA.
Three-trophic level interactions: sex ratios and oviposition preferences of parasitoids respond to plants.

Plants affect interactions between herbivores and parasitoids. Our previous studies focused on cruciferous plants, an herbivore, the diamondback moth (Plutella xylostella) and its major parasitoid (Diadegma insulare): abundance, sex ratios and plant preferences of both the diamondback moth and its parasitoid varied with plant type and quality. Our current work evaluates the generality of these interactions by assessing the effects of herbivore specialization (crucifer-specialist vs. generalist) and parasitoid reproductive strategy (solitary vs. gregarious). We use the crucifer-specialist, Pieris rapae and its gregarious parasitoid, Cotesia glomeratus, as well as the generalist Trichoplusia ni and its solitary parasitoid Patrocloides montanus. Results support our previous work: oviposition preferences and sex ratios of both parastioids respond strongly to plants. Both species also produced fewer female offspring on plants that were less preferred by their hosts.

KHANNA, ANUPAMA AND VICTORIA A. BOROWICZ. Illinois State University, Normal, IL, 61790-4120, USA.
How do nitrogen source and clipping affect growth and foliar nitrogen of Soybeans?

Because nitrogen-fixing plants are not limited by soil nitrogen they are often assumed to be similar to plants receiving nitrogen from fertilizer. However, other researchers have shown that some legumes are more harmed by defoliation when nitrogen-fixing than when nitrogen fertilized. We examined the effects of nitrogen source and defoliation on biomass allocation and foliar nitrogen concentration in soybeans (Glycine max). Seedlings were assigned to one of six treatments that were combinations of nitrogen source (high N fertilizer, low N fertilizer, or inoculated with Rhizobium) and clipping (no clipping or removal of half of each leaflet after six weeks). Plants were harvested two weeks after the clipping treatment. Nitrogen source significantly affected allocation of biomass: Plants receiving high nitrogen fertilizer had greater shoot mas and mass of reproductive tissue than either N-stressed or N-fixing plants but N-fixing plants had greater root mass. Plants receiving high N fertilizer also invested a greater proportion of total mass in reproductive tissue. Clipping reduced root and shoot mass. Neither clipping nor nitrogen source affected foliar nitrogen.

KIMMEL, ERNEST W., Educational Testing Service, Princeton, NJ, 08541, USA. Standardized assessment in science--can we do it better?

Implicit in the current arguments for standards-based education is the assumption that assessments of student accomplishment and performance will provide evidence as to whether students and schools have attained the "standards" set for each subject area. However, in order for the evidence to be comparable from one student to another and from one classroom or school or state to another, the assessment information must be collected through a standardized process. Standardized tests of science achievement have been used for many decades to make decisions about students and schools. This paper will review the criticisms that have been made of existing tests, will seek to evaluate the legitimacy of the criticisms in light of the emerging science assessment standards, and will suggest ways of improving the standardized components of science assessment in the future.

KIMMERER, R.W. State University of New York, College of Environmental Science and Forestry, Syracuse, NY 13210 USA Microsuccessional patterns in the Andean paramo

Community dynamics and spatial pattern were analyzed in a paramo grassland at an elevation of 4500 m in Cotopaxi National Park, Ecuador. The community is dominated by three growth forms; tussock grasses, microphyllous shrubs and the cushion plant, Azorella pedunculata. The hypothesis is tested that the three growth forms occur in a dynamic spatial pattern of sequential replacement. Patterns of replacement were determined from significant associations among life stages of the different growth forms. Cushion-forming Azorella colonizes patches of open soil , building a mat of organic matter. Recruitment of tussock grasses onto the Azorella mat exceeds that on open soil. Growth of tussock grasses locally eliminates Azorella and is associated with shrub mortality. Accumulation of mulch and subsequent senescence of tussocks is followed by re-establishment of Azorella.

KING, A. W., W. M. POST, and S. D. WULLSCHLEGER. Oak Ridge National Laboratory, Oak Ridge, TN, 37831, USA. The response of global NPP and vegetation carbon storage to changes in climate and atmospheric CO_2.

Carbon storage in terrestrial ecosystems is a consequence of balance and imbalance between processes of net primary production (NPP) and decomposition of dead organic matter. These processes are affected by climate, and thus any significant change in climate is likely to alter terrestrial carbon storage. Here, we explore the sensitivity of global NPP and vegetation carbon to changes in atmospheric CO_2 and climate with a global model of carbon storage in terrestrial ecosystems. A model of NPP is coupled with a carbon allocation model. NPP is a function of climate and atmospheric CO_2. We employ the model at a spatial scale of 0.5° latitude and 0.5° longitude. With no change in climate, a doubling of atmospheric CO_2 from 280 ppm to 560 ppm increases equilibrium global NPP (NPP°) by 13–27% depending upon the choice of CO_2 response function. The same doubling of atmospheric CO_2 increases equilibrium global vegetation carbon (GVC°) by 13–31%. Changes in climate from a set of five atmospheric GCMs yield increases in NPP° and GVC° of 8–13%. Combined changes in climate and atmospheric CO_2 increase NPP° by 24–37% and GVC° by 24–39%. We present maps of the altered distributions of NPP° and GVC°.

KING, GEORGE A., GREG BAUMGARDNER, and JEFFREY KERN. ManTech Environmental Technology Inc., Corvallis, OR, 97333 USA. Net primary productivity of non-forested lands in the United States.

Total plant net primary productivity (NPP) for non-forested lands in the conterminous United States was estimated using land cover data from the 1982 Natural Resources Inventory (NRI) database (USDA-SCS 1987) and several different NPP databases. The dominant land cover types included in the estimate are rangelands, pasturelands, croplands and other lands as defined by the 1982 NRI. Non-forested land comprises about 70% of the land surface of the conterminous US. Rangeland accounts for 49% of the non-forested land. The annual NPP for non-forested land is about 1.78 Pg-C or 3390 kg-C ha^{-1} yr^{-1}. Cropland is the most productive cover type, with a mean NPP of 5270 kg-C ha^{-1} yr^{-1}, while rangeland is the least productive, with a mean NPP of 2250 kg-C ha^{-1} yr^{-1}. NPP is the highest in the North Central region of the US (5540 kg-C ha^{-1} yr^{-1}) while the Rocky Mountain region has the least productive non-forested land (1820 kg-C ha^{-1} yr^{-1}). The coefficient of variability of the yearly cropland NPP is 9.3%. Rangeland NPP varies $\pm$ 30% from normal in favorable and unfavorable years. Overall, NPP for non-forested land in the US is estimated to vary by about $\pm$ 20% from the mean in favorable and unfavorable years, or about $\pm$ 0.35 Pg-C. The NPP estimates provided here will help validate continental-scale NPP models.

KING, JOHN L. University of Illinois, Chicago, IL 60607-7060. The effects of gap to understory gradients on tree juvenile performance and coexistence.

Treefall gaps are heterogeneous with respect to light and vegetation density. A split plot design transplant experiment was used to test the effect of gap position and the absence of competing roots on tree juvenile growth. Second year white ash (WA), black cherry (BC) and tulip poplar (TP) were transplanted into three gaps in Warren Woods MI. Within each gap, trees were planted in three positions: north of the center of canopy gap (C), the edge of the canopy gap (E), and in adjacent understory (US). Within each gap position, four trees were planted in plastic pots (20cm deep x 17cm deep), and four were planted without pots. Extension growth differed significantly among gap positions (from most to least: C-E-US), and among species (from most to least: TP-WA-BC). Each species' rank for extension growth was constant across all gap positions. The absence of competing roots had no significant effect on extension growth. These results suggest that gap heterogeneity is

important for the growth of juveniles of these species. However, within gap heterogeneity did not result in detectable tradeoffs among species and, hence, is not shown to contribute to the coexistence of these three species.

KING, JOHN S. Duke University, Durham, NC 27708, USA. Tree regeneration and herbaceous community response to fire exclusion in a forest-savanna mosaic in Gabon, central Africa.

Herbaceous and woody vegetation was sampled on twenty-six transects perpendicular to the forest edge after three years of fire protection in 1991. Three treatments were sampled: (1) absence of fire protection, (2) fire protection, and (3) fire protection and soil preparation. Species richness and number of individuals were compared using graphical analysis, a two-factor ANOVA, and ordination by detrended correspondence analysis (DCA). Species richness was greatest, for both herbaceous and woody plants, in mesic savannas. Herbaceous density was maximized in xeric savannas, while woody plants had greater density in mesic sites. Savanna type, mesic or xeric, was the most significant factor affecting plant community structure. The fire protection treatments did not have significant effect on woody species richness, but were significant when combined with savanna type ($p=0.02$). DCA ordination revealed that species were arrayed along the first axis according to their moisture requirements, confirming that soil moisture was the primary environmental gradient affecting plant communities.

KING, SAMMY L. Department of Wildlife and Fisheries Sciences, Texas A&M University, College Station, TX, 77843, USA. The Effects of the Hydroperiod on Two Impounded Bottomland Hardwood Stands

The effects of the hydroperiod on 2 impounded bottomland hardwood stands in east Texas were determined by analyzing stand structure, regeneration patterns, and tree stress and mortality. Overcup oak (Quercus lyrata) and willow oak (Q. phellos) were the dominant species in both impoundments. All species experienced poor regeneration in the last several years. Limited regeneration of all species except overcup oak was observed in this study. Establishment and mortality of overcup oak seedlings were correlated to the timing and duration of growing-season flooding. Tree stress and mortality were significantly higher in trees in larger diameter classes and/or that were flooded for longer periods. Temporal patterns suggested that tree mortality was a result of cumulative flooding events rather than any single event.

KIRKLEY, ALLISON F. AND STEVEN E. KELLEY. Washington State University, Pullman, WA, 99164 and Emory University, Atlanta, GA, 30322, USA. Aphid preferences for virus infected plants.

Barley yellow dwarf luteovirus (BYDV) is a cosmopolitan, aphid-transmitted virus which typically induces yellowing, reddening, and stunting of affected crop plants, but which is asymptomatic in many natural hosts, including the perennial grass, *Anthoxanthum odoratum* . Aphid preference in relation to viral disease was tested by mock-inoculating and inoculating individual tillers of *Anthoxanthum.* Infected individuals were then planted as single tillers next to mock-inoculated tillers of the same genotype in small pots, and a single aphid was placed in the pot, and allowed to move to and climb one of the two tillers. The results showed a strong tendency of aphids to choose virus-infected compared with virus-free plants. The results have important implications for aphids' sensory abilities, for aphid clone fitness, for viral strain fitness, and for plant fitness. These consequences were elucidated in a series of different laboratory studies.

KITUKU, VINCENT, M. Idaho Power Co., Boise, ID, 83707, USA. Regulated River Flows and Environmental Attributes' Effects on Riparian Vegetation Dynamics along the Snake River in the Hagerman Valley, Southwestern Idaho.

Effects of regulated river flows, soil and topographic factors were investigated on riparian vegetation density, cover and diversity in 1992. Relative flow fluctuations within the study area were estimated using portable Pressure Transducers' data and USGS records. Parameters of herbaceous, shrub and tree lifeforms and of individual species were considered in relation to winter, summer and spring flows. Significant correlation exist between mean seasonal flows and tree lifeform cover while the cover values of shrub and herbaceous lifeforms are positively and moderately correlated with relative % slope. Predictive models suggest that significant amounts of the total variation of tree lifeform cover and density are explained by mean seasonal flows. Mean spring flows, relative percent slope, elevation and soil factors account significantly for the total variation of cover and density in the herbaceous and shrub lifeforms. Individual tree species variations are mainly explained by flow variables and soil factors. Variations for individual herbaceous and shrub species are mainly explained by soil and topographic factors.

KJELLMARK, ERIC. Duke University, Durham, NC. Late Holocene vegetation change on Andros Island, Bahamas: Evidence of Caribbean climate change and human colonization.

Sediment cores from blue holes on Andros Island, Bahamas, contain a remarkably detailed record of the past vegetation. A Holocene dry period from at least 2000 to 1500 yr bp is evidenced by sedimentological and palynological facies from the basal portion of one core. This coincides with a suggested dry period in Central America and the Caribbean region, but it has never been found this far north and east. A hardwood vegetation is established at ca. 1500 yr bp and remains a dominant vegetation component until ~900 yr bp when pine and charcoal begin to increase in

abundance. At 750 yr bp, pinewoods replace the hardwoods and charcoal peaks indicating human disturbance. The 900 yr bp date for the onset of significant human disturbance is relatively late, compared with other estimates of human colonization of the Caribbean region, suggesting that the occupation of island interiors may have lagged behind that of the coastal regions.

KLEB, HEATHER R. and SCOTT D.WILSON. University of Regina, Regina, SK., S4S 0A2, Canada. The influence of vegetation on resource heterogeneity in prairie and forest soils.

Vegetation can influence levels of soil resources in plant communities, suggesting that vegetation may also influence soil resource heterogeneity. Our objective was to test whether vegetation influences soil N heterogeneity. A survey of available N and a number of other environmental variables found aspen forest to be generally more heterogeneous than native prairie. To test whether vegetation influences heterogeneity, soil cores were transplanted from prairie to prairie, prairie to forest, forest to forest, and forest to prairie. N was measured in ten samples in each core five months later. Two-factor ANOVA on coefficients of variation of N in the cores revealed a significant destination effect. Soil cores transplanted from prairie to forest adopted the greater heterogeneity of the forest, while those transplanted from forest to prairie adopted the lower heterogeneity of the prairie. There was no significant origin effect, so original levels of heterogeneity did not affect the heterogeneity observed after five months in the new site. This suggests that spatial variability of N uptake by plants influences the heterogeneity of soil N.

KLEINER, KARL, W., RICHARD E. DICKSON, and KENNETH F. RAFFA. University of Wisconsin, Madison, WI, 53706, USA and USDA Forest Service, Forestry Sciences Laboratory, Rhinelander, WI 54501, USA. ^{14}Carbon partitioning among primary metabolite and allelochemical fractions of aspen leaves.

After photosynthetic fixation of $^{14}CO_2$, we examined over a 72 hour time period, the partitioning of recently fixed ^{14}C among 10 chemical fractions representing growth and primary metabolism (lipids and pigments, amino acids, organic acids, sugars, protein, starch and residue) and allelochemical production (phenolic glycosides, water soluble phenolics and water insoluble phenolics) in recently mature aspen leaves. The percentage of ^{14}C in the sugar, starch and amino acids fractions was initially high, then declined,whereas the proportion in the lipids and pigments, protein and residue fractions increased over the 72 hour period. The percentage of ^{14}C partitioned to the 3 allelochemical fractions was not characterized by any consistent trend, but varied as much among individual plants as among time periods within the 72 hours. The combined ^{14}C partitioned to the 3 allelochemal fractions did not exceed 6% of the labeled carbon within the leaf.

KLEMOW, KENNETH M. Wilkes University, Wilkes-Barre, PA, 18766, USA. EcoInformatics: A laboratory exercise to introduce undergraduate students to the ecological literature.

Laboratory exercises in ecology courses typically enable students to gain a hands-on appreciation for ecological principles through experiments or simulations. Few published exercises introduce students to the general nature of the ecological literature, or to the typical structure of a published article. To that end, a laboratory exercise was developed to acquaint students at Wilkes University with the ecological literature. Each student is given a package of instructions and data sheets. The instructions include a discussion of the general structure of the ecological literature, and describes the process by which an article is published in a peer-reviewed journal. In the laboratory, each student is provided with representative literature, including issues of *Ecology* and *Science*, a volume from the *Annual Review* series, a technical book, a set of abstracts from a past ESA meeting, and a newsletter from the ESA's Washington Office. The students then conduct a comparative examination of each item as directed by the instructions, and record their observations on the data sheets.

KLINGENSMITH, KATHERINE M. and ROGER W. RUESS. Institute of Arctic Biology, University of Alaska Fairbanks, Alaska 99775, USA. Rhizosphere nitrogen fixation and denitrification in the Alaskan taiga.

The importance of symbiotic nitrogen fixation in primary succession is well accepted, while N inputs due to asymbiotic nitrogen fixation are assumed to be small. Few studies have yet to examine asymbiotic N inputs while also measuring denitrification, even though rhizospheres of plants are potential denitrification hotspots. We measured nitrogen fixation and denitrification in root zones of several dominant taiga species, including alder nodules. The highest nitrogen fixation rates were always associated with alder nodules, yet significant amounts were found with Equisetum roots. Denitrification was mostly associated with nitrogen fixing roots, at times canceling out N inputs, yet total N input due to asymbiotic nitrogen fixation was >1 kg N ha^{-1} yr^{-1}.

KLOEPPEL, BRIAN D., STITH T. GOWER, and PETER B. REICH. University of Wisconsin - Madison, Madison, WI, 53706, USA and University of Minnesota, St. Paul, MN, 55108, USA. Current and historical net primary productivity of control and fertilized western larch and sympatric evergreen conifers for wet and dry growing seasons along an edaphic gradient in western Montana, USA.

Net primary productivity of control and fertilized mixed stands of a deciduous conifer (Larix occidentalis) and sympatric evergreen conifers (Pseudotsuga menziesii or Pinus contorta) were compared along a natural edaphic gradient in western Montana. Net primary production of

the closed-canopy stands was measured using annual radial increments and site and species-specific allometric equations. Precipitation differed greatly between the 1992 and 1993 growing seasons thereby allowing us to examine the influence of water and nutrient availability on the evergreen and deciduous conifers along the natural edaphic gradient. Detailed stem analysis (sensu Duff and Nolan 1953) also allowed us to compare historical individual tree productivity between sympatric evergreen and deciduous conifers. Net primary productivity was greater for Douglas fir than western larch at the most xeric site, but the converse was true at the most mesic site indicating that drought tolerance is likely greater in Douglas fir than western larch. Fertilized stands exhibited greater net productivity than control stands during the wet 1993 season except at the most mesic site whereas during the dry 1992 season no fertilization effect occurred at the xeric site. Historical stem analysis indicated greater rates of height growth and stem productivity by Larix occidentalis than sympatric evergreen conifers early in stand development.

KLOPATEK, CAROLE COE, KEN MURPHY, JULIE ROSEN AND JEFFREY M. KLOPATEK. USDA Forest Service, Tempe, AZ 85287-2701 and Arizona State University, Tempe, AZ 85287-1601, USA. Decomposition and cellulose degradation along an elevational gradient in northern Arizona.

We present preliminary results from a research study on decomposition of litter material along an environmental gradient with a mean difference of 2° C from top to bottom. Bags containing ponderosa pine, pinyon pine, juniper, blue grama grass and snakeweed litter were placed along the gradient, running from Great Basin Desert scrub, through a pinyon-juniper woodland community, and up into a ponderosa pine forest. Soils from these sites were collected and analyzed for cellulose degrading bacteria during the fall and spring. Litter bags were removed every other month, weighed and analyzed for cellose and lignin concentrations. Although litter quality appears to be less in the lower end of the gradient, there were more cellulose degrading bacteria. Additionally, cellulose degraders were more predominant in the interspaces than under canopies that contained more carbon. Litter decomposition appears to be greater in the transition zones than in any of the other sites.

KLUS, DAWN JENKINS*, SUSAN KALISZ*, STEPHEN J. TONSOR* AND PETER S. CURTIS#. *Michigan State University, Kellogg Biological Station, Hickory Corners, MI 49060, USA. #The Ohio State University, Columbus, OH, 43210, USA. Intraspecific physiological variation in response to elevated atmospheric CO_2 in two populations of Plantago lanceolata.

The nature and magnitude of possible evolutionary change in response to elevated atmospheric CO_2 will be determined by the extent to which there is genetic variation in that response within a species. In this study we investigated physiological response to elevated CO_2 in 24 families from two populations of Plantago lanceolata. Seedlings of each family were divided between two CO_2 environments (ambient and twice-ambient) and were grown in open-top chambers. Photosynthesis and transpiration were measured on intact leaves of each plant at two separate times and at both CO_2 levels. Considerable differences among and within populations were observed at the two measurement times and at the two CO_2 levels. These results demonstrate that within this species genetic variation exists upon which elevated CO_2 may act as an agent of natural selection.

KNAPP, ALAN K. and PHILIP A. FAY. Kansas State University, Division of Biology, Ackert Hall, Manhattan, KS, 66502-4901, USA. Photosynthetic recovery after shading in *Baptisia leucophaea* and *Helianthus annuus*.

Two species differing greatly in stomatal responses to variable sunlight were examined for differences in mesophyll level-photosynthetic recovery after shading. Field gas exchange during alternating full sun/5 minutes shade (300-400 μmol m^{-2} s^{-1} PFD) showed that the cool season perennial, *Baptisia leucophaea*, had stomata that did not close when shaded. Photosynthetic recovery upon reillumination occurred within 1 minute. In contrast, the warm season annual *Helianthus annuus* had stomata that rapidly closed during shading, and showed a significant lag in photosynthetic recovery when reilluminated. Photosynthetic O_2 dynamics measured in a saturating CO_2 atmosphere verified that *Baptisia* had no loss of biochemical induction when shaded. *Helianthus* photosynthetic O_2 dynamics showed that stomatal closure caused the lag in photosynthetic recovery in the field, but deeper shading caused an additional biochemical induction los s. For most prairie plant species, stomatal closure rather than induction loss limits photosynthetic recovery after shading unless light levels are very low.

KNEESHAW, DANIEL and YVES BERGERON. Université du Québec à Montréal, C.P. 8888, Succ. A., Montréal, Québec, Canada, H3C 3P8. The characterization of spruce budworm caused gap dynamics in the southern boreal forest.

In the past century in the eastern boreal forest spruce budworm outbreaks have been increasing in severity and duration while fire frequency has been decreasing. Budworm created canopy gaps are thus having a greater influence on successional processes yet boreal forest gap dynamics remain poorly characterized. In northwestern Quebec canopy gaps were sampled along transects in forests of different age to determine gap size distributions, species of gap makers and response by gap fillers. The results from this study show that most gaps are created due to budworm caused mortality and that approximately 10% of young forests (77 years old) are in gaps while 25% and 45% respectively of medium aged (146 years old) and old forests (233 years old) canopies are in gaps. Although recruitment is highly variable, balsam fir was identified as the primary replacement species in all but the largest gaps for which stand recovery is predicted to be quite long due to the inadequate regeneration observed for all tree species.

KNOPS, JOHANNES M. H., THOMAS H. NASH III and WILLIAM H. SCHLESINGER. Arizona State University, Tempe, AZ, 85287, USA and Duke University, Durham, NC, 27706, USA. The influence of epiphytic lichen litter on the oak leaf litter decomposition in mixed litter bags.

We measured oak leaf decomposition in litterbags with or without lichen litter, as part of a study of the importance of epiphytic lichens (*Ramalina menziesii*) in the nutrient cycle of a blue oak (*Quercus douglasii*) woodland in California. Decomposition of the oak leaves was slow, 20% in the first year and an additional 30% in the subsequent three years. Oak leaves showed an increase in nitrogen from 0.9 to 1.6%, whereas phosphorus decreased from 0.4 to 0.1%. This resulted in a N loss of 10-15% and a P loss of 90% over 4 years. Lichen litter decomposition had a different pattern, only about five percent mass was lost in the first year, followed by a more rapid loss of 70 percent in the subsequent three years. Lichens showed an increase in N from 1.0 to 2.0%, whereas P increased from 0.09 to 0.12%. This resulted in a N loss of 50% whereas 45% of P was immobilized in the first year, followed by a rapid release of 90% of P in the subsequent years. The presence of lichen litter significantly lowered the oak leaf decomposition rate and its release of N and P for the first 3 years. This negative effect of lichen litter on oak leaf decomposition could be caused by a change in litter quality, as shown by the initial P immobilization, by a direct effect of secondary compounds present in the lichen thallus, or by an alteration of the water balance of the litter. Epiphytic lichens may, therefore, play a larger role in the ecosystem nutrient cycling than has been thought previously.

KNOWLES, DAVID B., and JOSEPH J. LUCZKOVICH. East Carolina University and the Institute or Coastal and Marine Resources, Greenville, NC, 27858, USA. Experimental analysis of the effects of thin-layer dredged spoil deposition on the vegetation and soil characteristics of a *Juncus roemerianus*-dominated marsh in North Carolina.

The deposition of a thin layer of dredged spoil onto adjacent marshes has been proposed as environmentally acceptable means of disposal. We experimentally manipulated the spoil thickness deposited in a *Juncus roemerianus*-dominated marsh. Spoil material excavated from a shallow canal was applied onto replicated $16m^2$ plots at treatment depths of approximately 2cm, 4cm, and 10cm; treatment plots were compared to unaltered controls. One year after dredged spoil was applied, *Juncus roemerianus* biomass was reduced by 43%, 29% and 79%, and shoot density declined by 16%, 44%, and 94%, respectively for the 2cm, 4cm, and 10cm treatments. *Distichlis spicata* biomass and density increased in the 10cm treatments. The deposition of dredged material resulted in increased porewater hydrogen sulfide concentrations, increased the surface soil inorganic fraction, and raised marsh surface elevation thus shortening hydroperiod. There was no evidence of glyphosate herbicides or excess heavy metals in spoil samples.

KNOX, ROBERT G., K. JON RANSON, JOHN F. WEISHAMPEL, and GUOQING SUN. NASA/Goddard Space Flight Center, Greenbelt, MD, 20771, USA. Modeling forested landscapes: limits to conventional remote sensing for estimating parameter fields.

Remote sensing is generally viewed as the most promising approach for rapidly estimating fields of plant biomass, leaf area, and cover types for functional modeling of landscapes. We used an individual-based model of forest dynamics and physical models of the interaction of electromagnetic radiation with forest canopies to predict changes in optical and microwave remote sensing signals during forest succession for a landscape in south-central Maine, USA. Modeling results and comparisons with field data confirmed ready detection of changes during the early stages of reforestation. Because of demographic stochasticity and well-known 'saturation' of the signal in dense vegetation canopies, conventional techniques could not readily distinguish among later stages of stand development. Alternative techniques may be more suited to closed canopy forests but will need to be tested in a variety of different ecosystems before we can recommend their wide adoption.

KOBE, RICHARD K., JOHN A. SILANDER, STEPHEN W. PACALA, CHARLES D. CANHAM. Univ. of Connecticut, Storrs, CT 06269, Princeton Univ., Princeton, NJ 08544, and Institute of Ecosystem Studies, Millbrook, NY 12545. Sapling performance and geographic variation in forests.

We have characterized inter- and intra-specific differences in mortality and growth of juvenile trees, which predict shifts in canopy tree dominance at three different sites. We developed mortality and growth functions for a similar set of species at Great Mountain Forest (low pH, nutrient poor soils), a calcareous bedrock region in CT (neutral pH, nutrient rich soils), and at site in central-western Michigan (low pH, nutrient poor soils). Species-specific patterns of juvenile growth and mortality are very similar in the nutrient poor soils of Great Mountain and the MI site, but are strikingly different in the nutrient rich calcareous region. Integrating these differences into a simulator of forest dynamics (SORTIE) predicts the relative dominance of mature trees. Thus we show that inter- and intra-specific variation in juvenile growth and mortality at the stand level can lead to patterns of species distributions at the landscape level.

KOCH, GEORGE W. and JAMES T. RANDERSON. Stanford University and Carnegie Institution of Plant Biology, Stanford, CA 94305, USA. Interannual variation in climate-potential net primary productivity relationships in differing ecosystems of California.

The seasonality and interannual variation in potential net primary production (NPP) were examined in differing vegetation types in California over three years of contrasting precipitation using co-registered maps of climate, vegetation, and 1km biweekly NDVI derived from high resolution satellite AVHRR data. Differences in seasonality of the vegetation types (annual grassland, chamise chaparral, deciduous oak woodland, and evergreen oak) were clearly evident and corresponded well to patterns observed in field studies. In years and locations having

high precipitation the annual peak in NDVI occurred later in all vegetation classes. The annual sum of biweekly NDVI was correlated with annual precipitation in all vegetation types, although the slopes and intercepts of the regressions differed among types. Annual grassland showed the largest increase in sumNDVI per unit increase in total precipitation and most of the variation in grassland sumNDVI was explained by variation in autumn precipitation. In general the ratio of sumNDVI to annual precipitation was dependent on the temporal distribution of precipitation with respect to the long-term average pattern. Published relationships between precipitation and NPP were used to develop equations relating annual NDVI sum to NPP.

KÖCHY, MARTIN and SCOTT D. WILSON. University of Regina, Regina, SASK., S4S 0A2, CANADA. Abiotic, species, and habitat controls of litter decomposition in prairie and forest.

Nitrogen and mass loss in prairie (Carex sp., Stipa comata, Koeleria gracilis, Bouteloua gracilis) and aspen (Populus tremuloides) litter was measured over a summer in a complete factorial field experiment in Saskatchewan, Canada. The four treatments were litter type (grass or aspen), time (after 4, 9, 16, and 21 weeks), habitat type (prairie or aspen forest), and shading (with or without additional shade). Nitrogen loss was measured with ion-exchange resins. Grass (C:N=44) decomposed significantly faster (k[years]= 1.34) than aspen (C:N=79; k= 0.43) probably because of differences in litter quality. Habitat type and shading had no main effect, but decomposition was significantly faster in prairie plots without shade, probably due to higher temperatures. N loss in all treatments was not larger than N deposition. Analysis of total N in litter suggests that N was lost by litter fragmentation and not by biotic mineralization. The results show (1)that decomposition rate depends mainly on species identity of litter, not the abiotic environment associated with grass or aspen and (2)that N-deposition may conceal actual N mineralization.

KOHLMANN, STEPHAN G. and KENNETH L. RISENHOOVER. Texas A&M University, College Station, TX, 77843, USA. Patch use by Northern Bobwhites: Effects of spatial scale and pre-harvest information.

If foragers exploit patches only as long as gains exceed total foraging costs, the "giving-up density" (GUD) of resources remaining after patch abandonment may indicate foraging costs and habitat values. Testing the GUD-model with captive Northern Bobwhites (Colinus virginianus) in controlled experiments we used depletable, artificial patches (seed trays) to determine the effect of pre-harvest information and inter-patch distance on patch selection of bobwhites. In predictable patch arrangements bobwhites foraged density-dependently, while random patch arrangements caused density independent harvest. Bobwhites foraged selectively when patches were spaced 1-2 m, but foraged density-independently in clumped and widely dispersed (> 3 m) patch arrangements. Predictability of resources and the spatial scale of foraging decisions are critical components of foraging behavior of bobwhites. GUD in artificial seed trays is a powerful indicator of foraging preferences and habitat values.

KOLASA, JUREK. McMaster University, Hamilton, Ontario, L8S 4K1, Canada. Structure vagueness in experimental communities.

Deterministic and stochastic forces interact to shape community structure. Quantification of their respective roles is important for (i) understanding current and predicting future community states and (ii) evaluation of observed patterns. These roles were studied experimentally by creating twenty artificial communities (20 invertebrate species representing typical fauna of coastal erosional rock pools; 3L capacity plastic bowls; location: Discovery Bay Marine Laboratory, Jamaica; duration: 10 days) by mixing samples of live fauna from 15 natural rock pools and distributing them evenly into artificial containers arranged in a homogeneous environment. The communities were then randomly sampled on 6 dates. Results: species richness declined steadily from a mean of 13 to 6 (max-min: 16-5) per community but the mean abundance showed no change over time. More importantly, while the mean coefficient of variation in richness per community remained largely unchanged, this coefficient showed a marked increasing trend for persisting species. Furthermore, the communities diverged significantly in composition (Dissimilarity Index more than doubled at the end of experiment).

KOLB, T.E., T.S. FREDERICKSEN, B.J. JOYCE, K.C. STEINER. Northern Arizona University, Flagstaff, AZ, 86011, USA and the Pennsylvania State University, University Park, PA, 16802, USA. Relationships between foliar gas exchange and environment for different-sized black cherry (Prunus serotina Ehrh.) trees.

Relationships between foliar gas exchange characteristics and environmental parameters were studied for different-sized black cherry trees in central Pennsylvania. Daily patterns of gas exchange (net photosynthesis, stomatal conductance), environment (leaf-to-air VPD, PAR, leaf temperature, relative humidity) and predawn xylem water potential were measured at weekly intervals between late spring and early autumn of 1993 in both the upper and lower crowns of open-grown seedlings, understory saplings, and mature trees. Relationships between net photosynthetic rate and stomatal conductance differed between size classes and crown positions. Net photosynthesis was more tightly coupled to stomatal conductance in high light environments (upper crowns of seedlings and mature trees) compared with low light environments (understory saplings and lower crowns of seedlings and mature trees). Environmental regulation of net photosynthetic rate and stomatal conductance differed between high and low light environments, with PAR the most important driving variable in low light and VPD most important in high light. In high light environments, relationships between photosynthetic rate, stomatal conductance, predawn water potential and environmental parameters differed between seedlings and mature trees.

KOONCE, ANDREA L., TIMOTHY E. PAYSEN and BONNI M. CORCORAN. USDA Forest Service, Pacific Southwest Research Station, Riverside, CA 92507. Preliminary indicators of vigor loss after fire in a tropical pine savanna.

Each year, 90 percent of the Caribbean pine (Pinus caribaea var hondurensis (Benecl) Barr. et Golf.) stands in the Miskito coast region of northeastern Nicaragua burn in wildfires. This pathological fire cycle is a result of the presence of a large number of human-caused fire starts, and a highly flammable sedge understory. The pines are rarely killed by fire, but do suffer severe losses in productivity. Preliminary assessments of tree vigor, using electrical resistance techniques, indicate that stand-level vigor loss after a single fire continues for a number of years. The impact of repeated burns is yet to be evaluated.

KOPTUR, SUZANNE, STEVEN F. OBERBAUER, KURT VON KLEIST III, KEVIN WHELAN, SUZANNE KENNEDY, and SURA SELIGER. Florida International University, Miami, FL 33199, USA. A comparison of damage and recovery from Hurricane Andrew in three upland forest types of the Everglades.

Everglades National Park (ENP) has the dubious distinction of being the largest national park in close proximity to a major urban area (Miami), and intensive land use up to the park boundaries has left no buffer zone to ameliorate the many anthropogenic disturbance effects on the remaining natural communities. Recently, these communities experienced a severe natural disturbance when Hurricane Andrew passed through ENP in August 1992. In September 1992 we initiated a study of tropical hardwood hammocks, cypress domes, and second-growth pinelands in the Long Pine Key area of ENP in order to determine the extent of damage and short-term recovery responses of these different communities. Damage was most severe in the hardwood hammocks, and larger trees were most likely to be seriously damaged in all habitats. Regrowth of damaged individuals is common in hammocks and cypress domes, but not in pinelands. Colonization of openings in our study areas is primarily by native species previously represented in that particular forest (< 3% exotic species). Overall, the composition of these communities is likely to remain very similar to that which existed prior to Hurricane Andrew.

KOROL, R.L. USDA Intermountain Research Station, Moscow, ID. 83843. Testing a process-based model for predicting stand and tree growth.

TREE-BGC, a variant of FOREST-BGC, is an physiological process-based model that calculates the cycling of carbon, water and nitrogen in and through forested ecosystems. A disaggregation logic was used to allocate stand level estimates of carbon gain and respiration costs to individual trees growing in uneven-aged stands. Allometric equations were used to allocate stem growth between height and diameter. Mortality occurred when the respiration demands of the tree exceeded the carbon allocated to the tree. Plot level estimates of basal area and growth were highly correlated with actual measurements (r^2 = 0.94 and 0.96, respectively; n = 24). The simulated cumulative diameter and height distributions were not significantly different than the actual cumulative diameter and height distributions for 23 of the 24 plots (α = 0.05). The model was shown to predict volume growth to within ±20 m^3 ha^{-1}, and basal area growth to within ±10 m^2 ha^{-1} (α = 0.05), over a 20-year period. Both the height and basal area growth rates were affected by stand structure and density. Stand mortality appeared to emulate the so-called self-thinning rule and a maximum size-density relationship was found.

KOTANEN, PETER M. University of California, Berkeley, CA, 94720, USA. Revegetation of grassland soil disturbances: When do invaders win?

I have monitored the vegetation of a variety of experimental soil disturbances (excavation, burial, stirring, and simulated pocket gopher mounds) and areas naturally disturbed by feral pigs, as well as undisturbed controls. Different types of disturbance had significantly different effects on revegetation, and revegetation occurred more rapidly in an annual community than in mixed annual-perennial vegetation. These results suggest that one type of soil disturbance rarely may be fully substitutable for another, and that similar disturbances may have different effects in different communities. Most disturbances initially provided habitat for a variety of native plants, but in subsequent years favored alien annual grasses. Many natural vegetation types are structured by recurring disturbances, and contain species which require disturbance for persistence; these systems may be threatened if their disturbance regime is altered or suppressed. Unfortunately, this same disturbance regime also may facilitate invasion by weedy aliens.

KOUTERICK, K.B., J.M. SKELLY, T.S. FREDERICKSEN, T.E. KOLB, J.E. SAVAGE, K.R. SNYDER. Penn State University, University Park, PA, 16802, USA. Foliar ozone injury and gas exchange among black cherry genotypes.

The effect of differing ozone exposures on seedlings of black cherry genotypes was investigated in northcentral Pennsylvania. Ozone exclusion treatments were administered to half-sib families R12 and MO-7, and wild-type (WT) grown in open-top chambers. Over the 1993 growing season, leaf gas exchange and stem volume were related to percentage of foliar ozone injury observed as adaxial stipple. Ozone symptoms decreased significantly with increasing ozone filtration. R12 exhibited the most severe foliar injury, while WT seedlings showed slightly less symptoms. MO-7 had the least amount of foliar injury. No clear trends in stomatal conductance or net photosynthesis were observed until August. During August, foliar injury was positively related to stomatal conductance. Stomatal conductance values were greatest in R12,

followed by WT and MO-7. Photosynthesis followed the same pattern as stomatal conductance. Dark respiration rates were variable across treatments for the entire growing season. Differing ozone exposures did not affect stem volume, but stem volume of seedlings of all families in the open plot were significantly lower than seedlings within chambers. Overall, R12 had higher stem volume than MO-7 and WT seedlings.

KRASNY, MARIANNE E. Cornell University, Ithaca, NY, 14853, USA. Cornell University Environmental Sciences Outreach Programs: Mobilizing Educators and Volunteer Leaders.

Cornell University conducts a number of pre-college environmental sciences education programs for teachers, informal educators from nature centers, museums, government agencies, and non-profit organizations, and volunteer leaders. The goal of these programs is to encourage educators and their students to engage in environmental sciences research and investigations. In one program, teachers participate in a six-week, on-campus research experience focusing on composting science, following which they engage students in a variety of classes and after-school clubs in composting research. A second program trains teams of teachers and informal educators to conduct investigations into land use changes in their communities using aerial photographs and maps. A third program involves training educators to conduct youth sportfishing clubs, through which young people learn about aquatic ecology, fisheries management, and environmental stewardship. Many of the individuals trained through these programs have developed exemplary youth education programs, and it appears that these most active educators have a clear vision of how their environmental sciences education program fits in with their on-going professional or volunteer activities.

KRAUSE, STEVEN C. and KENNETH F. RAFFA. University of Wisconsin, Madison, WI 53706, USA. Does defoliation differentially affect insect herbivores from separate feeding guilds?

Evergreen conifers store carbohydrates and nutrients primarily within needles. Since these reserves are allocated for growth and defense, we tested the hypothesis that defoliation reduces long-term tolerance to herbivores using red pine, Pinus resinosa, and four insect species. Ten-year-old trees were artificially defoliated 0% to 99% of their leaf mass, and monitored for 3 years. Non-linear responses to defoliation were observed in performance of a folivorous sawfly, Neodiprion lecontei, and foliar concentrations of nitrogen, monoterpenes and resin acids. Defoliation reduced host tolerance to the weevil, Hylobius pales, and bark beetle, Ips pini, but it had little effect on gypsy moth, Lymantria dispar. Aboveground tree productivity was inversely correlated with defoliation intensity. Results indicate that defoliation influences the long-term relationship between conifer productivity and resistance to herbivores, and it may predispose trees to colonization by sub-cortical insects.

KRESS, LANCE W., RAMESH MURTHY, and PHILIP DOUGHERTY. USDA - Forest Service, Research Triangle Park, NC 27709 USA. The impact of elevated carbon dioxide on the branch growth of loblolly pine as influenced by water and nutrition.

Branches of field grown loblolly pine trees growing under four different water and fertility regimes were exposed continuously to three different CO_2 environments for a growing season. There were four trees in each of the soil regimes (control, fertilized, irrigated, and fertilized and irrigated). Three branches on each tree were individually enclosed in chambers containing CO_2 environments of ambient, ambient plus 175ppm, or ambient plus 350ppm. Data were collected on terminal extension, diameter, needle length, needle number, and needle longevity. The positive impact of elevated CO_2 was greatest on both of the irrigated treatments. In the plus 175ppm and plus 350ppm environments, respectively, the growth increases were 9% and 23% for the fertilized and irrigated trees and 41% and 59% for the irrigated only trees. There was no apparent impact of CO_2 on needle number or needle longevity.

KRUKONIS, GREGORY P. University of Arizona, Tucson, AZ 85721, USA. Encapsulation within host spores as a mechanism facilitating bacteriophage survival of hostile conditions.

The hypothesis that bacteriophage persistence during hostile conditions can be facilitated by encapsulation within bacterial spores was tested in the laboratory using soil microcosms containing a common soil bacteria (*Bacillus subtilis*) and a phage to which it is susceptible. The use of mutants of *B. subtilis* incapable of forming spores allowed the examination of the effect of sporulation on the interaction between B. subtilis and phage. Use of a phage mutant incapable of temperate reproduction eliminated the possibility that phage persistence was due lysogenic association with the host bacteria. Conditions were found--low host density in combination with soil conditions hostile to free phage--under which periodic entrapment in, and release from, bacterial spores was required for phage persistence. Experiments with wild phage revealed that phage become entrapped within bacterial spores in nature, and tests with laboratory strains of *B. subtilis* found that some wild phage have the ability to increase the frequency of host sporulation. Encapsulation within host spores provides phage with a dormancy mechanism that has the advantage of terminating automatically when conditions favorable for bacterial germination and growth occur.

KUBISKE, MARK E. and KURT S. PREGITZER. Michigan State University, East Lansing, MI 48824, USA. Effect of elevated CO_2 on photosynthetic plasticity to growth light conditions in tree species of contrasting shade tolerance.

The purpose of this study was to test the hypothesis that elevated atmospheric CO_2 will induce a shift in photosynthetic light response (A/Q) that varies directly with species' intrinsic shade tolerance. Light saturated A (A_{sat}) was highest under elevated CO_2 (714 ppm) in sun plants of Betula papyrifera (intolerant) and Quercus rubra (intermediate) and in shade plants of Acer rubrum (tolerant). Acer exhibited the greatest CO_2-induced shift in A/Q plasticity to growth light conditions, including leaf absorbtivity, light compensation point (Γ) and quantum yield (ϕ). Shade plants of Betula exhibited no shift in A/Q with elevated CO_2 whereas Quercus and Acer had lower Γ and higher A_{sat}. ϕ increased with CO_2 in shade plants of Acer and sun plants of Quercus. These results suggest that changes in carbon balance of understory seedlings may differentially shift with increasing CO_2 depending upon species plasticity to sun versus shade conditions.

KUEHNY, JEFF S. and MARY A. TOPA. Boyce Thompson Institute, Ithaca, NY, 14853, USA. Diurnal changes in ^{14}C assimilation, allocation and partitioning in loblolly pine seedlings.

Carbon transport to roots is a function of the carbon source/sink relationship between shoots and roots and their respective carbon metabolism. Short-term ^{14}C-labeling experiments are often used to determine allocation and partitioning patterns of recently-assimilated $^{14}CO_2$, but any conclusions concerning transport must be made with an understanding of how labeling of the pool available for transport might change with leaf carbon metabolism. The objectives of this study were to determine if labeling shoots of loblolly pine (*Pinus taeda* L.) with $^{14}CO_2$ at a particular time of day significantly altered ^{14}C partitioning and allocation in shoots and roots, and when maximum transport to roots occurred. Loblolly pine seedlings were grown in continuously-flowing solution culture for 15 weeks. The shoots were labeled with $^{14}CO_2$ at 1000, 1200, 1400 and 1600 h. Shoots and roots were harvested 0, 4, 12, 24 and 48 h after the ^{14}C-labeling period. Shoot-respired $^{14}CO_2$ increased continuously during the 48-h chase in those seedlings labeled at 1000h. Seedlings labeled later in the day, however, respired more $^{14}CO_2$ within the first 12-24 h of the chase period, with minimal respiratory losses during the remainder of the chase period. The allocation of total ^{14}C to shoot and root tissue and the partitioning of ^{14}C in the ethanol-soluble and starch fractions varied with time of labeling.

KUHLMANN, MARK L. Florida State University, Tallahassee, FL, 32306, USA. Indirect effects of a predatory gastropod on a suite of benthic fishes.

In St. Joseph Bay, FL, pen shells (Atrina rigida) are the main prey of horse conchs (Pleuroploca gigantea). Shells of dead Atrina are used as shelters and nest sites by blennies (Hypsoblennius hentzi and Chasmodes saburrae), clingfish (Gobiesox strumosus) and toadfish (Opsanus beta). Short-term shelter addition experiments caused an increase both in abundance, and frequency of egg-guarding, in blennies and clingfish, suggesting an important indirect effect of horse conchs on the distribution and reproductive activity of these species. To quantify the effect of horse conch predation on the fishes, 4 pen shell mortality-levels were simulated by adding shell mimics at controlled rates over 5 months. Preliminary analyses indicate that blenny and clingfish reproductive output and abundance tended to increase with Atrina mortality rate, while toadfish showed no consistent response. However, high between-site variation suggests that other factors also strongly influence fish populations.

KUNIN, WILLIAM E. NERC Centre for Population Biology, Imperial College Silwood Park, Ascot, BERKS, SL5 7PY, UK. Ecological consequences of local rarity and their implications for rare-common differences.

The study of density-dependence has for too long centered on phenomena that apply as species approach their carrying capacities; the dynamics of low-density effects (Allee effects and their opposite) may be equally interesting. The size and density of a species' population may affect its interactions with other species and with its environment. Low local population density in a plant, for example, can result in dramatic declines in the quantity and quality of pollinator services it receives, significant shifts in its herbivore load, and important changes in the competitive environment it faces. Population size effects may also be significant, but may be quite different from the effects of density. These factors may, in turn, affect population performance, creating potential positive and negative feedback loops that may draw populations toward or buffer them against local extinction. In addition, the ecological consequences of population size and density may cause plastic phenotypic responses, and so may help explain some observed differences between rare and common species.

KUPERMAN, ROMAN G, and CHRISTOPHER P. DUNN. Argonne National Laboratory, Argonne, IL, 60439, USA. Ecological effects of soil contamination at Aberdeen Proving Ground, Maryland.

Assessment of the ecological condition of contaminated soil was conducted in portions of the U.S. Army's Aberdeen Proving Ground, Maryland as part of an ecological risk assessment. This area is covered by open fields, woods and nontidal marshes. Chemicals disposed of in open burning pits included methylphosphonothioic acid, dichlorodiethyl sulfide, and titanium tetrachloride and sulfur trioxide/chlorosulfonic acid. Previous soil analyses showed extensive surface soil contamination with metals, nitrate, PCBs and pesticides. This assessment included characterizing soil biota, biologically-mediated processes in soil and aboveground biomass. Field surveys of the soil invertebrate communities showed significant reductions in the total abundance of animals, reductions in the abundance of several taxonomic and functional groups of soil invertebrates, and changes in the activity

of epigeic arthropods in contaminated areas when compared with the local "background" area. Laboratory toxicity tests also demonstrated that microbial activity and success of egg hatching of ground beetle Harpalus pensylvanicus were reduced in contaminated soils. These results suggest that impacts to soil ecosystems should be explicitly considered in ecological risk assessment.

KWIT, CHARLES AND WILLIAM J.PLATT. Louisiana State University, Baton Rouge, LA, 70803, USA.
Plant communities and species associations of steephead ravine forests.

Ravine forests in northern Florida steepheads occur along a topographic gradient that commonly extends 30 m from low creeksides to xeric uplands. These hardwood hammocks contain a wide variety of plants, including the endemic Florida yew, *Taxus floridana*. Vegetation was surveyed using belt transects located in two ravine systems of the Apalachicola Bluffs and Ravines Preserve (Liberty Co., FL). Principal components analysis, performed on 30 elevation classes containing 21 major species, indicates changes in plant composition and abundance along the elevational gradient and suggests the existence of three distinct plant communities: lowland evergreen swamp forests, midslope mesic mixed species hardwood forests, and upland xeric hardwood forests. *Taxus floridana* is closely associated with the mixed species hardwood forest type, which is dominated by American beech and southern magnolia and is widespread throughout the Southeastern Coastal Plain.

KYHL, JOHN F., STEVEN D. HENDRIX, ROBERT W. CRUDEN. Department of Biological Sciences, University of Iowa, Iowa City, IA 52242. Effects of population size on reproduction in the prairie perennial, Phlox pilosa.

With continued habitat fragmentation, natural areas and their constituent populations are being greatly reduced in size. Such decreases in population size have many unknown effects on long term population viability. Using the prairie species Phlox pilosa, at 25 sites in northwest and southeast Iowa, we show that there is a significant and positive correlation between the number of flowering ramets in a population and four reproductive characteristics. These include the number and proportion of flowers per stem producing capsules, the number of seeds produced per stem, and the average number of seeds produced per capsule. However, flower number per stem, average seed biomass per stem, stem height, and stem biomass were unaffected by population size. Lower capsule and seed production in small, isolated populations may be due to a lack of pollinators, suggesting that the viability of these population is threatened.

JABLONSKI, LEANNE M. and CATHERINE J. POTVIN. McGill University, Montreal, QC, CANADA H3A 1B1.
Influence of Vegetative C and N Storage on the Reproductive Response to Increased CO_2 in Raphanus.

We investigated whether plants possessing greater carbon storage capacity would show reproductive enhancement in increased CO_2. Four radish varieties differing in root:shoot ratio were grown for one season under 350 and 650 $\mu l\ l^{-1}$ CO_2 and two levels of N fertilization. The controlled environment program simulated diurnal and seasonal fluctuations in temperature, relative humidity, photoperiod and light intensity. Physiological parameters of foliar photosynthesis, starch, chlorophyll and protein and also hypocotyl carbon storage were measured during the pre-reproductive phase, and phenology was followed. Flowering was not affected by treatments. Reproductive biomass was increased in response to CO_2 in some varieties and was influenced by N. Path analysis will be used to examine which physiological and growth parameters best predict the reproductive response to increased CO_2.

JACK, JEFFREY D. Dartmouth College, Hanover, NH, 03755, USA. Direct and indirect effects on freshwater planktonic ciliate assemblages.

Bottle experiments were performed in two lakes to assess the effect of temporal changes in metazooplankton community structure on ciliate assemblages. Whole water samples were filtered to separate the protozoa and bacteria from the metazooplankton. The filtrate was added to a series of 4 L bottles, some of which were set aside as controls. The metazooplankton groups (rotifers, cladocerans and copepods) were then added to the remaining bottles as single groups or in combinations of groups. The bottles were suspended from a buoy in the lake for 2.5 days. The bottles were retrieved and sampled in the field for bacteria, phytoplankton, ciliates, rotifers, cladocerans and copepods. Throughout the study, rotifers often had strong positive indirect effects on larger (>40 μm) ciliates with escape responses and slight negative indirect effects on small ciliates when crustacean zooplankton were also present. The copepods had strong negative direct effects on all but the largest ciliates. Large cladocerans had substantial negative direct effects on ciliates, while smaller cladocerans sometimes had measurable indirect effects. These experiments show that the importance of top-down effects on ciliates varies with the structure of metazooplankton community.

JACOB, JAMES and BERT G. DRAKE. Smithsonian Environmental Research Center, Edgewater, MD 21037, USA. Rubisco concentration and total leaf carboxylase activity was reduced but leaf and canopy photosynthesis remained high in Scirpus olneyi grown in the field at elevated atmospheric CO_2 for seven years.

Photosynthetic gas exchange by leaves (A) at different leaf internal CO_2 concentrations (C_i) were measured and related to leaf biochemical composition and canopy photosynthesis in Scirpus olneyi grown in open top chambers in the field at ambient and elevated (ambient + 340 ppm) CO_2. Plants from elevated CO_2 had significantly higher (52%) A than plants from ambient CO_2 when measured in their respective growth CO_2 concentrations. Elevated CO_2 decreased leaf soluble protein (40-52%) and Rubisco (30-55%) contents, increased soluble sugar (52%) and starch (44%). Rubisco activation state increased slightly, but the in situ leaf carboxylase activity decreased substantially in elevated CO_2 grown leaves and this caused lower initial slope of the response of A to C_i. The CO_2 saturated photosynthetic rate was higher in leaves from elevated CO_2 than leaves from ambient CO_2. A model of canopy photosynthesis using measured parameters of leaf photosynthesis showed that total CO_2 assimilated per m^2 land area per day increased markedly in the elevated CO_2 treatment.

JACQMAIN, E. I., R. J. MITCHELL, AND R. H. JONES. School of Forestry, Auburn University, AL, 36849, USA. Oak distribution along an edaphic moisture gradient in fire-maintained longleaf pine-wiregrass ecosystems.

Oak community structure, and several environmental factors were sampled in 70 plots along a hydrologic gradient. Environmental variables included: soil, litter, and fuel nutrient and moisture characteristics; topographic position; light availability; overstory pine basal area; wiregrass cover; and distance to nearest firebreak. Species distributions were strongly correlated with geomorphology over all sites. Mean number of overstory oak stems ranged from 140 per hectare (std.dev.=67.8) in the xeric sandhill sites to 5 per hectare (std.dev.=11.2) in wet-mesic sites. Oaks in the mesic and wet-mesic plots were concentrated within the seedling/sprout layer (98% and 99%, respectively) whereas oaks in the xeric plots were distributed throughout three strata (82% seedling/sprout, 8.2% understory, 9.1% overstory). Xeric sandhills were dominated by turkey and sand post oak with lesser amounts of bluejack and sand live oaks. Wet-mesic sites were dominated by southern red and live oaks and lesser amounts of swamp laurel oak. Intermediate sites had the most oak species including mixtures of xeric and wet-mesic species plus water and laurel oaks. Variability among plots within the same moisture categories may relate to variations in fire history.

JAGER, HENRIETTE I., MICHAEL J. SALE, HAL E. CARDWELL, DONALD L. DEANGELIS, MARK J. BEVELHIMER, and CHARLES C. COUTANT. Oak Ridge National Laboratory, Oak Ridge, TN, 37831-6036, USA. Streamflow effects on spawning, rearing, and outmigration of fall-run chinook salmon (Oncorhynchus tshawytscha) predicted by a spatial and individual-based model.

The threat posed to Pacific salmon by competing water demands is a great concern to regulators of the hydropower industry. Finding the balance between fish resource and economic objectives depends on our ability to quantify flow effects on salmon production. Because field experiments are impractical, simulation models are needed to predict the effects of minimum flows on chinook salmon during their freshwater residence. We have developed a model to simulate the survival and development of eggs and alevins in redds and the growth, survival, and movement of juvenile chinook in response to local stream conditions (flow, temperature, chinook and predator density). Model results suggest that smolt production during dry years can be increased by raising spring minimum flows.

JAMES, FRANCES C., and CHARLES E. MCCULLOCH. Department of Biological Science, Florida State University, Tallahassee, Florida 32306, and Biometrics Unit, 337 Warren Hall, Cornell University, Ithaca, New York 14853. How to strengthen inferences about causes of trends in bird populations.

The determination of causes of long-term trends in bird populations is difficult because the problem encompasses a broad geographic scale and there are many competing explanations. True controlled experiments are usually not feasible, but in some situations quasiexperiments (those without random assignment of experimental units to treatments) can provide inferences about causes. Even so, such experiments are unlikely to encompass the geographic domain of interest. We advocate an additional step: the application of principles of quasiexperimental design to broad-scale comparative observational studies. On the basis of several examples, we compare the strength of inference allowed by different designs. A particularly good research design for such analyses is the multiple-time-series design.

JAMES, R. THOMAS. South Florida Water Management District, West Palm Beach, Florida, 33416, USA. Phosphorus Dynamics in Lake Okeechobee, Florida: Mechanistic and Statistical Model Comparisons

Total phosphorus concentrations (TP) in Lake Okeechobee, a eutrophic, sub-tropical lake in south Florida, increased from 0.06 mg l^{-1} in 1973 to 0.08 mg l^{-1} 1982. Since 1982 TP has not changed significantly. A mechanistic water quality model calibrated to 1985 and 1986 data did not mimic these TP trends when used to simulate the twenty-year period of record. The model included measured nutrient loads to the lake, a constant net settling rate, and a constant phosphorus flux from the sediments. I concluded that deviations

of simulated TP from observed TP must be related to changes in settling rate and sediment flux. Multiple regression models showed that date and annual average wind speed accounted for 76% of the variance in the TP deviations, but only 69% of the variance in annual average TP. This seven percent difference suggests that external loads have a small but significant impact on TP in the lake. The significance of date and wind in both regression models suggest that net sedimentation of phosphorus changed over time, and that wind resuspended sediments contribute to TP in Lake Okeechobee.

JAMISON, J., S.C. NODVIN. H. VAN MIEGROET, and A.K. ROSE. USDI, National Biological Survey-Cooperative Park Studies Unit, The University of Tennessee, Knoxville, TN, 37910, USA. Nitrogen dynamics in Southern Appalachian forests.

The effects of different age classes, elevation, and stand characteristics on nitrogen budgets and saturation were evaluated. We looked at two different stand types (cove hardwood; ~1036 m and red spruce/Fraser fir; ~1859 m). We also looked at the effect of stand age. Age classes for the cove hardwood stands were mature, degraded, and aggrading. Age classed for the spruce/fir stands were mature, late regeneration, and early regeneration. Levels of through-fall N input, soil-solution N concentrations, N mineralization and nitrification, and stream nitrate levels were measured at each site. Stand type had a significant influence on nitrogen budgets with spruce/fir stands exhibiting significantly higher levels of nitrate compared to cove hardwood stands. Stand age had a significant effect on nitrate leaching. Younger stands had significantly lower nitrate concentrations compared to mature stands. The presence of measurable levels of soil-solution nitrate in all stands suggest a range of nitrate saturation conditions. Nitrogen saturation is especially evident in the mature spruce/fir stand. Stream nitrate levels were significantly higher for spruce/fir stands. There were no significant differences among stands for nitrate levels in throughfall.

JASIENSKI, M. and F. A. BAZZAZ. Harvard University, Cambridge, MA, 02138, USA. Genotypic variation on crossed-gradients: a multifactorial approach to reaction norms in an annual plant

Multifactorial, fully-crossed experimental design was used to study the responses of naturally-occurring genotypes of clonally-propagated Polygonum pensylvanicum to crossed gradients of light, nutrients, and moisture. In the first experiment, plants from 25 genotypes were reared singly under all combinations of 5 light levels and 4 levels of nutrients. Genotypes differed significantly in total biomass and fruit biomass under most treatments, with the exception of the highest nutrient level combined with either the lowest or highest light intensity. In the second experiment, 14 genotypes were grown in competitive stands (as genotypic mixtures) under 8 combinations of light, nutrients, and moisture. Genotypes differed significantly in their average responses over all treatment combinations, but such differences did not depend on the particular levels of environmental variables. Overall, light and nutrients, but not soil moisture, had significant positive effects on plant biomass and seed production. Variation among genotypes was more pronounced at high nutrient level, irrespective of light intensity or soil moisture.The potential for microevolutionary change in annuals may therefore vary spatially and seasonally, depending on quite subtle differences in the combinations of environmental variables. The significance of such differences may only be assessed by examining multifactorial as opposed to single-gradient reaction norms.

JENKINS, DAVID G. Sangamon State University, Springfield, IL, 62794, USA. Do similar zooplankton communities develop in similar ponds?

Factors regulating zooplankton community structure have been studied for many years, yet studies often focus on contemporary factors (e.g., seasons, predation, competition) within the boundaries of single lakes. I studied zooplankton communities for one year in 12 new experimental ponds. Ponds were identically constructed, filled simultaneously, and had roughly similar physicochemistry through the study. Overall, 61 zooplankton species were recorded, but ponds accrued 31-40 zooplankton species and differed in species lists. One-third of the species never occurred in > 1/4 of the ponds. Seasonal successions were varied among ponds; populations were often asynchronous and/or had different amplitudes. McCune & Allen (1985) studied dissimilar old-growth forests on similar sites, and considered historical factors (e.g., seed dispersal) important in determining community structure. Like those forests, dispersal apparently regulated zooplankton community structure, and similar ponds did not develop similar zooplankton communities.

JOEL, GEESKE[1], ROBERT B. JACKSON[2], AND CHRISTOPHER B. FIELD[1]. [1]Carnegie Institution of Washington and [2]Stanford University, Stanford, CA 94305, USA. Elevated CO_2 and altered source/sink relationships: carbon allocation and nitrogen resorption in two annual grasses.

Predicting plant response to elevated CO_2 requires a better understanding of carbon and nitrogen interactions within plants. We altered C sources and sinks by increasing available CO_2 and clipping tillers of two common annual species (Avena fatua and Bromus mollis) and examined treatment effects on biomass, allocation, leaf and root properties, nitrogen pools and N retranslocation. Within 12 days of germination, total Avena biomass in elevated CO_2 increased by 25%, but the increased biomass was exclusively in roots. After 7 weeks there was still no change in Avena shoot biomass in elevated CO_2 and the number of tilllers produced also was unchanged. Leaf mass per unit area increased 11% and 29% for Avena and Bromus grown in high CO_2. Removing tillers increased the area of individual Avena leaves by 60% and resulted in significantly thinner roots, independent of CO_2 treatment. We summarize biomass, allocation, and N resorption for each species from germination through flowering.

JOHNSON, D.W. and H. VAN MIEGROET. Desert Research Institute, University of Nevada, Reno, NV 89506. USA and Forest Resources Department,Utah State University, Logan,UT USA. Nitrogen cycling and its effects upon soil processes in southernAppalachian red spruce and beech forests.

Spruce and beech forests in the Great Smoky Mountains are rich in N and soils are extremely acidic, and thus soil solutions are dominated by NO_3^-, SO_4^{2-}, Al and H^+. Large NO_3^- pulses at both spruce and nearby beech sites allowed the evaluation of several chemical relationships in conjunction with the Nutrient Cycling Model (NuCM). Inverse correlations between soil solution NO_3^- and SO_4^{2-} in the beech site were best by variations in pH-dependent SO_4^{2-} adsorption. In the spruce site, NO_3^- and SO_4^{2-} were positively correlated in the A horizon, indicating mineralization control over both ions and reflecting lower soil SO_4^{2-} adsorption capacity than in the beech site. NuCM failed to mimic the sequential peaks in soil solution Mg^{2+}, Ca^{2+}, and Al^{3+} concentration in the beech site because complete mixing of soil and solution by horizon was assumed. Thus, NuCM underestimated the potential reductions in Ca/Al during NO_3^-- pulses; a chromatographic model would be more appropriate.

JOHNSON, DEREK M. AND PETER D. STILING. University of South Florida, Tampa, FL, 33620, USA. A comparison of host choice between larval and adult Cactoblastis cactorum: Is one indicative of the other?

We investigated the host choice of Cactoblastis cactorum among four native Florida Opuntia spp. Cactoblastis cactorum is an exotic Phycitine moth native to South America. An ovipositing C. cactorum female lays an average of 50-80 eggs in a chain known as an egg stick. Since its arrival in Florida, via a Caribbean introduction, there has been concern for Florida's native Opuntia cacti. The adult moths are greater dispersers than the larvae, thus oviposition likely determines the host plant. However, low sample sizes in number of egg sticks laid makes determination of host preference difficult so we also investigated larval host choice and whether we could extrapolate adult host choice from this data. Both interspecific and intraspecific host choice was tested.

JOHNSON, E.A. and K. MIYANISHI. University of Calgary, Calgary, AB T2N 1N4 and University of Guelph, Guelph, ON N1G 2W1, CANADA. Old-growth, disturbance and ecosystem management.

The forested landscape consists of a mosaic of patches of different times since the last disturbance (i.e. different stand ages). Therefore, we can form a distribution of forest ages for the entire landscape (landscape age distribution). Studies of disturbance by fire in boreal and subalpine conifer forests have shown that the cumulative age distribution (landscape survivorship distribution) is best fit by a negative exponential model for which the parameter, the disturbance cycle, gives the time required to disturb an area equal in size to the study area. This distribution describes the rate at which parts of the landscape will survive disturbance and consequently, it tells us the percentage of the landscape that will survive to be 'old growth' forest. Empirical studies show that old forests make up a small proportion of the boreal and subalpine landscape, regardless of how old-growth is defined. We introduce the concept of characteristic oldest age which is a function of disturbance cycle and size of the study area.

JOHNSON, DOUGLAS H. National Biological Survey, Northern Prairie Wildlife Research Center, Jamestown, ND 58401, USA. Habitat block size for grassland birds: a test using Conservation Reserve Program fields.

The Conservation Reserve Program (CRP) has restored perennial grassland to thousands of hectares of former cropland in the Upper Midwest. These grasslands provide a natural experiment on the effect of size of habitat block on breeding bird communities. We surveyed breeding birds in 1990-92 on several hundred CRP fields in nine counties in four states (MN, ND, SD, and MT). Most common species were the Grasshopper Sparrow (Ammodramus savannarum) and Lark Bunting (Calamospiza melanocorys), with average densities of 21.0 and 20.5 breeding pairs per 100 ha, respectively. Among the other common prairie birds were Western Meadowlark (Sturnella neglecta), Horned Lark (Eremophila alpestris), Savannah Sparrow (Passerculus sandwichensis), and Bobolink (Dolichonyx oryzivorus). For a sample of fields, we determined the size of the block of contiguous habitat containing each field and related this to the frequency of occurrence and estimated density of birds in the field. Because densities of birds varied regionally and annually, analyses were done within county and year. Responses to block size varied among species.

JOHNSON, HYRUM B., BRUCE KIMBALL, STEVE LEAVITT. USDA-ARS, Temple, TX 76502 USA, USDA-ARS, Phoenix, AZ 85040 and University of Arizona, Tucson, AZ 85721. Carbon Isotope Assessment of Intrinsic Water Use Efficiency of C_3 Plants in Two FACE Experiments.

FACE (Free-Air CO_2 Enrichment) provides a means for evaluating the direct effects of elevated CO_2 on terrestrial ecosystems under field conditions. Intrinsic water use efficiency (IWUE), defined as A/g where $A/g = C_a\ (1-C_i/C_a)/1.6$ with A being photosynthesis, g being conductance to water vapor and C_a and C_i being the CO_2 concentration in the air and leaf respectively, was determined from the carbon isotope signatures of cotton and wheat, C_3 plants, growing at ambient and elevated CO_2 (550 ppm) in the field in Arizona. Sorghum and corn, C_4 plants, served as monitors of $^{13}C/^{12}C$ ratios of CO_2 in air. Cotton and wheat exhibited increases

in IWUE of 50% and 31% respectively, with a CO_2 enrichment of 52%. Higher C_a's rather than large changes in C_i/C_a accounted for most of the increase in IWUE. Productivity of terrestrial ecosystems should rise with CO_2 in the future as a consequence of increased water use efficiency.

JOHNSON, J.S. and E.A. JOHNSON. Dept. of Biological Sciences and Kananaskis Field Stations, University of Calgary, Calgary, AB, T2N 1N4, CANADA. Opening of semi-serotinous cones of Picea mariana by fire and ambient heating.

Picea mariana cone scales do not reflex immediately on maturation. Cones near the apex of the tree are closed while those cones below the apex are open. This is the result of cones developing only on branches less than 4 years old and cones opening gradually without a forest fire for 4-5 years after genesis. Cones are prevented from opening by a resin (melting temperature of 63°C) which keeps the scales from reflexing as they dry. There is a logarithmic relationship between the temperature and time required for cone opening multiplied by the cones' thermal properties (which is the ratio of the cone's thermal resistance and heating capacity). Therefore, transient heating by forest fires will open cones in a matter of seconds to minutes while heating by ambient air or direct beam solar radiation will require hours of continuous heating.

JOHNSON, L. C.,G. R. SHAVER, A. E. GIBLIN, K. J. NADELHOFFER, E. B. RASTETTER, J. A. LAUNDRE, AND G. L. MURRAY. Ecosystems Center, Marine Biological Laboratory, Woods Hole, MA, 02543, U.S.A. Effect of elevated temperature and enhanced drainage on carbon balance of tundra microcosms.

We tested effects of temperature and drainage on C balance of intact soil and tundra vegetation over a simulated season. We measured C budgets(CO_2 and CH_4 emissions and dissolved CO_2,CH_4 and DOC in soil water) of Eriophorum vaginatum tussock and moss-dominated intertussock microcosms at two temperatures(7°and 15°C, season maxima) and two water regimes (saturated and field capacity). Net ecosystem productivity was strongly affected by water. Averaged over temperature and microhabitat, the rate of net C loss from microcosms at field capacity was ~5x the saturated microcosms. Only saturated,15°C tussock microcosms showed net C storage integrated over the whole season. Ecosystem respiration was strongly affected by water and less by temperature. Respiration rates at field capacity were ~2x the rates under saturated conditions. Elevated temperature caused a 1.5x increase. Other C components were <20% of gaseous CO_2 losses. Results indicate that C in tundra exists in a fragile balance between storage and release that is controlled mainly by water regime.

JOHNSON, MARK G. ManTech Environmental Technology, Inc., U.S. EPA Environmental Research Laboratory, Corvallis, OR, 97333, USA. Will a Breakdown in Nutrient Cycling Limit the Long-Term Response of Forested Systems to Elevated CO_2 and Climate Change?

Rising atmospheric CO_2 and climate change may have dramatic effects on forested systems. Under elevated CO_2 most forest species increase their allocation of C to roots to acquire additional resources for growth. A large portion of photosynthate is released belowground through root turnover, root exudates, or symbiotic exchange. This injection of C belowground may stimulate the mineralization of soil organic matter and mineral weathering; increasing nutrient availability and plant growth in the short-term. It is uncertain, however, what the long-term effects on nutrient cycling will be. Will supply keep pace with demand? Will CO_2 stimulated mineralization be short-lived? Will the breakdown in nutrient cycling ultimately limit the biospheric response to elevated CO_2? Initial results from long-term CO_2 exposure studies indicate that increased nutrient use efficiencies and increased nutrient supplies may sustain the CO_2 effect in the short-term. It is likely, however, that in the long-term, nutrient supplies will eventually limit the growth response to elevated CO_2 in forested systems.

JOHNSON, MARK S. and ROLAND R. ROTH. Dept. of Entomology and Applied Ecology, University of Delaware, Newark, DE, 19717 USA The effects of age on breeding success on of wood thrushes (*Hylocichla mustelina*).

The possibility that productivity varies with age in birds may be relevant to the lower reproductive success reported for Neotropical migrants nesting in forest fragments. We asked if age and age-related factors affected the success of Wood Thrushes in a 15 ha Delaware woodlot. We used 1984-1993 data from an intensive study of a banded population. From 1984-1990, yearlings (SYs) fledged fewer young/yr than older (after second year, ASY) ones and SY-SY pairs fledged fewer than other pair types. ASY ♂♂ and ♀♀ had more nest attempts than SYs, but not more failures, indicating more persistence in producing a second brood. ASYs gained the time for renesting by starting nests earlier than SYs. Using 1984-'90 nest data, we constructed a contour map of habitat quality (=productivity) and compared success of SY and ASY owners of 1991-1993 nests in low (LQ) and high quality (HQ) areas. In general, SY clutch size and production in LQ sites were lower than in HQ sites and those of ASYs; ASY clutch size and production did not differ between HQ and LQ sites. Our results are consistent with the view that age structure may affect productivity of a population, especially when breeding conditions degrade.

JOHNSON, NANCY COLLINS. University of New Mexico, Albuquerque, NM, 87131-1091, USA. Structure and function of mycorrhizae in disturbed and undisturbed ecosystems.

Human activities inadvertently affect the structure and function of mycorrhizae. Experiments indicate that fertilization, tillage, grazing and plant monocultures impact the species

composition of mycorrhizal fungal communities. This is significant because species of mycorrhizal fungi differ in their effects on plants. Anthropogenic disturbances may select for mycorrhizae that are more or less mutualistic, particularly if they impact the carbon exchanged between host plants and mycorrhizal fungi. For example, fertilization causes plants to allocate more photosynthate to above-ground structure and less to root exudates. This could select for species and strains of mycorrhizal fungi that parasitically acquire and sequester hose carbon and select against less aggressive (more mutualistic) fungi. Mycorrhizae are potential stabilizing or destabilizing forces in ecosystems. Mutualistic mycorrhizae could contribute to ecosystem resiliency, while parasitic mycorrhizae could contribute to successional changes in natural systems, or generate yield decline in agricultural systems.

JOHNSON, PAUL D. and KENNETH M. BROWN. Louisiana State University, Department of Zoology, Baton Rouge, LA, 70803-1725 USA. Habitat-specific life histories in the stream pleurocerid *Elimia semicarinata*.

We repeatedly and quantitatively sampled several habitats in Doe Run Creek, Kentucky, to determine if there were differences in the abundance and size distribution of the pleurocerid grazer *Elimia semicarinata*. Densities were always greater in vegetation beds than in non-vegetated areas irrespective of flow regime, and snails were smaller as well, suggesting density dependence. Snails were also smaller in lotic than in lentic unvegetated areas, suggesting greater bioenergetic costs to snail growth in areas of high flow. Fewer juveniles occurred in lotic habitats, suggesting either reduced reproduction or migration to vegetated sites or unvegetated, low flow sites. In unvegetated sites, densities are higher at unshaded areas, and sizes are smaller. When all areas are compared, sizes are smallest at vegetated sites, followed by lotic sites, and are greatest at lentic, shaded sites. Thus snail sizes and densities are affected by the presence of vegetation, degree of shading and thus possibly periphyton abundance, and current velocity. These differences are maintained even though colonization experiments suggest high migration rates within unvegetated habitats.

JOHNSON, SANDRA L. and DAVID E. LINCOLN. University of South Carolina, Columbia, SC 29208, USA. Growth and defense dynamics of *Heterotheca subaxillaris* under three levels of defoliation.

We investigated the response of *Heterotheca subaxillaris* plants to defoliation and allocation to meet the conflicting requirements for continued growth, defense and reproduction. Defoliation on *H. subaxillaris* was simulated to resemble herbivory by its specialist folivore, *Zygograma heterothecae*, at levels comparable to those sustained in the field. Defoliation over five harvests from June through November allowed us to look at the dynamics of growth. Although tissue was removed at three significantly different levels ($P < .001$), neither relative growth rates nor final accumulations of leaf, shoot or total biomass differed significantly among treatments. Under low defoliation, plants seemed to partition resources similarly to control plants. Under high defoliation, plants responded differently with slow growth and early flowering, followed by a burst of increased growth. These results suggest compensatory responses to the 10-25% leaf area removals that may be masked by high natural variability in growth rate. Gas chromatographic analysis of volatile mono- and sesquiterpenes over a series of five harvests shows a definite developmental pattern of defense chemical production ($P < .01$). The tendency for lower quanitities of defense compounds in defoliated plants was not significant, but it suggests a tradeoff relationship between growth and defense and not an induced response. Differences in flower production between treatments were not significant.

JONES, MICHAEL H.[1], S. ELLEN MACDONALD[1], AND GREGORY H. R. HENRY[2]. [1]University of Alberta, Edmonton, AB, and [2] University of British Columbia, Vancouver, BC, CANADA. Effects of experimentally-warmed tundra on diurnal gas exchange in Salix, Carex, and Eriophorum in a high-arctic lowland oasis.

Gas exchange was measured for the willow Salix arctica and two sedge species, Carex aquatilus stans and Eriophorum angustifolium triste, at Alexandra Fiord, Ellesmere Island (78°53'N) in an experiment designed to simulate climate change. The tundra was warmed using passive, open-topped experimental chambers that raised daily mean temperatures approx. 2° over two seasons. The chambers are part of the International Tundra Experiment (ITEX), the objective of which is to assess potential impacts of global warming on tundra plant communities. Salix arctica was measured in dry tundra and on adjacent wet meadow hummocks. The sedges were measured on hummocks and in hollows in the wet meadow only. Gas exchange was measured every four hours for 48 hours for each species. For S. arctica, experimental warming had no effect in the dry tundra, but appeared to depress net assimilation (NA) in the wet meadow. Gas exchange parameters were slightly higher overall in the dry tundra for this species. For the sedges, the warming treatment had no major effect, although it caused some reduction of NA for Eriophorum on the hummocks. Gas exchange parameters were generally higher for Carex than for Eriophorum. No regular diurnal patterns of gas exchange were observed for any species.

JONES, R. CHRISTIAN. George Mason University, Fairfax, VA, 22030, USA. Factors affecting summer phytoplankton biomass in the tidal freshwater Potomac River.

Phytoplankton chlorophyll levels and related hydrologic, physical, and chemical factors have been measured in the mainstem channel region and in two shallow embayments on the tidal freshwater Potomac River below Washington, D.C. since 1984. Weekly to monthly measurements at multiple stations in each region were averaged over the summer months of June, July, and August to arrive at the values used for statistical and graphical analysis. In the river mainstem the strongest relationship was a negative one with summer average flow indicating the effect of residence time and flushing on phytoplankton development. Relationships with total phosphorus, temperature, and sunshine were inconclusive. In the shallow embayment a positive relationship with total phosphorus in addition to the negative relationship with flow indicated that both nutrients and flushing were important in that region.

JONES, R.H., R.W. PARRISH, B.G. LOCKABY and G.L. SOMERS. School of Forestry, Auburn University, AL, 36849, USA. Fine root productivity in two forested wetlands located in the coastal plain of Alabama.

Root coring was used to assess dry mass of living and dead fine roots (< 5 mm diam.) in two wetland forests dominated by swamp tupelo, sweetbay and mixed evergreen species. Soils are characterized by high organic matter content, low phosphorus availability, and extremes in microtopography. On each of five sample dates spread over one year, 40 cores (5 cm diameter by 50 cm deep) were collected from each forest, 20 from an area clearcut shortly after the first cores were collected, and 20 from an uncut control. Cores were mechanically washed and then sorted by hand. The mean maximum and minimum standing live root biomass were 4.41 and 2.83 tons per hectare, respectively. Overall mean dead root mass ranged from 1.95 to 1.06 tons per hectare. Individual sites differed in standing root mass and turnover rate, but no clear effect of harvest was noted. Productivity estimates ranged between 1.77 and 9.45 tons per hectare per year depending on method of calculation and site. Biomass and productivity were significantly affected by microtopographic position. Live root mass was greatest on convex hummocks, less on intermediate flat areas and lowest in concave hollows. Root turnover was greater on hummocks and hollows than in flat areas.

JOSLIN, J. D., F. C. THORNTON, and H. VAN MIEGROET. Tennessee Valley Authority and Utah State University. USA. Evidence for nutritional deficiencies in high elevation red spruce.

Evidence for a possible role of tree nutrition in the decline in red spruce radial growth at high elevations includes: (i) surveys of foliar nutrition along elevational gradients, (ii) field studies on impacts of acidic fog deposition on cation leaching and on concentrations of Al in soil solution, (iii) greenhouse fertilization studies of seedlings and field fertilization studies on saplings and mature trees, and (iv) results of x-ray microanalyses of fine root cross-sections of fertilized and non-fertilized trees. A review of these results indicates deficiencies of Ca and Zn, especially in the southern Appalachians. Both the enhancement of foliar leaching, and the elevation of soil solution Al by acidic cloud water deposition, may be mechanisms that are exacerbating these deficiencies.

JOYCE, BRIAN J. and KIM C. STEINER. Pennsylvania State University, University Park, PA, 16802, USA. Variation in shoot-length frequencies and bifurcation ratios in black cherry seedlings, saplings and mature canopy trees.

Observations of differential patterns of shoot growth and branch development between different sized black cherry *(Prunus serotina* Ehrh.) led to a quantitative investigation of variation in crown morphology. Shoot-length frequencies and bifurcation ratios were determined for open- and forest-grown seedlings and saplings and for branches from the upper and lower crown levels of mature canopy trees. The modal number of shoots in a given length class varied among the three size classes, between open- and forest-grown individuals of the same size class, and between the upper and lower crown of mature canopy trees. Bifurcation ratios of open-grown saplings were greater than forest-grown saplings as was the mean length of terminal shoots. A set of prediction equations was developed for each size class-growing environment combination expressing the number of shoots in a given length class as a function of the size of the parent branch.

JUDGE, MICHAEL L., FRANCISCO BORRERO and SEAN F. CRAIG. Manhattan College, Riverdale, NY, 10471, USA, Instituto de Investigacioner, Santa Marta AA 1016, Columbia and State University of New York, Stony Brook, NY, 11794, USA. Water flow effects on the growth of bivalves and tunicates: results from *in situ* manipulation of water currents.

In contrast to benthic passive suspension feeders, individual active suspension-feeding bivalves (mussels, scallops, oysters) and colonial tunicates did not exhibit any positive flow dependence on growth (although some species were inhibited by high flows). Juvenile bivalves (at low density to minimize food resource depletion) and tunicate colonies were attached to growth plates (9x9 cm) and suspended in mid-water column within a series of 12 tapered channels constructed subtidally in a Long Island estuary to bracket experimentally the existing tidal currents ± 50% (flow speeds ranged from <2 to >50 $cm \cdot s^{-1}$). Despite substantial growth by all species, the lack of treatment differences argue against proposed flux-dependent growth models.

JULIANO, STEVEN A. Illinois State University, Normal, IL, 61790-4120, USA. Interspecific competition, apparent competition, and the replacement of Aedes aegypti by Aedes albopictus: A field experiment with container-dwelling mosquitoes.

Invasion of the southern US by Aedes albopictus and the associated decline of Aedes aegypti suggest competitive exclusion, but laboratory competition experiments with laboratory strains and artificial food sources have shown no competitive advantage for A. albopictus. I evaluated competitive abilities of these species under more natural conditions in a field experiment. Using a randomized complete block design, each of 5 tires held 12 cages, each cage with different densities and combinations of hatchling larvae of the two Aedes, and with or without oak leaf

litter as a food source. For each species in each cage, I calculated r' (estimated cohort rate of increase) from survivorship, time to maturity, and fecundity (estimated from adult size). Strengths of inter- and intra-specific competition were similar for both species. Even at high combined density with no litter, A. albopictus produced many adults and had r'>0. At high combined density with no litter, A. aegypti produced few adults and had r'≤0. A. albopictus is competitively superior to A. aegypti due to the former's greater carrying capacity and lower requirement for per capita litter availability. In this experiment, competitive superiority of A. albopictus did not result from apparent competition mediated by parasitic protozoans (Ascogregarina), as parasitism rate for A. albopictus was much greater (~20%) than that for A. aegypti (<1%).

JURADO, ENRIQUE and JOEL FLORES. Facultad de Ciencias Forestales, UANL, A.P. 41 Linares, N.L. MEXICO. Germination and establishment characteristics of Tamaulipan Thornscrub plants.

Germination characteristics were studied for 24 especies of Tamaulipan Thornscrub, including trees, shrubs and twiners. Most species had their seeds germinated ten days after contact with water. Some species required scarification of teguments to promote germination. All species germinated at mean Summer temperature, most of them had fewer seeds germinated at mean Winter temperature. Seedlings were planted under three different conditions: (i) direct sunlight, (ii) artificial shade, and (iii) under the canopy of mature shrubs. Most seedlings grown under mature shrubs were eaten by predators, whereas those in artificial shade had higher survival and a larger number of leaves than those grown on direct sunlight.

LACHNICHT, SHARON L., ROBERT W. PARMELEE, DAVID A. MCCARTNEY AND MICHAEL F. ALLEN. Ohio State University, Columbus, OH, 43210, USA. Soil macroporosity and saturated hydraulic flow in agroecosystems with different densities of earthworms.

Soil macropore area by three size classes (1-8, 8-16 and >16 mm) at three depths (10, 20 and 30 cm) was quantified in a corn agroecosystem with manipulated populations of earthworms (reduced, ambient, addition). Macropores in intact soil cores were traced onto acetate sheets, and their area determined by digital analysis. Saturated hydraulic flow and preferential flow pathways were determined by applying a water-soluble paint to the soil surface. In the earthworm addition plots, total macropore area was significantly greater than in earthworm reduction or ambient plots. The effect of earthworms on macropore area was largely due to increased area of large macropores (> 16 mm), many of which were recognizable as *Lumbricus terrestris* burrows. Many of these burrows were coated with paint suggesting that they were important preferential flow pathways. Saturated hydraulic flow rate was positively correlated with the area of small macropores at 10 cm. Our results show that earthworms can increase soil macroporosity and preferential flow pathways, and have the potential to influence the leaching of nutrients from the system.

LANGAN, SUSAN J. AND STEPHEN D. DAVIS. Pepperdine University, Malibu, CA, 90263, USA. **Xylem dysfunction caused by freezing and water stress in two species of co-occurring chaparral shrubs.**

Water transport from the soil to leaves in higher plants is facilitated by xylem vessels and tracheids. Air bubbles in xylem (embolism) block water transport, potentially causing shoot dieback. We compared the differential vulnerabilities of *Malosma laurina* and *Ceanothus megacarpus* to both freezing-induced and water stress-induced embolism of their xylem. We found that *M. laurina* became 50% embolized at a water stress of -3 MPa and 100% embolized due to freezing at all hydration levels. In contrast, *C. megacarpus* became 50% embolized at a water stress of -9 MPa and 100% embolized due to freezing only after susbstantial dehydration (-3 MPa). Reducing thaw rates from about 50 C/hr to 5 C/ hr (normal thaw rate measured *in situ*) had no effect in embolism formation in *M. laurina* but significantly reduced embolism occurrence in *C. megacarpus* (embolism reduced from 74% to 35%). These results were consistent with field observations of differential shoot dieback between these two species after a natural freeze-thaw event in the Santa Monica Mountains of southern California. Funded by NSF grants BBS-9100731 and BSR-90-07288.

LANGELLOTTO, GAIL A., ROBERT F. DENNO and JAMES R. OTT. University of Maryland, College Park, MD, 20742, USA. The ecological basis for dispersal polymorphism in males: Evidence for a trade-off between flight capability and mating success.

The evolution of wing dimorphism in insects is based largely on the reproductive costs of flight capability in females. Comparable evidence for a trade-off between flight capability and fitness is not available for males. Evidence for such a trade-off was obtained by comparing several components of reproductive success between the two male wing forms (volant macropters and flightless brachypters) of *Prokelisia* planthoppers. In a competitive arena, brachypterous males were three times more successful in acquiring matings than their macropterous rivals. When caged with 10 females, single brachypterous males sired twice as many offspring as their macropterous counterparts. These results support the hypothesis that there are inherent reproductive costs which occur at the expense of dispersal capability in males. Coupled with existing data for females, such fitness differences between male wing forms provide a more general ecological basis for the existence of dispersal polymorphisms in insects.

LANKFORD, GEORGE K. and THOMAS R. WENTWORTH. North Carolina State University, Raleigh, NC, 27695-7612, USA. Vegetation responses to soil compaction and organic matter removal in a lower coastal plain loblolly pine (Pinus taeda L.) plantation.

Timber harvest operations increase soil bulk density and remove organic matter (OM; including the forest floor, in extreme cases). We have studied responses of native vegetation to varying degrees of soil compaction and OM removal in an experimental pine plantation in North Carolina. Soil properties (total carbon, total nitrogen, and bulk density) and cover ratings for vascular plant species were determined in permanent transects established in larger treatment plots. All measurements were recorded immediately prior to stand harvest and one year later. Soil bulk density was significantly affected by the compaction treatment. Detrended correspondence analysis (DCA) of the vegetation data indicated consistent pre- to postharvest compositional shifts for all plots along axis 1. The magnitude of temporal change along axis 1 was related to treatment; soil compaction alone affected vegetation much less than OM removal or compaction with OM removal. Block effects were evident in compositional trends on DCA axis 2.

LARSON, DIANE L. National Biological Survey, Northern Prairie Wildlife Research Center, Jamestown, ND 58401, USA. Hormonal response to environmental stress in larval Ambystoma tigrinum.

Stress hormones (e.g., cortisol and corticosterone) are important mediators of physiological and behavioral response to acute stress in vertebrates. If acute stress response is related to chronic stress, measurements of this response might provide an indication of environmental quality for the population. Objectives of this study were (1) to develop a non-destructive technique for assessing hormonal response to stress, and (2) to assess the relation between acute stress response and environmental stressors, under the hypothesis that larvae inhabiting degraded environments would show a diminished response to acute stress. To assess hormonal response to stress, we captured larvae in unbaited funnel traps left in wetlands over night. Blood samples were taken immediately from half the captured animals removed from traps; the remaining animals were sampled after 30 min confinement in 500 ml bottles (acute stress). Corticosterone levels in the two groups differed significantly. Larvae from wetlands with higher percentages of surrounding tilled land showed less response to acute stress than did larvae in areas with little tillage within the same physiographic region. Responses varied geographically.

LASKA, MARK S. Rutgers University, Piscataway, NJ 08855-1059, USA. Predicting the intensity of per capita competitive interactions from body size ratios of competitors.

This study experimentally tests whether the intensity of competitive interactions can be predicted, *a priori*, from the ratio of body sizes of species competing for a common limiting resource. Systematic comparisons of the competitive ability of several test species against a single species, or "zoometer", is assessed in replicated laboratory experiments using Cladocerans. To date, four species of *Daphnia* in competition with the zoometer, *Ceriodaphnia dubia*, have been examined. Per capita competitive ability (i.e., interaction strength) is measured as the extent to which each test species is able to change the abundance and size distribution of *C. dubia* during short-term experiments lasting for several generations. Multivariate analyses of variance show significant effects of competition on the abundance, body size, and biomass of the zoometer, and on each of its competitors. The abundance and body size distribution of *C. dubia* was significantly depressed by each of the test species. Positive correlations between per capita interaction strength and size distribution of competitors suggest that body size ratios may be useful predictors of competition.

LATTIN, JOHN D. Oregon State University, Corvallis, OR, 97331-2907, USA. The biological hazards of raw log importations: science vs. public policy.

Raw logs from Siberia arrived in California in 1990. Some were infested with pathogens, insects, and nematodes. Inadequate regulations existed so the logs were released and processed. Scientists were concerned that logs would be agents for exotic pests. A temporary ban was placed on these imports. Scientists met to assess the risks. Existing mitigation procedures were deemed inadequate to assure pest-free logs. Immediately, log shipments from New Zealand and Chile were proposed. Shipments from New Zealand were infested. Outside reviews of the risk assessments prepared on New Zealand and Chilean imports were very critical. In spite of these reviews, USDA/APHIS prepared an interim regulation allowing New Zealand log importations in 1993. Market forces, rather than science, seem to dominate the policy-making process.

LATTO, JOHN G. and CHERYL J. BRIGGS. University of Westminster, London, W1M 8JS, UK and Imperial College, Silwood Park, Ascot, Berks, SL5 7PY, UK. Factors affecting the distribution and abundance of a gall-forming midge.

Rhopalomyia californica is a gall-forming cecidomyid midge that is found in coastal areas of California, with its host plant, Baccharis pilularis. The southern limit of the distribution of the midge is thought to be Santa Barbara. Normal, multi-chambered galls are rare in the Santa Barbara area but single-chambered galls are readily found there. Reasons for these differences in gall morphology and distribution were

examined by field experiments at two sites: Santa Barbara, and Big Creek which is located 290 km to the North, well within the range of the normal galls. There were no differences in plant suitability for oviposition between the two sites but midges responded differently to the plants, each midge producing more galls at Santa Barbara but each gall contained, on average, less chambers. Egg predation was significantly higher at Santa Barbara than at Big Creek. Egg predation reduced both the number of galls produced per female and also the average number of chambers per gall that was produced. The identity of the predators is unknown. Parasitism caused a higher mortality at Santa Barbara than at Big Creek. There was no evidence for spatial density dependence at either site. When combined with realistic parasitism rates and likely fecundities, such mortality rates result in a negative growth rate for multi-chambered galls at Santa Barbara but a positive growth rate at Big Creek.

LAUENROTH, W. K., I. C. BURKE, and D. P. COFFIN. Colorado State University, Fort Collins, CO 80523, USA. Analysis of the response of soil water to climate change.

We used a daily time step soil water model to investigate the potential effects of changes in temperature and precipitation on soil water dynamics in the central grassland region of the U.S. We collected 20-years of driving variable data from each of 300 USGS weather stations throughout the region. Simulations were run for each station and the results were entered into a GIS database for analysis and display. Soil water patterns under current climatic conditions reflected the large scale west-east precipitation and south-north temperature gradients. Bare soil evaporation accounted for a large proportion of water loss in the driest areas and was replaced by canopy interception in the wettest areas. Transpiration water loss reflected the regional pattern of net primary production, highest in the warm and wet areas and lowest in the warm and dry areas. Increased temperature affected both evaporation and transpiration losses largely by increasing the length of time when evaporative demand of the atmosphere was high. Increases and decreases in precipitation affected water supply directly. Interactions between changes in elevated temperature and increased or decreased precipitation depended upon the balance of changes in water supply and demand.

LAVOREL, S. Ecosystem Dynamics Group, Australian National University, Canberra ACT 0200, Australia. Mechanisms of maintenance of herbaceous species richness in patchy habitats with local disturbances.

Coexistence of plant species was studied with a spatially-explicit simulation model incorporating patchy habitat availability. Habitat maps were generated with the amount of suitable habitat and degree of clumping varying independently. Frequency of local disturbances was also varied quantatively. The number of coexisting species depended on both habitat pattern and disturbance frequency. An invasibility analysis was carried out to examine the contribution of dispersal efficiency (the number of seeds reaching suitable sites for germination), fraction of seeds available to germination each year, and local inter- and intraspecific competition to coexistence of species with different seed dispersal and dormancy strategies. Results show that the mechanism by which differences in regeneration niches between species competing for colonizable space lead to coexistence is the aggregation of conspecific seeds and the resulting partitioning of habitat between species. Thus, the conjunction of habitat heterogeneity and local disturbances are essential to the maintenance of species richness.

LAWLER, SHARON P. and D. BALCIUNAS. NERC Centre for Population Biology, Imperial College, UK. Effects of alternate prey and basal resource level in simple microcosm communities of protists.

Basal resources, food chain length and heterogeneity within trophic levels may influence the abundance of species at different trophic levels. To manipulate these factors, we assembled a three trophic level food chain and its subsets, using bacteria, one or two bacterivorous protists (*Chilomonas*, a small flagellate or *Colpidium*, a larger ciliate), and a predatory protist, *Euplotes*. Communities were grown in either of two concentrations of medium. Bacterivores coexisted without predators and were more abundant at high nutrient levels. With predators, *Chilomonas* went extinct at both nutrient levels but the larger *Colpidium* persisted. Predators became more abundant at the high nutrient level when the small prey was present, but went extinct if only the large prey were present in high nutrient microcosms. The larger prey obtained a size refuge when grown at high nutrient levels, demonstrating that nutrients can have complex effects on trophic cascades.

LAWRENCE, DEBORAH C. Duke University, Durham, NC 27708-0339, USA. The effects of disturbance history on tree species diversity under shifting cultivation.

Vegetation, soil characteristics and disturbance history were described for 15 fallow upland rice fields, aged 5 to 33 yrs, in a village in West Kalimantan, Indonesia. At each field, the diversity of tree species was determined using randomly placed, nested plots (0.1 ha for trees ≥ 10 cm dbh; 0.01 ha for saplings and trees ≥ 5 cm dbh). Twelve 30-cm soil core samples were taken at each vegetation plot. The samples were then mixed, sun-dried, and sub-sampled for analysis. I noted both patch age and the number of times the patch had been cultivated. Soils were analyzed for soil organic matter, soil charcoal, N, and P. I explore functional relationships among tree species diversity (both richness and evenness), soil nutrient status, patch age and the number of times the patch had been disturbed. Preliminary results suggest that tree species richness and evenness increase as a function of the number of times disturbed. The relationship between species diversity and patch age is less clear and appears to depend on the disturbance history of the site.

LAWSON(1), DAN, NANCY J. HUNTLY(1), RICHARD S. INOUYE(1), and WALTER P. CARSON(2). (1)Idaho State University, Pocatello, ID, 83209, USA and (2)Princeton University, Princeton NJ, 08544, USA. Woody species invasion along field margins of different age and aspect.

We mapped and measured trees and shrubs along 25 forest-field margins in 18 old-fields (1-66 years since abandonment) at Cedar Creek Natural History Area, MN. *Quercus borealis-ellipsoidalis* was the most common tree species (56% of trees); *Corylus americana*, *Rubus spp.*, *Rosa arkansana*, *Rhus glabra*, and *Euonymus alatus* accounted for 90% of the shrubs. Tree and shrub stem number and species diversity decreased at increasing distances from the woods. Counter to our expectations, they showed no clear correlation with field age. Tree height and diameter increased with field age. Aspen were disproportionately abundant in east facing margins and entirely absent from south facing margins. Margins with southern aspects had a significantly higher proportion of oaks at all distances from the treeline. Our analysis identified two distinct groups of fields, those dominated by oaks and those in which oak abundance remained low, independent of field age and tree density.

LEAVITT, ALLISON R. and ORIE L. LOUCKS. Miami University, Institute of Environmental Science and Department of Zoology, Oxford, OH 45056, USA. Linkages between human and ecological systems evident in long-term management of ecologically sensitive reserves.

The 1990's has seen increased use of precise long-term goals in planning for sustainable use and protection of large conservation areas. These goals, both human and ecological, are expressed frequently as ecological endpoints. A key question becomes: what research on both social and ecological endpoint dynamics will advance understanding of linkages between the elements of ecological systems and the overlain human systems? Establishing ecological and societal endpoints represents a change in how area-wide planning is done, particularly ecologically-based planning for sustainability. In important respects this shift represents a new paradigm. The classical planning paradigm, and the more recent landscape conservation paradigm, will be compared quantitatively to evaluate the two approaches over a sixty year period at three sites in the United States. Differences between Winton Woods, Greenhills, Ohio (from 1938), the Pinelands National Reserve (from 1980), and The Nature Conservancy's Virginia Coast Reserve (from 1988) will illustrate the extent to which use of precise endpoints can make a difference in the operation of protected areas.

LEE, DAVID W., DANIEL BASKARAN, MARZALINA MANSOR, HARIS MOHAMED AND SON KHEONG YAP. Florida International University and Fairchild Tropical Garden, Miami, FL, 33199, USA and Forest Research Institute of Malaysia, Kuala Lumpur, Malaysia. Responses of eight Malaysian rainforest tree seedlings to simulated forest shade.

We studied the growth responses of *Dryobalanops aromatica*, *Endospermum malaccense*, *Hopea helferei*, *Hopea odorata*, *Hopea wightiana*, *Parkia javanica*, *Sindora echinocalyx*, and *Shorea singkawang* to (1) low PAR (3 % full sun) and low or high R:FR (0.23 or 1.25); (2) medium PAR (12.0 %) and low or high R:FR; and (3) high PAR (40 %) and high R:FR conditions in shadehouses. Although the pioneer species (EM and PJ) responded most strongly to reduced R:FR in internode length and final height, all species were affected by reduced R:FR at varying levels of organization. Three shade tolerant taxa (DA, HO and SS) branched much less under these conditions. In all taxa the effects of reduced R:FR supplemented those of reduced PAR, particularly at intermediate fluxes, and there is little evidence of interaction between the two light variables.

LECHOWICZ, MARTIN J., ZHANG MING WANG and CATHERINE POTVIN. Department of Biology, McGill University, Montreal, Quebec H3A 1B1, Canada. **Responses of black spruce seedlings to simulated present versus future seedbed environments.**

We investigated the effects of nitrogen availability and present versus future climates on the seedling performance of 16 maternal families of *Picea mariana* (Mill.) B.S.P. over two simulated growing seasons. Realistic diurnal and seasonal patterns of temperature, relative humidity, photoperiod, and light intensity were simulated. The future climate increased seedling survival, total and root dry mass, rate of winter bud development, photosynthetic capacity, and water and nitrogen use efficiencies, but decreased foliar nitrogen, and changed biomass allocation patterns. Greater nitrogen availability improved seedling performance and changed biomass allocation patterns. The future climate increased seedling survival, rate of bud development, and nitrogen use efficiency much more in the low than in the high nitrogen regime. Seedling performance in the 2nd season was dependent on initial seed mass, but less than in the 1st year. Families presently selected for rapid growth may not do as well under future conditions, at least in terms of early establishment.

LEFF, LAURA G., J VAUN MCARTHUR and L. J. SHIMKETS. Kent State University, Kent, OH, 44242-0001, USA and Savannah River Ecology Laboratory, Aiken, SC 29802, USA. Comparison of methods for identification of aquatic bacteria.

Traditionally, physiological tests are used to identify bacteria. Molecular techniques increase accuracy but are rarely applied to freshwater bacteria. Bacteria collected from Upper Three

Creek were identified using physiological tests, fatty acid analysis, and hybridization with taxon-specific DNA probes. Physiological tests were sometimes inaccurate, and only 50% of isolates were identified. Of isolates identified as Pseudomonas cepacia, 35% failed to hybridize with a P. cepacia-specific probe and 44% were not P. cepacia based on fatty acid analysis. Molecular probes allow identification of many isolates but this approach is limited by availability of taxon-specific probes. All three approaches rely on culture of bacteria, but because typically less than 1% of bacteria in nature can be cultured, direct identification approaches are needed. Because of these limitations, identification schemes for ecological studies should utilize multiple techniques.

LEFRANÇOIS, C. and L. MAILLETTE. CGCP, P.O. Box 9734, Ottawa, Ontario, Canada K1G 5J4; Université du Québec à Trois-Rivières, C.P. 500, Trois-Rivières, Québec, Canada G9A 5H7. The Canadian Global Change Program.

Global change affects climate and many other processes of the biosphere, atmosphere, geosphere, oceans and human societies. The Canadian Global Change Program (CGCP) is a multidisciplinary body established in 1985 by the Royal Society of Canada. The CGCP stimulates research projects, acts as national link to international programs such as the International Geosphere-Biosphere Programme, assists in policy formulation, maintains a database of global change activities in Canada, and promotes awareness of global change issues among researchers, policy makers, educators, and the general public. The importance of human societies as forcing functions of global change is integrated in the activities of the CGCP (e.g. long-term ecosystem monitoring, reduction of greenhouse gas emission, population growth and resource use). CGCP publications include a quarterly newsletter (DELTA), overviews of major issues, policy recommendations, proceedings of workshops and conferences, and documents destined to educators.

LEI, SIMON A. and LAWRENCE R. WALKER. University of Nevada, Las Vegas, Las Vegas, NV, 89154, USA. Environmental factors influencing the distribution of Coleogyne communities in southern Nevada.

The shrub, Coleogyne ramosissima (blackbrush), forms a nearly monospecific community between 1,040 - 2,175 m elevation in southern Nevada. We characterized to what extent environmental factors correlated with Coleogyne density at the lower elevational boundary. Soil pH, soil depth, and soil and air temperatures were negatively correlated with Coleogyne density. In contrast, gravimetric soil moisture and total soil Kjeldahl nitrogen were positively correlated with Coleogyne density. Edaphic factors appear to play a major role in determining the distribution of the Coleogyne community.

LEMASTER, MICHAEL, JULIA A. JONES, ANDREW R. MOLDENKE and CHRISTIAN E. TORGERSEN. Oregon State University, Corvallis, OR 97331 USA. Spatial heterogeneity of soil invertebrates and edaphic properties in a coniferous forest.

Geostatistical tools (semi-variogram, correlogram) were used to compare heterogeneity in soil arthropod density, O-horizon depth, moisture content, temperature and pH in two adjacent plots: 1) a heterogeneous mix of age classes with a high density of old-growth Douglas-fir; 2) a homogeneous post-fire stand of pure regrowth Douglas-fir. Spatial analysis revealed distinguishable differences between old-growth and regrowth between sampled years. In the hot dry spring of 1992, short range variability and patches (0-5m), especially in pH, moisture, O-horizon depth and faunal census were more pronounced in the homogeneous regrowth plot, whereas long range patterns (17-22m) were more pronounced in the heterogeneous old-growth plot. In the cold wet spring of 1993 both old-growth and regrowth forest plots had only short range variation. Principal components analysis of arthropod species diversity revealed consistent correlates with microhabitat phenomena.

LENIHAN, JAMES M. and RONALD P. NEILSON. Oregon State University and U.S. Forest Service, Corvallis, OR, 97333, USA. **Climatic variability, fire, and vegetation modeling in the North American Central Grassland Region.**

In developing an equilibrium vegetation model for assessing the sensitivity of natural vegetation to climatic change in the Central Grasslands, we encountered difficulties in establishing solely climatic determinants for grasslands. Under the normal climate, woody plant dominance was predicted for much of the region supporting open grassland at the time of European settlement. Climatic data for historic periods and a fire model were used to test whether grass dominance was promoted by 1) climatic periods distinct from the normal period, 2) by fire, or 3) by the interactive effect of both. Grass/woody ratios in test simulations exhibited spatio-temporal variation produced by complex interactions among PET, precipitation seasonality, competition for soil moisture, and fuel characteristics determining fire intensity. Results support concepts of plant community thresholds and multiple steady states in the Central Grassland region.

LEONG, JOAN M. and ROBBIN W. THORP. University of California, Davis, Davis, CA, 95616, USA. Pollination in natural and recreated vernal pool habitats: beware of imitations.

It is currently unknown whether the ecological properties of artificially constructed or recreated vernal pool habitats are similar to those of natural vernal pool habitats. In this study, we test the hypothesis that pollination processes differ in recreated and natural vernal pool habitats by comparing the pollination of Blennosperma nanum nanum (Asteraceae) in a recreated and natural vernal pool site. We experimentally compared pollination at both sites by using arrays of potted plants grown in a greenhouse. The results of our study reveal that pollination processes are markedly diminished at the recreated site relative to the natural site. At the recreated site, insect visitation rates to B. n. nanum flower heads were at least an order of magnitude lower than those at the natural site, and insect visitor species richness was reduced by three-fold compared to the visitor species richness at the natural site. Furthermore, the specialist solitary bee typically associated with B. n. nanum was not present at the recreated site. The seed set of B. n. nanum plants at the recreated site was consistently lower than the seed set of plants at the natural site. Therefore, our data imply that B. n. nanum plants at the recreated vernal pool site have lower reproductive success than their counterparts at the natural vernal pool site.

LERTZMAN, KEN, RACHEL McGHEE and SARI SAUNDERS. School of Resource and Environmental Management, Simon Fraser University, Burnaby, B.C. V5A IS6, Canada. Are persistent vine maple patches alternative stable states in conifer forest?

Vine maple (*Acer circinatum*) is a common understory tree of the Pacific northwest. While most common in riparian and younger upland forests, it may persist in canopy openings into older forests. Three alternative hypotheses account for this: 1) vine maple patches are ephemeral and will be eliminated by adjacent conifers, 2) vine maple persistence in conifer stands reflects an edaphic mosaic, and 3) vine maples persist by maintaining canopy gaps in which they outcompete conifers. We examined 80 year old unmanaged stands which developed after logging. Most vine maple clones date to stand establishment and many continue to produce new cohorts of stems. Vine maples appear not to be associated with distinct soil conditions and, while some are in decline, others show continued viability (live:dead stem ratios, growth rates, etc.). Light regimes in gaps under vine maples offer poorer opportunities for conifer establishment than the adjacent conifer understory. While some vine maple patches are ephemeral nodes of delayed successional trajectory, others appear to be persistent alternative states to the surrounding conifer forest. This has implications for the development of stand structure over successional time and for conservation in managed forests, where hardwoods are often eliminated. Persistent hardwood induced heterogeneity may be of significance for biological diversity because of its role during the transition from younger to older stands. In a companion research project, we have found that vine maple patches are associated with greater abundance and species richness of birds than adjacent conifer areas.

LESSMANN, JEANNINE M., IRVING A. MENDELSSOHN and MARK W. HESTER. Louisiana State University, Baton Rouge, LA, 70808, USA. Population variation in growth response to flooding in three marsh species.

Comparative studies were conducted to evaluate population differences with respect to flooding for *Panicum hemitomon, Spartina patens,* and *Spartina alterniflora.* Effects on leaf elongation and biomass partitioning were measured to identify any ecotypic variations in these species. Eighteen populations of *P. hemitomon,* 19 populations of *S. patens,* and 25 populations of *S. alterniflora* collected along the Louisiana and Texas coasts were cultivated in a greenhouse study, with 5 replicates of all populations for each species placed in Nalgene tanks in a randomized block design. For each sampling period elongation rates of the youngest leaves were measured at water levels varying from 0 to 39 cm above the soil surface over a period of 65, 60, and 56 days for *P. hemitomon , S. patens* and *S. alterniflora,* respectively. During each flooding period soil E_h was measured at the surface and at a depth of 7 cm. At the end of the experiment all populations were harvested for above water biomass, below water biomass, and for below ground biomass, with further partitioning into stems, leaves, roots, and rhizomes. Tests of flooding tolerance among these populations indicated a potential differentiation under flooding stress.

LEWIN, J., and R. STOTTLEMYER. Dept. Biological Sci., Michigan Technological Univ., Houghton, MI, 49931, USA, and National Biological Survey, 240 W. Prospect Rd., Ft. Collins, CO, 80526, USA. Linkages between canopy throughfall, soil solution, and seepage lake chemistry in a Northern Michigan Lake.

Precipitation, throughfall, soil solution, and seepage lake chemistry were quantified for five years at Legion Lake, a clear-water seepage lake in Pictured Rocks National Lakeshore, MI. The objective was to identify mechanisms responsible for the acidic (pH = 4.8) and poorly buffered (ANC = -10.6 μeq L^{-1}) lake condition. Lake NH_4^+ and NO_3^- concentrations peaked with spring melt, but H^+ and SO_4^{2-} did not vary. Except for SO_4^{2-}, lake concentrations of other contaminants were significantly lower than in precipitation. Overall, soil solution anion concentrations were most similar to lake concentrations. Benthic cores show evidence of anthropic inputs, especially Pb, and 10 fold the sedimentation rate of similar clear-water, oligotrophic lakes. The high flocculation rates likely are due to precipitation of humic acid inputs supplied from conterminous bogs.

LEWIS, J.D., D.T. TISSUE and B.R. STRAIN. Dept. of Botany, Duke Univ., Durham, NC 27708, USA. Effect of elevated CO2 on photosynthesis in non-nutrient limited Pinus taeda plants.

We examined the effect of elevated CO2 on photosynthetic capacity in non-nutrient limited Pinus taeda plants. Plants were grown in open-top chambers maintained at either ambient or ambient+30

Pa CO2. Leaf nitrogen levels indicated that no plants were N limited. Photosynthesis at the growth CO2 was significantly higher in plants grown at elevated CO2. However, elevated CO2 did not significantly affect rubisco activity and activation state, chlorophyll content, electron transport capacity or phosphate regeneration capacity. All parameters were significantly greater during the growing season than during the winter. Additionally, photosynthesis declined approximately 75% in elevated CO2-grown plants from May to January, but only 50% in ambient CO2-grown plants. These results indicate that elevated CO2 will not affect photosynthetic capacity in non-nutrient limited P. taeda, but will increase seasonal fluctuations in photosynthesis.

LEYDEN, BARBARA, W. University of South Florida, Tampa, FL 33620, USA. Forces of environmental flux in Central America during the Holocene.

A review of palynological and limnological data from Central America serves as a framework for evaluating environmental stability during the Holocene. The magnitude of climatic forcing after the early Holocene has not produced the dramatic changes that spanned the transition to post-glacial conditions. Nevertheless, climatic variability and human disturbance have had a significant impact on the vegetation of the region. This discussion has relevance for broader questions of species diversity and the long-term stability of vegetation associations in the tropics.

LEX, DAPHNE P. and VIRGINIA M. CARD. Macalester College, 1600 Grand Ave, St. Paul MN 55105. Winter limnology of Brownie Lake, a small meromictic lake in Minneapolis, Minnesota.

Brownie Lake is a small (7 ha) relatively deep (13m) eutrophic (secchi 3-8m) meromictic lake in the Minneapolis Chain of Lakes. The phytoplankton is dominated by diatoms as a result of iron limitation of blue-green algae (Swain 1986). Onset of meromixis has been dated to canal construction in 1914, which lowered the lake level and decreased the surface area to depth ratio of the already well-sheltered lake (Swain 1986). Monitering of the seasonal physical, chemical and biological limnology of Brownie Lake was begun in November 1993. Experimental manipulation of the lake revealed that the winter phytoplankton community is affected by light and nutrient availability and water temperature. The development of the spring diatom bloom began under the ice in late winter, triggered by increasing light levels. Autumn and winter diatoms were mostly *Asterionella formosa*. Spring diatoms were mostly *Fragilaria crotonensis* and *Stephanodiscus minutulus* complex.

LI, HABIN, ROSS A. VIRGINIA, WILLIAM H. SCHLESINGER, and JAMES F. REYNOLDS. Duke University, Durham, NC 27708, USA and Dartmouth College, Hanover, NH 03755, USA. Spatial heterogeneity in soil resources of desert communities in the Jornada basin, New Mexico.

Schlesinger et al. (1990) hypothesize that desertification has altered a previous, relatively uniform distribution of soil resources (i.e., water and nitrogen) by increasing their temporal and spatial heterogeneity, leading to changes in community composition and biogeochemical processes in arid ecosystems of the Southwestern US. Here we show some supporting evidence from the Jornada basin, New Mexico. Soil samples were taken from five vegetation types (i.e., grassland, creosotebush, mesquite dunes, tarbush, and playa) in 7x7 grids at three scales (i.e., 10, 1, and 0.1 meter) and analyzed for soil nitrogen, pH, and saturated water. Spatial heterogeneity was quantified by semivariogram and autocorrelation analyses. Our results show that the soil properties are significantly different among the five vegetation types. The semivariograms from grassland are relatively flat and have high nugget to sill ratio, indicating dominance of the random variation and homogeneous distribution of the soil properties. In contrast, the semivariograms from creosotebush and mesquite dunes are well structured and have high sill values with short range values, indicating strong presence of the autocorrelated variation and heterogeneous distribution. We conclude that spatial heterogeneity should increase in the processes of desertification, just as it increases from grassland to shrublands.

LICHTER, JOHN. University of Minnesota. St Paul, MN 55108, USA. Evidence for change in climate variability during the late-Holocene inferred from a sequence of Lake Michigan dune ridges.

The timing of ridge formation at a sequence of northern Lake Michigan foredune ridges was calibrated with the historical lake-level record and with climate records to reconstruct a history of climate-related lake-level variation. Foredune ridges are constructed during receding and low lake levels related to regional drought. Shore recession during high lake levels may promote eolian erosion which modifies the shore-parallel foredune ridges into parabolic dunes. A chronology of ridge formation over the last 2400 years indicates that parabolic dunes developed only during periods of frequent ridge formation and drought. Analyses of ridge formation during the historical record of lake-level variation suggest that this association results from increased variability in regional water balances as opposed to variation in sediment supply. Periods of high variability in regional water balances occurred between 380 BC and AD 20, AD 20-300, AD 880-990, AD 1180-1280, and AD 1520-1650.

LIEBMAN, MATT, FRANK DRUMMOND, JIANXIN ZHANG and SUE CORSON. University of Maine, Orono, ME, 04469-5722, USA. Effects of tillage practices, rotation crops, and insect seed predators on weed dynamics in potato production systems.

Previous field research and ecological models suggest that when substantial quantities of weed seeds are produced during one phase of a crop rotation sequence, weed infestation of subsequent crops will be lower when soil is inverted with a moldboard plow (MP) than when it is stirred with a chisel plow (CP). Conversely, when weed seed production is very low because of crop interference, cultivation, or herbicide application, levels of weed infestation in CP systems should be equal or lower than in MP systems. Our results corroborate these predictions: when potatoes (Solanum tuberosum) were grown following oats (Avena sativa) or berseem clover (Trifolium alexandrinum), weed density and biomass and potato yield loss to weed interference were all significantly lower in MP than CP treatments. When potatoes were grown after a multispecies green manure or barley (Hordeum vulgare), both of which greatly suppressed weed growth, no difference in weed density and biomass occurred between MP and CP treatments and there was no weed-related yield loss in either treatment. Weed dynamics in these fields are probably also affected by the (accidentally) introduced ground beetle Harpalus rufipes (Carabidae), which is the dominant insect seed predator in northern Maine agroecosystems and which can consume >85% of weed seeds available on the soil surface.

LINCOLN, DAVID E. University of South Carolina, Columbia SC 29208, USA. Responses of herbivore-tree relations to elevated carbon dioxide conditions.

Insect consumers of trees can be substantially influenced by plant-mediated effects of elevated carbon dioxide. Increases in the internal carbon supply of trees changes leaf quality for herbivores, particularly leaf eating insects. Enhanced photosynthesis leads to an accumulation of starch and other carbohydrates which herbivores can use as energy sources. The enhanced carbohydrate production also leads to a decline in the carbon:nitrogen ratio, which constitutes a reduced nutritional value for consumers. The production of phenolic metabolites in leaves also appears to be responsive to elevated carbon dioxide. The shikimic acid pathway leading to phenolic compounds apparently is sensitive to internal carbon supply, perhaps via 'overflow' metabolism, compared to other secondary metabolic pathways, e.g. the mevalonic pathway leading to terpenoids, which appear to be more highly regulated. Leaf-eating insects are responsive to all of these changes in leaf quality. Many of the changes which have been observed can be rationalized on the basis of responses to reduced leaf nitrogen (e.g. enhanced consumption, reduced growth and fecundity), increased carbohydrates (enhanced consumption, increased efficiency of nitrogen use), and increased secondary metabolites (e.g. reduced growth). On the other hand, individual species of insect, e.g. gypsy moth, may respond differently to some hosts, e.g. aspen versus red oak, or even have little response to others (e.g. white oak).

LINDSAY, SARA M. University of South Carolina, Columbia, SC, 29208, USA. Modeling interactions among predation, disturbance, and recruitment in marine sedimentary habitats.

Adult infauna actively modify marine sedimentary habitats, producing landscapes of disturbed sediment. Recent research has shown that new juvenile infauna can distinguish between disturbed and undisturbed sites and actively reject disturbed sites, which are often associated with high juvenile mortality. Thus patterns of adult disturbance should influence patterns of juvenile recruitment. Infauna often lose body parts exposed above the sediment surface to browsing predators, resulting in reduced activity and consequently reduced disturbance. Browsing predation therefore can alter the disturbance landscape that juveniles encounter. A simulation model has been developed to predict the effect of different browsing predation regimes on infaunal disturbance patterns and on juvenile recruitment/mortality. Simulations of a polychaete assemblage show decreasing juvenile mortality with increasing numbers of regenerating worms. The relationship of juvenile mortality to disturbance is highly dependent on the spatial distributions of adult worms (regenerating and intact) and juveniles.

LINK, STEVEN O., RONALD N. KICKERT, MICHAEL J. FAYER AND GLENDON W. GEE. Pacific Northwest Laboratory, Richland, WA 99352, USA. The role of vegetation in barriers and the prediction of soil water dynamics.

The Hanford Barrier Program was developed to design an earthen cover system to inhibit water infiltration, plant and animal intrusion, and wind and water erosion. Plants have a significant role in barrier function. Lysimeter studies indicate that a surface layer of fine soil with deep-rooted plants precludes drainage even with three times normal precipitation. Two simulation models, Soil Water Infiltration and Movement (SWIM) and Simulation of Production and Utilization of Rangelands (SPUR-91) were compared for their ability to predict soil water storage dynamics with and without plants in weighing lysimeters: These models adequately predicted soil water storage dynamics for the weighing lysimeters. The range of root mean square error values for the two models was 7.0 to 19.8. Research was funded by the U.S. Department of Energy under Contract DE-AC06-76RLO 1830.

LIPSON, DAVID A., BOWMAN, WILLIAM D. and RUSSELL K. MONSON. University of Colorado, Boulder, CO, 80309, USA. Luxury uptake and storage of nitrogen in the alpine plant, *Bistorta bistortoides*.

Bistorta bistortoides grown in N fertilized plots in the alpine community of Niwot Ridge in Colorado have significantly higher concentrations of N in the rhizome relative to unfertilized controls from the same area. The increased level of N in fertilized plants was stored mostly in the

form of N-rich amino acids, which accounted for 46% of total N in the rhizome in fertilized plants compared to 30% in unfertilized controls. The concentrations of other forms of N (insoluble and soluble proteins) were similar in fertilized and unfertilized plants. Of the increased amino acid storage in fertilized plants, most (60%) was sequestered in the proximal third of the rhizome, which represents the most active storage pool in terms of supporting future shoot growth. However, a significant fraction (40%) was stored in the less active, distal portions of the rhizome. We conclude that luxury uptake and storage of N in this alpine species is accommodated through (1) the increased synthesis of storage amino acids, particularly those with high N fractions such as arginine and glutamine, and (2) allocation of a considerable fraction to what we hypothesize is a relatively inert storage pool.

LITVAK, M.E., P.C. HARLEY, M. WILDERMUTH AND R.K. MONSON. University of Colorado, Boulder, CO 80309, USA and National Center for Atmospheric Research, Boulder, CO 80307, USA. The environmental and developmental controls over isoprene emissions from aspen trees.

In situ measurements of the seasonal pattern of isoprene emission from aspen clones indicated that the springtime onset of emissions was delayed for up to four weeks following leaf emergence. The early-season induction of isoprene emission rate is independent of photosynthetic development, being instead controlled by accumulated temperature. After induction, however, isoprene emission rate was positively correlated with leaf starch concentration and photosynthesis rate. In greenhouse studies, nitrogen and PFD regimes were shown to influence isoprene emission rate in the same manner as photosynthetic rate. In sun-grown trees, isoprene emission rate was positively correlated with leaf nitrogen content. There was no correlation between nitrogen content and isoprene emission rate in shade trees. The results of these studies demonstrate a role for accumulated temperature in the early-season induction of isoprene emission, followed by dependence on leaf carbon balance and photosynthetic capacity.

LIU, JIANGUO[1], PETER S. ASHTON[1], PAMELA HALL[1] and SEAN C. THOMAS[2]. 1. Harvard Institute for International Development, Harvard University, Cambridge, MA 02138, USA; 2. Department of Organismic and Evolutionary Biology, Harvard University, Cambridge, MA 02138, USA. A Neighborhood Model for Tree-Tree Interactions in a Tropical Rain Forest.

We have developed an empirical neighborhood model which describes the relationship between relative diameter growth rate and the effects of neighbors in tropical rain forest trees. Our analyses comprised 607 species with population sizes of greater than 50 individuals from the 50 ha permanent plot at Pasoh Forest Reserve in Malaysia. Neighborhood size was assumed to vary as a function of the diameter of the focal tree. Effective neighbors were those whose diameters were larger than that of the focal individual. The index of neighborhood effect was defined as cumulative basal area of the neighboring trees discounted by the distances between the focal tree and the neighboring individuals. Preliminary results of the model indicate that 94% of the tested species showed a significant negative correlation between growth rates and neighborhood effects. This model explained 0.7-72%, with an average of 22% of the variance in relative growth rate for the tested species. The results of some alternative models, the relative value of these approaches, and statistical issues will be discussed.

LIU, SHANYIN AND ROBERT O. TESKEY. University of Georgia, Athens, GA, 30602, USA. Effect of tree ages on the relationship between leaf photosynthesis and nitrogen content in current year foliage of loblolly pines.

A number of studies have reported a significant positive correlation of leaf photosynthetic capacity (P_{max})to nitrogen content (N) in plants. Though this pattern is consistent in crops and deciduous woody plants, results are contradictory in evergreen conifers and little is known if tree ages impose any impact on the relationship. This study examined if tree ages affect the relationship between leaf photosynthesis and N in current year foliage of loblolly pine trees, using four ages (3, 7, 13, 18) and by creating gradients in foliar nitrogen content through nitrogen fertilizer application. There was a significant correlation between leaf P_{max} to N on both dry weight basis and leaf area basis in 7-year-old trees, only on dry weight basis in 13-year-old seedlings but no correlation in both 3-year-old and 18-year-old trees, suggesting that tree ages might have some effect on the relationship.

LOCKABY, B.G., R.H. JONES and J.A. ENTRY. School of Forestry and Department of Agronomy and Soils, Auburn University, AL, 36849, USA. Soil disturbance impacts on community structure and function in forested wetlands.

Soil disturbances are a principal feature of many forested wetland ecosystems. Flooding, the dominant disturbance, reduces soil oxygen and thereby alters many soil chemical and biological properties, especially the availability and form of key plant nutrients such as phosphorus, and nitrogen. Plant root responses to flood-altered soil conditions include tolerance, growth toward well oxygenated (surface) horizons, mortality and production of new roots or specialized tissues. Species-specific responses result in a well known sorting of communities along flooding gradients with corresponding gradients in alpha diversity, above- and belowground productivity. Since feeder root systems are shallow and water levels have both short and long term cycles, some

communities along the flooding gradient are under stress most of the time. Other soil disturbances include sedimentation or erosion which can cause direct injury to plant roots or indirectly affect plants by altering soil aeration. Direct physical soil disturbances from blow downs or logging can damage root systems of existing trees and thereby shift regeneration away from re-sprouting and toward new seedlings which may have lower initial rates of productivity and nutrient assimilation.

LOEHLE, CRAIG, RON SUNDELL, AND PAM SYDELKO. Argonne National Laboratory, 9700 S. Cass Ave., Argonne, IL 60439, USA. Rate of forest spread on abandoned farmland in Central Kansas.

A large tract of land taken out of agriculture at the Ft. Riley military base was studied for forest recovery rate using aerial photos taken 16 years apart. Controlled and uncontrolled burns occurred during this time. On dissected terrain, forest spread was substantial during this period. Forest initially occurred along stream channels. All spread was to areas immediately adjacent to existing forest. A spatially explicit contagion model modified by topography successfully predicted forest spread. In flatter terrain, no forest spread could be detected, indicating more effective regulation of forest area by fire in such locations. Implications for land management are discussed.

LOEWENSTEIN, EDWARD F.[1], HAROLD E. GARRETT[1], PAUL S. JOHNSON[2] and JOHN P. DWYER[1]. [1]University of Missouri, Columbia, MO, 65211, USA. [2]North Central Forest Experiment Station, Columbia, MO, 65211, USA. Forest changes through forty years of uneven-age management in the Missouri Ozarks.

The sustainability of a selective-cutting management plan which has been in practice for over 40 years was assessed. Age, diameter and species composition, for trees > 4.1 cm dbh, were sampled on 259 hectares of a 60,730 hectare forest in the Missouri Ozarks. The current diameter distribution of the study area is negative-exponential, typical of a balanced, uneven-aged stand. Although there is a significant relationship between age and diameter ($P < .0001$, $R^2 = 0.39$), the age distribution is normal (range 10-230 years, mode 55 years). Due to the longevity of forest trees, the current management plan has not been in place long enough to determine its ultimate effect on the age distribution of the forest. Historical records from permanent plots throughout the forest show that there have been significant increases in the basal area of Pinus echinata Mill. and Quercus alba L. through the entire 40 years of management. Basal area of other species increased through the first 20 years, but have since remained relatively constant.

LOEWENSTEIN, N.J. and S.G. PALLARDY. University of Missouri, Columbia, MO, 65211, USA. Root-to-shoot communication in two Central Hardwood forest species: Juglans nigra and Quercus alba.

Root-sourced control of stomatal conductance in drought-tolerant white oak (Quercus alba L.) and drought-sensitive (Juglans nigra L.) was investigated in greenhouse drought studies. Stomatal conductance of black walnut seedlings in the early phases of drought was more closely linked to predawn (≈ soil) water potential than to leaf water potential. In contrast, stomatal conductance of white oak seedlings was not preferentially linked to soil or leaf water potential. While concentrations of abscisic acid (ABA) in the xylem sap of both species increased in response to water stress, average concentrations were an order of magnitude higher in water-stressed black walnut (1.04×10^4 $\mu mol/m^3$) than in white oak (0.94×10^3 $\mu mol/m^3$). Even though ABA concentration increased substantially in water-stressed black walnut, total flux to the leaves declined because of accentuated stomatal closure. ABA flux was slightly greater in water-stressed white oak because of a smaller relative reduction in transpiration rate. Stomata of black walnut seedlings were much more responsive to changes in the concentration of xylem sap ABA.

LOMAX, DANIEL P., BETH H. HORNESS, LYNDAL L. JOHNSON, JOHN T. LANDAHL and USHA VARANASI. Northwest Fisheries Science Center, National Marine Fisheries Service, NOAA, Seattle, WA, USA. Threshold levels for toxic effects of sediment-associated PAHs on marine biota from urban and nonurban embayments of the United States.

The Environmental Conservation Division of the National Marine Fisheries Service has been conducting studies investigating the effects of marine pollution on the health of benthic fish since 1979. A large amount of data relating biological effects to exposure to sediments contaminated with polycyclic aromatic hydrocarbons (PAHs) exists as a result of the many field and laboratory studies conducted since this time. These effects include the presence of hepatic lesions, high biliary levels of PAH metabolites, elevated activity of hepatic xenobiotic metabolizing enzymes and impaired reproductive success. A comprehensive analysis of these data was undertaken in an effort to estimate thresholds for concentrations of PAHs in sediment below which the effects previously described did not occur. Our primary objectives were to determine: 1) at what levels of chemical contamination are thresholds observed for those species examined and 2) how our findings compare with the sediment quality standards of other agencies. Thresholds were determined with the Hockey Stick regression model. Our results show that most effects exhibit thresholds at 500 - 1000 ng/g, with slight variances among species due to differences in sensitivity. These values are considerably lower than standards derived from the Apparent Effects Threshold and other similar methods used for evaluating sediment toxicity. This approach yields significant insight into the impact of low level contamination and may provide a useful alternative for evaluating sediment quality within urban areas.

LOMOLINO, MARK V. and MICHAEL L. ROSENZWEIG. University of Oklahoma, Norman, OK, 73019, USA and University of Arizona, Tucson, AZ, 85721, USA. Rarity and community ecology: Who gets the tiny bits of broken stick?

Rarity should accompany **ecological intolerance**, the adaptation of a species to a rich, restricted niche. So, tolerant species should evolve to be intolerant and rare. Abundance and geographical range will correlate if some species coexist by having diverse tolerances.

High trophic level has long been implicated in rarity, and evidence is accumulating in favor of this hypothesis. Diversity in insect food webs declines semilogarithmically with trophic level. High arctic vertebrates lose high trophic levels when productivity falls below a certain threshold. Theoretical studies based on soil species also suggest such a threshold.

Natural selection can reinforce **narrow habitat selection**, producing guilds of rare species with high extinction rates. But, to increase extinction rates, the rarity must also restrict geographical range. Vrba notes the case of aardvarks in which the habitat selection may buffer the species existence by simultaneously requiring the species to hone its ability to find its habitat over a broad geographical range.

But **no species is safe**. Extraordinarily common species can implode, losing most or all of their range within a single human lifetime. North American examples include American chestnut, passenger pigeon and American burying beetle. The most abundant species can also produce rare species in evolutionary time by centrifugal speciation of peripheral isolates in ecologically restricted situations.

LOOPE, LLOYD L., AND ARTHUR C. MEDEIROS. National Biological Survey, Haleakala National Park, Makawao, Maui, HI, 96768, USA. Interagency efforts to control spread of a highly invasive tree (Miconia calvescens) on Maui, Hawaii.

Miconia calvescens (Melastomataceae), native to neotropical forests at 300- 1800 m elevation, is now known to be an unusually aggressive invader of moist island habitats. Introduced to Tahiti in 1937, dense thickets of M. calvescens had by the 1980s replaced the native forest over most of the island, with dramatic reduction of biological diversity. After the late F.R. Fosberg saw this species in Tahiti in 1971, he reported that "it is the one plant that could really destroy the native Hawaiian forest." Because of its attractive purple and green foliage, it was inadvertently introduced to Hawaii as an ornamental in the 1970s. After its detection on Maui by conservation agencies in 1990, an alarm was raised. Nearly 20,000 individuals of M. calvescens were removed from private lands by agency staff and volunteers in 1991-93, and control appeared feasible. However, in September 1993, an aerial vegetation survey discovered a previously undetected Miconia population on state land -- far larger (over ca. 100 ha) than all previously known populations on Maui. An interagency working group developed and began (January 1994) implementation of a containment strategy, initially involving helicopter herbicide (Garlon 4) spraying of individual emergent Miconia trees and monitoring of results.

LOOPE, W.L., A.K. McEACHERN, and J.B. ANDERTON. NBS, Munising, MI, USA 49862; NBS, Ventura, CA, USA 93001; and Dept. of Geography, Univ. of Wisc., Madison, WI, USA 53706. Response of vegetation to climate-driven cycles of coastal disturbance along Lake Superior, USA

A sequence of buried soils in a perched dune field along Lake Superior's southern shore appears to record initial burial of a coastal pine forest about 5500 BP and five to seven subsequent episodes of dune stabilization and complete/partial forestation, each followed by forest burial. The cyclic burial of soils appears to be linked to climate-driven fluctuations in levels of Lake Superior. Organic matter from dated paleosols includes macrofossils and pollen, suggesting that a record of forest change is present. Community data gathered from extant monitoring plots suggests that the past 120 years constitute the early stages of a forestation mode. These data may enable us to construct rough models of changing habitat suitability for dune adapted plant species during the late Holocene and to observe/predict details of community dynamics under various climatic conditions and disturbance regimes.

LOSEY, JOHN E. and ROBERT F. DENNO. University of Maryland, College Park, MD, 20742, USA. Interactions between foliar and ground predators: Synergistic predation of aphids.

Predator species may affect each other's predation rate by influencing prey behavior and/or distribution. The impact on total prey consumption by both predators will be positive (synergistic) if the behavioral change in the prey caused by one predator makes the prey more susceptible to the other predator. Foliar predators in alfalfa were found to elicit "dropping" behavior in aphids which exposes them to ground predators. Ground predators are not usually considered to be important aphid predators alfalfa. In a model alfalfa system where no foliar predators were present, aphids stayed on plants and ground predators did not consume aphids. However, when a foliar predator was present, aphids dropped off the plant, and the ground predator consumed a significant number of aphids. The combined impact of the foliar and ground predators was greater than the sum of their individual impacts (a synergistic interaction). This is one of the first studies to demonstrate a positive interaction between predator guilds and it implies that ground predators may be more important in this system than previously realized.

LOVETT, G.M., K.C. WEATHERS, and S.E. LINDBERG. Institute of Ecosystem Studies, Millbrook, NY, 12545, USA and Oak Ridge National Laboratory, Oak Ridge, TN, 37831, USA. Atmospheric deposition to high-elevation forests.

Three important phenomena characterize atmospheric deposition to high-elevation forests: 1) multiple deposition mechanisms (wet, dry, and cloud deposition), 2) high rates of deposition, and 3) high spatial variability. The high rates of deposition are caused by changes in meteorological conditions with elevation, especially increasing wind speed and cloud immersion frequency.

The high spatial variability of deposition is a result of the regulation of cloud and dry deposition rates by microclimatic and canopy structure conditions, which can be extremely heterogeneous in mountain landscapes. Spruce-fir forests are often "hot spots" of deposition when viewed in a landscape or regional context because of their elevation, exposure, and evergreen canopy. In this talk we will consider atmospheric deposition to high-elevation forests in both the northeastern and southeastern U.S., using field data and geographic information systems to illustrate deposition patterns.

LOY, CARIN C. and CLIFFORD C. AMUNDSEN University of Tennessee, Knoxville, TN, 37996, USA. Dynamics of 50 Year Old Reservoir Riparian Shore Habitats, Watts Bar Reservoir, Tennessee.

Watts Bar Reservoir was created in 1942 by closure of a dam which inundated 180 kilometers of the Tennessee Valley. Water pooled above the historic river floodplain up into the mesic pre-reservoir habitat, eliminating the historic riverine riparian habitat. Reservoir water levels are now managed such that flooding patterns of the 4400 ha of potentially riparian habitat are counter-seasonal to local streams and rivers. Winter pool lows are alternated with summer highs with the greatest extent of inundation taking place during the growing season. Two seasonal aquatic pool edges have been imposed and, where geomorphology and topoedaphics allow, riparian communities are developing on once mesic sites. Forest transects taken within the summer shore riparian zone show that hydric individuals now outnumber mesic taxa stems. Surviving mesic individuals tend to be larger, older, and not reproducing. Annual bole increment is restricted by incursive linear saturation of the summer substrate. Basal areas ($<20 m^2/ha$) are less than taxonomically comparable stable bottom forest stands of the region. However, litter production is comparatively high at over 5.0 mt/ha and can be related to canopy development status.

LU, YINGQING. University of Wisconsin-Madison, Madison, WI, 53706, USA. Differences in flower production between selfed and outcrossed progeny of Jewelweed, *Impatiens capensis*.

Why should species such as jewelweed both outcross and self via chasmogamous and cleistogamous flowers on the same plant? In a greenhouse experiment (unbalanced randomized block design), I examined 118 offspring of 25 maternal plants from 3 field sites. I found significantly higher numbers of total flowers produced on outcrossed offspring than on selfed offspring from the same families ($p=0.003$). Total flower numbers were also affected by maternal plants ($p=0.015$). Chasmogamous flowers were about 20% of total flowers. This percentage remained surprisingly stable across 3 sites and between both outcrossed and selfed progeny. The results imply that the reproductive behavior of jewelweed might be subject to selection to favor an appropriate ratio of selfed and outcrossed progeny to achieve the maximum success and stability of the genetic constitution of the next generation.

LUBCHENCO, JANE, PAUL G. RISSER and PETER ALPERT. Oregon State University, Corvallis, OR, 97331-2914, USA; Miami University, Oxford, OH, 45056, USA; and University of Massachusetts, Amherst, MA, 01003, USA. The Sustainable Biosphere Project.

The Sustainable Biosphere Project (SBP) is an international, interdisciplinary, multi-year project of SCOPE, the Scientific Committee on Problems of the Environment. The object of the SBP is to understand the biophysical, social and economic determinants of sustainable ecological systems and to stimulate the implementation of practices and policies that will lead toward a sustainable biosphere. The SBP consists of seven regional Case Studies, each one located in a different region of the world. The first two Case Studies are the Amazon and the Southern African Savanna. Each Case Study focuses on specific natural resource use patterns identified by stakeholders within these regions. Each Case Study will build an analyzed information base, evaluate the sustainability of current practices and policies, and work with stakeholders to produce alternate practice and policy options for sustainable ecological systems. These options will be considered from many viewpoints, including comprehensive ecological, economic and social considerations.

LUCZKOVICH, JOSEPH J., DAVID B. KNOWLES, and PACE WILBER. East Carolina University, Greenville, NC, 27858, USA and U. S. Army Corps of Engineers Waterways Experiment Station, 3909 Halls Ferry Road, Vicksburg, MS, 39180, USA. Changes induced in fish and invertebrate communities by experimentally varying the thickness of dredged materials deposited in a *Juncus roemerianus* marsh.

Deposition of materials dredged from navigable waterways onto adjacent wetlands in thin layers has been proposed as an alternative to upland or subtidal disposal. In order to determine a no-effect level, we deposited dredged materials onto 16 experimental plots (16 m^2 each) in a *Juncus roemerianus*-dominated marsh in four thicknesses: unaltered controls (0 cm), 2 cm, 4 cm, and 10 cm. Pre- and post-dredging censuses of the plant communities present on each plot were made bimonthly using four 0.07 m^2 quadrats to estimate shoot density, two 0.03 m^2 pitfall traps to estimate abundance of fishes and large invertebrates, and five 0.004 m^2 diameter corers to estimate macroinvertbrates. There were no significant changes in total invertebrate abundances due to treatments as measured with pit traps, but a highly significant effect of date. Based on cores, invertebrate communities became oligochaete-dominated in the 10 cm treatments. Fish abundance declined significantly in 4 and 10 cm plots relative to controls, but there was a significant interaction with season.

LUDSIN, STUART A. and DENNIS R. DeVRIES. Auburn University, Auburn, AL, 36849, USA. A mechanistic approach to understanding first-year survival of largemouth bass (Micropterus salmoides): the influence of hatch date, overwinter mortality, and gizzard shad (Dorosoma cepedianum).

Although factors affecting survival of young-of-year largemouth bass have been well-studied in north-temperate systems, little is known from southern systems, with their relatively mild winters. We quantified the influence of hatch date, overwinter mortality, and gizzard shad presence on growth and survival of age-0 bass in large experimental ponds in Alabama (n=6; 2-5 ha). Because age was positively related to daily growth rate and bass length, early-hatched bass possessed both size and growth advantages, relative to later-hatched bass. Without shad, size-dependent overwinter mortality occurred, with mortality rate inversely related to bass length, suggesting that fish that survived over winter were primarily early-hatched fish. Because larval shad and bass densities were positively correlated, and shad can compete with other bass prey (i.e., bluegill, Lepomis macrochirus) for zooplankton, overwinter mortality may intensify in the presence of gizzard shad.

LUE, KUANG-YAANG and PAO-LING, KAO, Dept. of Biology, National Taiwan Normal University, Taipei, Taiwan. 117. R.O.C. Study on the resource partitioning among sympatric frogs in Taiwan.

This study was conduted from Oct. 1992 to Dec. 1993, in a small pond near Taipei, Taiwan. Total 12 species of frogs were recorded from the study site. By cluster analysis, Hyla chinensis, Rhacophorus smaragdinus, Polypedates megacephalus, Chirixalus idiootocus were grouped as tree dwelling species,while Rh. taipeianus, Rana adenopleura, R. latochi, R. longicrus, R. swinhoana, Microhyla ornata and Bufo gargarizaus were terrestrial ones. The data showed that the resource partitionings among these sympatric frogs are quite prominent, either by breeding seasons, breeding sites, the timing of activity or food items. Niche breadth and Niche overlape are calculated. The species succession of this amphibian community are discussed in detail.

LUECKE, CHRIS. Utah State University, Logan, Utah, 84322, USA. Recovery and resilience of the fish assemblage of a subalpine lake to manipulations of the dominant species.

The fish assemblage of Castle Lake, California was manipulated by varying stocking rates of rainbow trout during 1988-1993. Historical records indicate that rainbow trout were the most abundant fish species present from 1960 until 1988. This population was maintained by stocking a constant number of juvenile trout annually. From 1988 through 1990 no stocking occurred, and densities of rainbow trout declined by an order of magnitude. During this period abundances of brook trout and golden shiners increased dramatically. Overall fish biomass was relatively constant during this period. In 1991 stocking of rainbow trout was resumed. Densities of brook trout and golden shiners declined as rainbow abundances increased. The strong effect of rainbow trout on recruitment of other fishes resulted from a combination of competition and predation effects. Bioenergetics modeling of fish consumption patterns indicated that zooplanktivory was highest in years with low densities of rainbow trout. These results suggests zooplankton populations may benefit from the presence of rainbow trout.

LUH, HANG-KWANG, STUART L. PIMM, and GARETH RUSSELL. University of Tennessee, Knoxville, TN 37996-0810, U.S.A. The assembly of ecological communities—a Boolean hypercube approach.

A Boolean hypercube is used to simulate the process of ecological community assembly. The vertices on the hypercube represent all possible communities. The transition pathways connecting the community states show the directions of community assembly. The topological properties of Boolean hypercubes and the dynamic behavior of community assembly depend upon the constraints that determine the directions of the transition pathways. If the transition pathways are specified at random (i.e., no constraint is applied), a community may pass all possible species combinations during the process of assembly. The complexity of a Boolean hypercube increases when more restricted constraints of configuration are applied (e.g., the presence or absence of each species affects the next stage of community).

LUO, JIANGANG, STEPHEN B. BRANDT and CARL F. CERCO. (JL) Chesapeake Biological Laboratory, Solomons, MD, 20688, USA. (SBB) Great Lakes Center, Buffalo State College, Buffalo, NY, 14222, USA. (CFC) Army Corps of Engineers, Wicksburg, MS, 39180. A 3-D Spatially-explicit Model of Striped bass, Morone saxatilis, growth rate in Chesapeake Bay.

Spatially-explicit models demonstrate how the spatial patterning and absolute scaling of the environment affect species-specific consumption rate and growth rate. Space is modeled as an explicit feature of the environment by subdividing the habitat into homogeneous units that define a cube for a geographical coordinate system and water depth. Each cube represents a volume of water that is characterized by a specific set of environmental variables (prey biomass, water temperature and dissolved oxygen) provided by a 3-D water quality model. A foraging model and a bioenergetics growth model transforms the environmental variables into a single value, growth rate potential. The result is a three-dimensional representation of striped bass growth rate potential. The growth rate potential integrates the physiological response and the needs of the predator and thus, can be interpreted in the context of habitat quality. In the future, we will use the model to test how nutrient reduction and global warming affect habitat quality.

LUO Y., R.B. JACKSON, C.B. FIELD, AND H.A. MOONEY. Stanford University, Stanford, CA 94305, USA and Carnegie Institution of Washington, Stanford, CA 94305, USA. Responses of soil respiration to elevated CO_2 in two California grassland ecosystems.

Estimates of soil respiration (SR) in current and elevated CO_2 are critical for predicting future global carbon budgets. We measured SR in two California grassland ecosystems (sandstone and serpentine) growing at ambient and ambient+350 ppm CO_2. SR was higher in elevated CO_2 for both ecosystems in the field, but differences were not significant. At peak plant growth, SR was approximately 6 μmol m^{-2} s^{-1} in elevated CO_2 and 5 μmol m^{-2} s^{-1} in ambient CO_2 for both ecosystems. We also examined soil respiration in monocultures of 7 grassland species grown in microecosystems (10-cm diameter by 1-m deep tubes). SR was approximately 2 μmol m^{-2} s^{-1} for Plantago, Bromus, Hemizonia, and Calycadenia and 7 - 8 μmol m^{-2} s^{-1} for Lolium, Avena, and Vulpia. Elevated CO_2 significantly increased soil respiration by 20-30% in Bromus, Hemizonia, and Lolium monocultures. SR was significantly correlated with total plant biomass as averaged across all species.

LUTTENTON, MARK, MARTY HORGAN AND DAVID LODGE. Grand Valley State University, Allendale, MI, 49401, Cornell University, Ithaca, NY, 14853 and University of Notre Dame, Notre Dame, IN, 46656. Littoral periphyton response to grazing by crayfish and snails.

Periphyton communities were established on unglazed clay tiles (5x5 cm) incubated in enclosures in the littoral zone of Carrol Lake, WI. In the lab, pairs of tiles were placed in individual arenas randomly assigned to one of five treatments including: 1) no grazers, 2) 1 Orconectes rusticus, 3) 1 O. propinquus, 4) 1 O. virilus and 5) 10 Amnicola spp. After 96 hours periphyton was collected and community composition and algal biovolume determined. Total algal biovolume was significantly reduced by all grazers except O. rusticus. The responses of dominant algal taxa (diatoms) to grazers were species-specific. However, the relative abundance of most taxa did not change. Clearly, snails and crayfish both impact littoral periphyton directly as grazers.

LYNCH, ELIZABETH A. University of Minnesota, St. Paul, MN, 55108, USA. Holocene changes in a park-forest vegetation mosaic in the Wind River Range, Wyoming.

The modern mid-elevation vegetation of the Rocky Mountains is a mosaic of conifer forests and open parks dominated by sagebrush (*Artemisia* spp.), grasses, and other herbs. It is not known how this pattern originated or how sensitive the balance between forest and park is to disturbance. Using pollen from sediments of five small ponds in Fish Creek Park, WY (elev. 2700 m), I reconstructed the last 8000 yrs of changes in the park-forest mosaic in an area of about 16 km^2. Surface samples collected from 52 ponds in the Fish Creek Park area and from forest and park sites in Wyoming and Colorado indicate that park and forest pollen assemblages can be distinguished using multivariate statistical methods and conifer:herb pollen ratios. Fossil pollen from the five sediment cores shows that the distribution of the two vegetation types on the landscape has changed through the Holocene, and that the changes in vegetation are gradual. Past changes from park to forest have apparently occurred much more slowly than changes from forest to park, suggesting that areas subjected to recent clearcutting may remain unforested for centuries.

LYONS, SHEILA A. and CHRISTOPHER C. SMITH. Kansas State University, Manhattan, KS, 66502, USA. Experimental seed dispersal using models of large herbivores.

Adhesive seed dispersal is an important, but poorly studied mechanism by which seeds are disseminated. We constructed models using either bison or white-tailed deer pelage to investigate seed dispersal of 2 Desmodium species. Studies were conducted in woodland and prairie habitats on the Konza Prairie Research Natural Area in NE Kansas. Fruits of D. illinoense, a prairie species, and D. glutinosum, a woodland species, possess hooked hairs which facilitate adhesion. Bison hair is long and wooly compared with white-tailed deer hair which is short and coarse. We predicted that the bison model would disperse fruits farther from a parent plant than the deer model. Fruits of both species were carried greater distances on the bison model than on the deer model in both habitat types. Thus, the post-settlement decline in bison number and increase in deer populations may impact the population dynamics of these plant species.

MABRY, CATHERINE M. AND DAVID R. FOSTER. Harvard Forest, Petersham, MA, 01366, USA. Response of forest vegetation to regional physiographic and disturbance gradients

The relationship between the distribution of individual species and physical site and historical (anthropogenic and natural disturbance) factors was analyzed for a 37-town region in north central Massachusetts. Analysis of pre-settlement witness tree data demonstrated that species distribution was largely controlled by elevation and latitude. Since settlement the landscape underwent extensive deforestation for agriculture followed by reforestation; subsequently, the forest was disturbed by the 1938 hurricane and salvage operations. We hypothesized that 1) anthropogenic and natural disturbance are now important factors

controlling species distribution, 2) that individual species respond to different factors, and 3) some species will demonstrate a generalized distribution (i.e. will not vary according to the regional gradients). All species were surveyed in approximately 10 random plots per town. Contingency table analyses were used to evaluate the association between species and environmental and historical factors. After adjusting for multiple comparisons 46 of 123 species showed no relationship to the measured variables. Species were most commonly related to elevation, hurricane/salvage damage; slope, landscape position and drainage were also important factors.

MACK, ANDREW L. University of Miami, Coral Gables, FL, 33124, USA. Distance and non-randomness of seed dispersal by the Dwarf Cassowary, Casuarius bennetti, in Papua New Guinea.

Aglaia flavida (Meliaceae) produces huge ($\bar{x}$=160g) diaspores that fall to the rainforest floor and are dispersed by the large, flightless cassowaries of New Guinea. I marked fallen diaspores under 20 Aglaia trees in a 260 ha study area then searched c. 400 ha for cassowary droppings containing marked seeds. Thirty marked seeds from nine trees were found in 29 droppings of free-ranging cassowaries. The 30 dispersal distances formed a normal distribution. Mean dispersal distance was 388 m (range=95-993m, SD=108); these seeds were on average 170 m (SD=114) from the nearest mature female Aglaia tree. Dispersal was non-random because most (75.8%) seeds moved uphill and all droppings were on level ground despite the study area being mostly steep terrain. Non-random dispersal is due to cassowaries preferentially travelling and resting on level ground.

MACKENZIE, MARK D. and STITH T. GOWER. University of Wisconsin-Madison, Madison, WI, 53706. Terrestrial ecosystem properties that influence regional hydrology of the NTL-LTER: an integrated GIS, remote sensing, and process model approach.

As part of its ongoing effort to understand terrestrial and aquatic interactions, the North Temperate Lakes Long-Term Ecological Research (NTL-LTER) site is currently developing a spatially explicit regional hydrologic model. This paper discusses the application of geographic information systems (GIS), remote sensing, and a process model (FOREST-BGC) to elucidate the influence of land use change and landform on properties of forest landscapes that may influence past, present, and future regional hydrology. We use remotely sensed information such as landcover and LAI and other spatial data stored in a GIS (e.g. soils, landform, topography) to drive an ecosystem process model that simulates carbon, nitrogen, and water budgets. Output from this model is linked with other components of the regional hydrologic model using the GIS. Important results to date include: over the last century a significant change from evergreen to deciduous forest cover has occurred and forest composition and leaf area index are correlated to landform. The GIS has been important in integrating spatial data derived from a variety of scales while remote sensing has been shown to be useful in estimating structural properties at regional scales.

MACKEY, ELLEN M.[1], RICHARD GREEN[1], BOYD NEWBY[2], DAVID MATIS[2], JOHN BRADLEY[3], DENISE KARAVIDAS[4], and MARIE CAMPBELL[5]. [1]The Metropolitan Water District of Southern California, Los Angeles, CA 90071; [2]California Department of Forestry and Fire Protection, Perris, CA, 92570; [3]U.S. Fish and Wildlife Service, Carlsbad, CA, 92008; [4]Aerial Information Systems, Inc., Redlands, CA, 92373; [5]Sapphos Environmental, Pasadena, CA, 91105; USA. Integrating fire management plans and conservation of endangered species.

An interagency team comprising the Metropolitan Water District of Southern California (Metropolitan), the California Department of Forestry and Fire Protection (CDF), and the U.S. Fish and Wildlife Service (USFWS) have prepared a fire management plan (FMP) for Metropolitan's Lake Mathews facility, Riverside County, CA. The FMP provides presuppression, suppression and post-suppression activities for the management of a 5900-acre multispecies ecological reserve managed with the California Department of Fish and Game. The ecological reserve provides habitat for over 45 state and federal sensitive species including the Stephens' kangaroo rat and the California gnatcatcher. Within the reserve, five fire zones have been established to develop a strategic framework for merging individual resources concerns with fire control challenges. The five zones are further organized into 27 fire management units (FMUs). These FMUs were developed to provide site specific pre-planned information to guide on-the-ground fire fighting activities for CDF.

MACKLIN, ERIC A. Duke University, Durham, NC, 27708, USA. Scaling from individuals to communities in models of plant community ecology.

Much of recent theory in plant community ecology falls into two categories: (1) spatial models of competition avoidance mediated by colonization and extinction of discrete patches where within-patch dynamics are completely described by competitive dominance of one community member (metapopulation models), and (2) non-spatial models of competitive interactions mediated by resource acquisition and resource-dependent growth where dynamics at the level of the stand are scaled directly from physiological properties of individuals (consumer-resource models). I present a consumer-resource model that unifies these two approaches by considering physiological properties of individuals in a continuous spatial context. Predictions of competitive dynamics, successional sequences, and maintenance of biodiversity demonstrate that common metapopulation and consumer-resource models can be viewed as special cases of the broader modelling framework defined by this model. Further, the individual-based approach provides a mechanistic interpretation of the phenomenology predicted by more classical models of competition.

MAGILL, ALISON H. and JOHN D. ABER. University of New Hampshire, Durham, NH, 03824, USA. Plant and soil responses to six years of chronic nitrogen additions at the Harvard Forest, Mass.

Ecosystem response to NH_4NO_3 additions (0, 50 and 150 Kg $N*ha^{-1}*yr^{-1}$) in two stands (red pine and mixed hardwood) at the Harvard Forest, Petersham MA, was monitored for six years through analysis of green foliage and litter chemistry, tree growth, soil mineralization and nitrification rates (in situ buried bags) and B horizon lysimeters. Net N mineralization rate in the organic horizon of the pine 150 plot decreased from 60% of the total (organic plus mineral) in 1988 to 39% in 1991. Control stand values were 53% and 52% respectively. This trend continues through 1993. Lysimeter NO_3-N concentration began to increase in the pine 150 plot in 1990, ranging from 4 to 18 mg/L and was negligible in all other treatments. Percent nitrogen in green foliage was significantly different between treatments for red maple and red pine. Of the total nitrogen applied, only 8-28% could be accounted for in the various ecosystem components. One possibility is that the soil may have a larger capacity as a nitrogen sink than originally hypothesized which would be important in delaying nitrogen saturation and subsequent nitrate leaching.

MAGOULICK, DANIEL D. University of Pittsburgh, Pittsburgh, PA, 15260. Influence of introduced rainbow trout on position choice of native brook trout.

Introduced rainbow trout (Oncorhynchus mykiss) are commonly thought to exclude brook trout (Salvelinus fontinalis) from streams in eastern North America, although mechanisms of this interaction have been little studied. Position choice is particularly important to trout and other drift feeding fishes in streams and may play a role in species interactions. I tested the effect of rainbow trout on brook trout position choice by observing position establishment of 12 enclosed interspecific pairs in a small mountain stream, then removing rainbow trout and observing position shifts of brook trout. In all cases in which dominance hierarchies were established (n=5), brook trout were the dominant species. Numbers of brook trout shifting positions after rainbow trout removal were not significantly different than would be expected by chance. Rainbow trout also had no affect on number of forages made by brook trout. However, in the 9 cases in which brook trout position choice was clearly demonstrated, all brook trout that did not shift position upon rainbow trout removal (n=5) were noted to be dominant fish. Clearly, brook trout dominance predicts the outcome of position shifts and the data suggest that the dominant fish gain the best positions. During this study all dominant fish were brook trout. However, prior work suggests that dominance relations may undergo seasonal shifts in these species. If this is the case, then a complex pattern of dominance and position choice during the year may influence the population dynamics of brook trout and rainbow trout in streams.

MAIER, CHRIS A. and PHILLIP M. DOUGHERTY. USDA Forest Service, RTP, NC 27709. Effects of fertilization on stem and branch respiration in a 9-year old loblolly pine (Pinus taeda L.) plantation.

Estimates of respiration rates of woody tissue are essential for understanding the carbon balance of trees and are critical to the development of models that predict forest productivity under varying climate conditions. We measured the diurnal and seasonal respiration rates of stem and branches in plots of 9-year old loblolly pine under controlled moisture and nutrient conditions. Stem and branch respiration were always higher in fertilized plots than in control plots, with the differences being greatest during the growing season. Maximum growing season respiration in stems ranged from 5 to 7 $\mu mol\ m^{-2}s^{-1}$ in fertilized plots and 1.5 to 2.5 $\mu mol\ m^{-2}s^{-1}$ in control plots. Stem respiration during the growing season correlated well with annual stem growth and tissue nitrogen concentration. Similar differences in respiration between treatments were measured in branches but rates were generally much lower. The Q_{10} value was 2.0 for both stem and branches and was not affected by growing season or treatment.

MAILLETTE, L. Université du Québec à Trois-Rivières, C.P. 500, Trois-Rivières, Québec, Canada G9A 5H7. *Staphylea trifolia* L. at the northern limit of its distribution.

S. trifolia (bladdernut) is an erect shrub of moist woods and thickets in eastern North America. The species reaches its northern limit of distribution in Bécancour, Québec (46°20'N, 72°30'W). This study examines two populations of *S. trifolia* growing under mature maple stands: the limit-population of Bécancour and a more southern one in Oka, Québec (45°30'N, 74°00'W). Compared to other limit-populations in which plants typically have stunted growth and lack sexual reproduction, Bécancour and Oka shrubs were thriving. Furthermore, Bécancour individuals grew faster in height and diameter, were taller, had bigger stem diameters and flowered more than Oka individuals, despite cooler temperatures in Bécancour than Oka (1815 vs 1965 day-degrees above 5°C). However, shading by canopy trees was heavier in Oka than Bécancour and may have been more limiting to shrubs than air temperature. Biogeogeographical implications of the findings are discussed.

MANN, CARROLL J. AND ROBERT G. WETZEL, University of Alabama, Tuscaloosa, AL 35487-0344, USA. Loading and bacterial utilization of dissolved organic carbon from emergent macrophytes.

Dissolved organic carbon (DOC) from leachate of aquatic macrophytes represents a significant source of organic carbon for wetland and littoral bacteria. DOC released from live and senescent portions (gradient of fully photosynthetic to fully senescent) of the rush *Juncus*

effusus was evaluated in experimental leachate treatments of organic-free water for 24 h. Leachate of DOC from photosynthetic tissue was not significantly different (Kruskal-Wallis non-parametric rank analysis) from that released from senescent portions. However, among photosynthetic stems (culms) containing live tissue, a significant increase in DOC was released in the gradient of fully photosynthetic to three-quarters senescent (1.9 to 5.2 mg C L^{-1} cm^{-2}, respectively; $p = 0.0065$). Among the senescent tissue of *J. effusus*, loadings of DOC from half to three-quarters senescent were significantly higher than loadings from the fully senescent culms ($p = 0.005$). Leachate solutions were treated with wetland bacteria for 4-day periods with daily subsamples removed for bacterial protein productivity analyses (tritiated leucine methodology). Readily biodegradable DOC resulted in marked increases in bacterial productivity in early stages (0 to day 1) followed by rapid declines in bacterial productivity (days 1-2).

MANN, LINDA K., GEORGE MARTIN, JOE ABRELL, and DAVE MERIWETHER. ORNL, Oak Ridge, TN, 37831-6038, USA; USFS, Cleveland, TN, 37320, USA; GSMNP, Gatlinburg, TN, 37828, USA; TVA, Norris, TN, 37828. Selection criteria for adding management units to the SAMAB regional biosphere reserve.

The SAMAB (Southern Appalachian Man and the Biosphere) regional biosphere reserve initially consisted of three land management units in the southern Appalachians (Great Smoky Mountains National Park, Coweeta Hydrologic Laboratory, and Oak Ridge National Laboratory's National Environmental Research Park). Traditional biosphere reserves in UNESCOs Man and the Biosphere (MAB) program have been defined by 'core', 'buffer', and 'transition' zones. These concepts are difficult to apply to regional biosphere reserves. Therefore, selection criteria for incorporating additional land management units into SAMAB were developed which recognize 4 components of the regional reserve: biosphere reserve (core) units, varied and harmonious landscapes, modified landscapes, and the zone of cooperation. Selection criteria define ecological, political, logistic, and educational requirements for inclusion. The Tennessee River Gorge Trust is currently under evaluation for inclusion in SAMAB.

MAPES, CAROL C., JASON C. VENDETTI, and KELLY J. STONER. Kutztown University, Kutztown, PA, 19530. The effect of light on pupariation of the goldenrod gall fly Eurosta solidaginis.

Pupariation of Eurosta solidaginis has been shown to be affected by temperature, but the effect of light on puparium initiation has not been studied. During the fall, third instar larvae scrape exit tunnels from the center of the gall to the surface, leaving a thin layer of tissue or a "window" over the tunnel. The "window" may provide the larvae with light cues necessary to initiate puparium formation in the spring. When third instar larvae that had been removed from overwintering galls were subjected to total darkness or to a 14 hour photoperiod, the light treatment resulted in an increase in the percentage of puparia formed. When larvae were selected from galls with incomplete exit tunnels and were subjected to a 14 hour photoperiod or total darkness, a significantly higher percentage of larvae formed puparia in the light. In addition, light-treated larvae removed from galls with completed exit tunnels formed puparia sooner than those from galls with incomplete tunnels. These results suggest that light plays a role in the process of puparium formation by E. solidaginis.

MARINO, PAUL C., D. LANDIS and K. GROSS. Mississippi State University, Mississippi State, MS 39762 USA, Michigan State University, East Lansing, MI 48821 USA and Michigan State University, Hickory Corner, MI 49060 USA. Post-dispersal weed seed loss in Michigan maize fields in relation to landscape structure.

At 5 and 100 m from a hedgerow, 3 replicates of no exlusion, invertebrate, vertebrate and invertebrate+vertebrate exclusion treatments (spring post-tillage study) and vertebrate and no exclusion treatments (over-winter study) were established. In each treatment, 25 seed of 5 annual weeds were scattered on sterilized soil and left 4 wks (post-tillage study) and December -April (over winter study). In the post-tillage study, there were significantly fewer amaranthus retroflexus seedlings in control vs. invert., vert. and vert.+invert. exclusion treatments (6%, 11%, 17% and 20% germination, respectively). In the over-winter study, there were more seedlings of the 3 larger seeded species (Abutalon therophrasti, Setaria lutescens and Panicum dichotominflorum) in control vs. vert. exclusion plots. For both studies and all species, seed loss was similar 5 vs. 100 m from hedgerows and was variable among/within fields.

MARKS, JANE C., M.S. PARKER, AND M.E. POWER. Integrative Biology, University of CA, Berkeley, CA, USA 94720. The relative importance of nutrients, grazing and predation on food web structure.

We manipulated nutrients, grazers and predators in a slow riffle in the Eel river, CA, to compare resource and trophic control of community structure. We altered nutrient concentrations with nutrient diffusing substrates. We manipulated accessibility of substrates to grazers and predators by placing them in 0.06 m^2 enclosures with 3 mesh sizes. The 'grazer free' treatment excluded grazers > 0.3 mm, the 'grazers only' treatment included grazing insects but excluded most predators, and the 'predator treatment' included grazing insects, large defended grazers (snails), and predators (stickleback fish and damselfly larvae). Nutrient enrichment increased algal biomass. Grazers reduced algae at all nutrient levels, whether predators were present or not. One explanation for the relatively small effect of predators on algae is that predator densities were not high enough to cause a strong trophic cascade. Alternatively, grazing by snails might have overridden the positive effects of predators on algae. We tested this by manipulating the densities of snails and predators. High densities of predators (2 sticklebacks or 4 damselflies / enclosure) caused a strong trophic cascade regardless of the presence of snails. In contrast, low predator

densities (2 damselflies /enclosure) did not result in a trophic cascade. The negative effect of snails (6 snails/enclosure) on algae was much smaller than the negative effect of grazing insects. Algal assemblages on substrates in the open river were similar to low predator density treatments.

MARKS, SUSAN and DAVID E. LINCOLN. **Winthrop University, Rock Hill, SC, 29733,** USA and University of South Carolina, **Columbia, SC, 29208, USA. An anti-herbivore defense mutualism under elevated CO2 levels.**

Previous studies have shown that insects typically consume more when fed leaf tissue grown under CO2 enrichment, but with few negative effects on growth. On the other hand, Lepidopteran larvae fed tissue infected with Balansiae fungal endophytes (which produce toxic alkaloids) typically eat less but suffer negative effects on growth and survival. This study was carried out to see how these two factors would interact to affect consumption and growth of Fall Armyworm larvae (Spodoptera frugiperda). Infected and uninfected ramets of a single genotype of tall fescue (Festuca arundinacea) were grown under CO2 concentrations of 400 and 700 ul/L. Larvae had increased relative growth in the high CO2 treatment, but decreased growth when fed infected tissue. Relative consumption of leaf tissue was greater in the high CO2 treatment, but was not effected by infection. CO2 level, infection, and their interaction all significantly reduced the efficiency of conversion of food ingested (ECI). It appears that tall fescue may not be as well defended against herbivores under CO2 enrichment, although insects may still avoid and be negatively effected by endophyte infected plants.

MARSHALL, DIANE L., MICHAEL W. FOLSOM, COLLEEN A. HATFIELD AND TOBY BENNETT. University of New Mexico, Albuquerque, NM, 87131, USA. Exploitation vs. interference competition among pollen grains: which has a greater effect on seed paternity?

When pollen arrives on stigmas, there is the opportunity for both races for access to ovules (exploitation competition) and interference with the germination and growth of pollen from other donors (interference competition). While most studies have focused on speed of pollen tube growth, and hence exploitation, we have shown that interference among pollen grains also occurs in wild radish. Further data, on seed paternity were collected to test which mode of competition was most likely to have affected pollen donor success. Differences in speed of pollen germination among four pollen donors evaluated on each of 16 maternal plants showed no correlation with the number of seeds sired after mixed pollinations. However, in a subsequent experiment, the opportunity for interference affected the paternity of seeds. Since pollen loads are often mixed in nature, interference competition among pollen grains may be important in the ecology and evolution of plant reproduction.

MARSHALL, JOHN D., J. ZHANG, W. C. REMBER, D. JENNINGS, AND P. LARSON. Department of Forest Resources,University of Idaho, Moscow, ID 83843-1133 and Department of Geology, Washington State University, Pullman, WA 99164. **Stable carbon isotope ratios and intrinsic water-use efficiency of Miocene fossil leaves compared to modern congeners.**

Miocene fossil leaves of forest trees were extracted from the Clarkia, Idaho fossil beds and their stable carbon isotope ratios were analyzed. Fossils had higher lignin concentrations and lower cellulose concentrations than modern leaves due to diagenesis and the HF used to extract the fossils. Therefore, $\delta^{13}C$ of extracted fossil lignin was compared to that of modern lignin. Fossil lignin $\delta^{13}C$ was significantly different from that of congeneric modern leaves (paired t-test, $P < 0.0001$), but was 1.9 ‰ less negative. Gymnosperms (Metasequoia, Taxodium) were less negative than angiosperms (e.g., Magnolia, Quercus, Acer, Persea), but no difference between evergreen and deciduous species was detected. Using published estimates of the concentration and $\delta^{13}C$ of atmospheric CO_2 during the Miocene we estimated the CO_2 partial pressure gradient across the stomata (intrinsic water-use efficiency). Intrinsic water-use efficiency was at least 70% higher during this past "greenhouse" period than at present.

MARSHALL, SAMUEL D. University of Tennessee, Knoxville, TN 37996. Territorial aggregation by the burrowing wolf spider *Geolycosa xera*: Mechanisms of formation.

In this study I document territorial aggregation by *G. xera* and test for proximate mechanisms to account for this paradoxical combination of aggregative and spacing behavior. Non-random dispersal of burrows was found using the Pielou goodness-of-fit test (Pielou 1977). I found that the pattern of dispersion of burrows were often aggregated at the level at of the patch, and overdispersed at a fine scale, supporting my contention that these spiders occur in territorial aggregations. I tested for both ecological and social determinants of patterns of dispersion. Environmental variables tested were habitat structure (pattern analysis and discriminant analysis), prey (using sticky traps), and substratum moisture (using percent water of substratum). Behavioral determinants tested were conspecific attraction and limited dispersal (to explain aggregation) and territorial behavior (to explain the overdispersion). My findings were that open sand was the only environmental constraint on dispersion, and that social spacing accounted for the overdispersion at a fine scale. Aggregations form via the limited dispersal of spiderlings from the maternal burrow. Life in these aggregations is costly for smaller individuals due to dominance interactions with larger neighbors.

MARTENS, SCOTT N. Los Alamos National Laboratory, Los Alamos, NM 87545 USA. Testing models of tree canopy structure.

Models of tree canopy structure are difficult to test because of a lack of data which are suitably detailed. Previously, I have made three-dimensional reconstructions of individual trees from measured data. These reconstructions have been used to test assumptions about the dispersion of canopy elements in two- and three-dimensional space. Lacunarity analysis has also been used to describe the texture of the reconstructed canopies. Further tests regarding models of the nature of tree branching structures have been made. Results using probability distribution functions for branching measured from real trees show that branching in *Juglans* is not Markovian. Specific constraints or rules are necessary to achieve simulations of branching structure which are faithful to the originally measured trees.

MARTIN, MARC-ANDRÉ and NAOMI CAPPUCCINO. Université du Québec à Montréal, Montréal, PQ, H3C 3P8, CANADA . The dynamics of the birch tube-maker Acrobasis betulella in a fragmented habitat.

Habitat fragmentation may affect the dynamics of phytophagous insects by increasing the degree of isolation of patches and the proportion of edge habitat. We examined the effect of isolation and edges on the abundance of the birch tube-maker, Acrobasis betulella, on islands in Lake Duparquet in northwestern Québec. A. betulella makes large leaf-shelters, which allowed us to remove all individuals from 13 small islands in 1992. Recolonization was greatest on isolated islands far from the shore or from other islands. Parasitoids were also able to recolonize the islands; however the parasitism rate was lower on the recolonized islands than on unmanipulated control islands. Neither island area nor the abundance of birch on the islands had a significant influence on recolonization. A. betulella also occurs primarily on habitat edges. Larvae on edge plants develop significantly faster than those in the shady patch interior. The response of A. betulella to both patch isolation and edges indicates that this species would be favored by increasing habitat fragmentation.

MARTINEZ, NEO D. Bodega Marine Laboratory, University of California at Davis, PO Box 247, Bodega Bay, CA 94923.
EMPIRICAL EXPLORATIONS OF THE BALANCE OF TROPHIC GENERALIZATION WITHIN SPECIOSE FOOD WEBS.

Empirical evidence suggests that connectance, a robust measure of mean trophic generality in communities, is roughly constant among foodwebs with varying numbers of species from a wide range of terrestrial, aquatic, and marine communities. Such universal consistency suggests that the mean fraction of species in ecological systems that each species consumes (i.e., generality), and is consumed by (i.e., vulnerability), is roughly constrained to 0.1. Analyses of two highly speciose foodwebs (a 182-taxa foodweb of Little Rock Lake, WI and a 585-taxa foodweb of Mirror Lake, NH) will be presented that suggest the distribution of connectance among species within ecological systems in terms of trophic generality appears distinct and more variable than the distribution in terms of trophic vulnerability. These distributions also appear relatively robust to the formidable problem of variable resolution of foodweb data. Species' trophic generality has a statistically significant ($P < 0.001$) positive relationship with species' trophic level and number of mutual predators. Species' vulnerability does not have such relationships. These distributions and relationships need more study to determine how widely these generalizations may apply. However, the constant connectance hypothesis appears sufficiently well-supported to warrant investigations of evolutionary and ecological mechanisms responsible for the behavior of connectance which, may lend insight into its distribution within foodwebs.

MARZOLF, ERICH R. and PATRICK J. MULHOLLAND. Oak Ridge National Laboratory, Oak Ridge, TN, 37831-6036, USA. A whole stream approach to metabolism measurement with implications for nutrient utilization and light limitation.

The relationships among gross community primary production (GPP), community respiration (CR_{24}) and nutrient uptake were investigated in a 62 m reach of Walker Branch, a first order woodland stream. GPP and CR_{24} were measured utilizing the upstream/downstream dissolved oxygen method under varying conditions of forest canopy development and day length. Dissolved oxygen and temperature were measured at 1 minute intervals for approximately 40 hours. Changes in DO were corrected for oxygen reaeration using a reaeration coefficient calculated with data from conservative and volatile tracer injections done within several days of DO measurements. Gross phosphorus uptake was measured during 90 minute injections of carrier-free $^{33}PO_4$ and $^{3}H_2O$ to the steam reach. Benthic GPP varied with light conditions as controlled by forest canopy development and day length. GPP was highest (25 $\mu g\ O_2\ m^{-2}\ sec^{-1}$) during the spring just prior to canopy closure and dropped rapidly to ~1.7 $\mu g\ O_2\ m^{-2}\ sec^{-1}$ as the forest canopy closed. CR_{24} exceeded GPP on all dates and reached a maximum of 48 $\mu g\ O_2\ m^{-2}\ sec^{-1}$ after leaf fall as expected in a forested watershed. Ambient stream nutrient concentrations and phosphorus uptake length varied inversely with total metabolic activity, suggesting an important biotic linkage between water quality and benthic metabolism.

MASON, KATHLEEN, MELODY GIORGI, ROBERT HARTLEY and RICHARD B. BRUGAM Dept. of Biological Sciences Southern Illinois University, Edwardsville, IL 62026. Paleoecological Evidence for Human Disturbance in an Upper Peninsula Lake.

We analysed pollen, lead-210 and diatoms from a 50 cm long core taken in a basin of Crooked Lake, Gogebic Co., Michigan that lies just outside the Sylvania Wilderness area. The watershed of this basin was clear-cut in about 1895 as shown by decreases in pine pollen in the sediment core. At the same level, lead-210 activities vary chaotically, indicating increased soil erosion from the watershed. After the clear cut, small numbers of diatoms of the genus Stephanodiscus appear in the fossil record. In about 1925 Asterionella formosa first appears in the lake. Comparisons with our suface sample data set indicate that this

increase implies a large increase in total phosphorus levels in the lake water. It is unclear what change occurred in the watershed to cause such an increase in lake trophic status. The watershed of the basin includes 8 small resort cabins. It may be that the construction of these cabins increased the trophic status of the lake.

MATSON, P.A., C.R. BILLOW, S. HALL and J. ZACHARIASSEN. University of California, Berkeley, CA 94720, USA and Stanford University, Stanford, CA 94305, USA. Fertilization practices in tropical sugar cane systems affect nitrogen trace gas fluxes.

Fertilizer use is increasing rapidly in the tropics, yet few studies have examined the effects of specific application practices or soil types on the relative fluxes of globally-important trace gases. We measured nitrous oxide and nitric oxide emissions and soil nitrogen pools following experimental surface and subsurface applications of urea in sugar cane fields on two different soil types in the Hawaiian Islands. When urea fertilizer was applied below the surface in mollisol soils on Maui, nitrous oxide fluxes were at least twice nitric oxide fluxes. When urea was applied on the soil surface, nitric oxide fluxes were up to 10 times greater than nitrous oxide fluxes. Fluxes did not exceed 14 ng cm^{-2} h^{-1} during the week after treatment. In contrast, fluxes of both gases from the young volcanic soils on Hawaii were much higher, ranging up to 250 and 30 ng cm^{-2} h^{-1} for nitric and nitrous oxide respectively during two weeks following fertilization. Nitric oxide was always higher than nitrous oxide, regardless of treatment.

MATTEI, JENNIFER H. Rutgers University, Piscataway, NJ, 08855, USA Herbivorous slugs, agents of selection with discriminating tastes.

Herbivorous slugs (Ario fasciatus) were used in bioassays to determine if they could distinguish between Brassica cultivars with varying levels of glucosinolates. The cultivars used had genetically set levels of glucosinolates ranging from low to moderate to high. I found that both in field tests and in laboratory leaf choice tests the slugs had a highly significant preference for brassica cultivars with the lowest levels of defense chemical and only a slight preference for plants with moderate levels of glucosinolates when compared to high-glucosinolate cultivars. Slug damage to a plant in the field usually resulted in the death of the plant. Thus, the presence or absence of generalist herbivores may directly affect the pattern of variation in the levels of chemical defenses within and between natural plant populations.

MATTER, STEPHEN F. University of Virginia, Charlottesville, VA, 22903, USA and The Blandy Experimental Farm, Boyce, VA, 22620, USA. Insect movement and its effect on density in host plant patches.

The role of insect movement in determining density patterns over host plant patches was examined using the beetle, Tetraopes tetraophthalmus and its host Asclepias syriaca, in an unmanipulated old-field setting. The resource concentration hypothesis suggests that movement out of smaller and into larger patches alone may result in higher densities in large versus small patches (Root, 1973). However, mark-recapture data for this species revealed that insect density was independent of patch size, and both emigration and immigration were inversely related to patch size. Furthermore, the amount of interpatch movement inherent to this system was not capable of producing a density increase with patch size.

MATTHEW, KATHRYN K. New Mexico Museum of Natural History & Science, Albuquerque, NM., 87104, USA. Community-based education in ecology and natural sciences.

Formation of effective and long-lasting ecology education programs requires collaboration between institutions, needs analysis of the intended audience, and solid evaluation. A group brought together by the ESA's Ecology In Education Workshops identified issues for New Mexico: statewide networking, melding Native American tribal customs and perspectives on the natural world into curriculum, and providing up-to-date technical skills and information on environmental problems. Several ongoing projects in New Mexico will be reported on that incorporate these issues: Rio Grande Bosque Education Survey, Water Ecology Project Expansion, and Native American Teachers Project. Barriers and successes will be reviewed.

MATZNER, STEVEN L. and JAMES H. RICHARDS. University of California, Davis, CA, 95616, USA. The effect of soil water stress on nitrogen uptake capacity in Artemisia tridentata

Nitrogen uptake capacity was assessed to determine if the ability of Artemisia tridentata to absorb a critical nutrient changed as the plant and roots were subjected to increasing levels of water stress. Plants were grown in 80 cm pots in a greenhouse at the University of California, Davis. Water was withheld and uptake capacity was measured during an 8-week drying cycle. Harvests were made sequentially as soil water potentials decreased from -0.03 MPa to -5.0 MPa. Excised roots from three depths were exposed to concentrations of 0.025, 0.1, 0.5, 1.0, and 2.0 mM $^{15}NH_4{}^{15}NO_3$ and uptake kinetics were determined. Declining soil water potentials depressed nitrogen uptake, but uptake capacity (the sum V_{max} NH_4+NO_3) did not change with drying, although it was affected by root nitrogen concentration. The sum K_m (NH_4+NO_3) increased as soil water potentials declined. Maintenance of nitrogen uptake capacity coupled with its demonstrated ability to conduct hydraulic lift may enable Artemisia tridentata to continue nitrogen uptake as soil water availability declines. These mechanisms may be important in the ability of Artemisia tridentata to continue growth and complete reproduction late in the season, when soil layers with higher nutrient availability are dry.

MAUFFETTE, YVES, MICHEL FORTIN and PAUL ALBERT[1]. Université du Québec à Montréal, GREF, C.P. 8888 Succ. A, Montréal, Qc, Canada, H3C 3P8. [1] Concordia University, Montréal, Qc, Canada, H3G 1M8. The impact of ozone on the biology and the feeding preference of forest tent caterpillar (*Malacosoma disstria* Hbn).

Three-year-old sugar maple seedlings were set in 9 open-top field chambers in the spring of 1992 and 1993. Three ozone concentrations were generated: charcoal-filtered ambient air (0X), ambient air concentration (1X) and 3 times ambient air concentration (3X). The aim of this study was to assess the indirect effects of sugar maple leaves exposed to different ozone concentrations on the biological performance and feeding preference of the forest tent caterpillar (*Malacosoma disstria* Hbn.). In 1992, the larvae reared on 1X foliage developed faster than those on 3X. In 1993, the individuals reared on 3X developed faster than those on 0X, Larval survival rates in 1992 and 1993 were not affected by ozone treatments. Ozone concentrations did not influence male and female pupal weights in 1992 but they did for males in 1993 whereby insects reared on the control were larger than 1X. Finally, 4th and 5th instar larvae showed a feeding preference for 3X foliage only in 1993. These results suggest that the forest tent caterpillar response to ozone is subject to yearly variation and ozone concentration.

MAURER, BRIAN A. Brigham Young University, Provo, UT, 84602, USA. Why are some species more common than others? The importance of geographic range structure for the evolution of biological diversity.

In order for a species to persist over time, it must be able to maintain persistent populations across a sufficiently large area that its likelihood of extinction remains small. The diversity of a group of species is determined by maintaining a low enough per species rate of extinction so that species losses can be offset by speciation. The structure of a species' geographic range has a profound effect on its ability to persist. Species with large geographic ranges tend to have a smaller proportion of their local populations in contact with extreme conditions. Abundant species show relatively less spatial variation than rare species. Rare species also tend to have more stringent constraints on their population dynamics than abundant species. These factors considered together suggest that rare species should have a higher likelihood of going extinct globally than abundant species because they are composed of many local populations that have relatively poor capabilities of persisting for over time. This has two consequences: first, there will be differential extinction between rare and abundant species in the same clade, and second, abundant species will have more opportunities to undergo speciation. Hence, the evolution of biological diversity will be governed primarily by what happens to widespread and abundant species.

MAVITY, E. and P. BERRANG. USDA Forest Service, Center for Forest Environmental Studies. Dry Branch, GA 31020, USA. Effects of Ozone on Solidago albopilosa, an Endangered Species of Goldenrod from Central Kentucky.

Solidago albopilosa Braun is an endangered species of goldenrod that is found in a very limited area of central Kentucky. The reasons for the limited distribution of this species are not known. The Daniel Boone National Forest was concerned that increases in ambient ozone might endanger the survival of this species. Little work has been done to assess the sensitivity of goldenrods to ozone and apparently none has been done on this endangered species. Plants were exposed to either ambient, half ambient or twice ambient concentrations of ozone for 39 days in mid summer using June 1992 data from Mammoth Cave National Park as ambient. Few statistically significant effects were found; however, consistent trends toward lower leaf and stem biomass, leaf area and less height growth in the higher ozone treatments were seen. Carbon allocation patterns appear to be different with plants in the higher treatment allocating more to reproductive structures. Net photosynthesis and leaf conductance were measured several days after fumigations ended and plants in the half ambient treatment had the lowest rates and plants in the highest treatment had the highest rate. No characteristic visible ozone injury was seen. This study suggests that ozone has little effect on Solidago albopilosa; however, concentrations used were quite low.

MAY, JEFFREY D. and KEITH T. KILLINGBECK. Marshall University, Huntington, WV, 25755, USA and University of Rhode Island, Kingston, RI, 02881, USA. Effects of herbivore-induced nutrient stress on zinc and copper resorption in scrub oak (*Quercus ilicifolia*).

Scrub oaks were completely defoliated (treatment plants) in the spring by gypsy moth (*Lymantria dispar*) larvae in 1986 and 1987, resulting in production of a second flush of leaves (secondary leaves) in each of those years. An insecticide was used to prevent herbivory in control plants. Although radial stem growth was reduced by 49% and acorn production by 88% in defoliated plants relative to controls, defoliation had little effect on zinc (Zn) and copper (Cu) content in green leaves. However, senesced secondary leaves of treatment plants exhibited significantly less of those elements than did the leaves of controls. Reduced levels of Zn and Cu were also evident in senesced primary leaves of treatment plants in 1988, when no defoliation occurred. Resorption efficiencies for Zn and Cu averaged 117% and 29% higher, respectively, in the gypsy moth impacted plants than in controls for all three years, supporting the hypothesis that resorption may be plastic in response to changes in the magnitude of internal nutrient pools. These results contrast with the lack of any significant change in resorption efficiency for nitrogen and phosphorus in the same plants, possibly because the latter elements were already being resorbed at maximal rates (72% and 75%, respectively) constrained by physiological limitations.

MAYER, CHRISTINE M. and DAVID H. WAHL. Center for Aquatic Ecology, Illinois Natural History Survey and Department of Ecology, Ethology and Evolution, University of Illinois, 607 E. Peabody Drive, Champaign, IL, 61820. Implications for growth and survival of ontogenic changes in prey selectivity in a larval fish.

Larval and juvenile fish which feed on zooplankton, choose prey from assemblages that vary in taxa, size, abundance and hence, their profit to the predator. These factors, along with the developmental stage of the fish may interact to determine prey selectivity as well as fish growth and survival. In laboratory and field enclosure experiments, small walleye fry (8-10mm) selected prey based on taxa and

size, choosing cladocerans and small organisms. Selectivity was effected by prey density. Medium fry (11-17mm) selected less strongly for cladocerans and for small and intermediate prey items, and did not have to change with prey density. Both sizes of fry experienced higher survival when fed exclusively cladoceran prey. Large fry (>20mm) showed no strong pattern of taxa selection, but are more likely to select copepods than were smaller fry. Unlike smaller fry they selected positively for large prey items. Prey type did not effect growth and survival of large fry. Selectivity, survival and growth differences among these sizes of larval fish were consistent with maximum consumption, capture efficiency and morphometric data. The larval period in fish is often considered homogeneous; however our results suggest the occurrence of ontogenic changes in prey selectivity which effect growth and survival.

McAULIFFE, JOSEPH R. and LESLIE D. McFADDEN. Desert Botanical Garden, Phoenix, AZ, 85008, USA and University of New Mexico, Albuquerque, NM, 87131, USA. Complex vegetation mosaics as a response to 2000 years of landscape evolution in a highly erodable terrain, upper Jadito Wash watershed, Navajo-Hopi Reservations, Arizona.

Processes responsible for many complex vegetation mosaics in arid lands are better understood if the recent geological histories of landscapes are deciphered. During the last several thousand years, erosion of steep hillslopes has led to the rapid and episodic alluviation of valleys. Radiocarbon dating of buried materials enabled reconstruction of the timing of major events of landscape evolution. Major vegetation differences correspond to variation in ages of alluvial surfaces. Surfaces formed several thousand years ago are dominated by pinyon-juniper woodlands; adjacent surfaces of a few hundred years of age are occupied by shrub-steppe but have low densities of young trees. Areas of most recent alluviation are occupied by short-lived, wind-dispersed shrubs; longer-lived species increase as a function of length of time since cessation of active alluviation.

MCCOLLUM, S. ANDY. Duke University, Durham, NC, 27708, USA. Mate Choice in Female Gray Treefrogs: Guess Genes?

According to the "good genes" hypothesis, in species in which there is female mate choice but the male provides only sperm, females should choose mates possessing superior genotypes. I tested this hypothesis for the gray treefrog, *Hyla chrysoscelis*. Over the course of two breeding seasons, I mated females with 1) males they chose in the field, 2) unmated males, and 3) males that had been selected by other females. I then reared the progeny of these half-sib matings and compared their growth and survival in replicated outdoor containers. The results of these experiments provide no evidence that the progeny of chosen males are in any way superior to those of unmated males.

MCCRAKEN, GARY F., STANLEY Z. GUFFY, CHARLES R. PARKER and STEPHEN E. MOORE. University of Tennessee, Knoxville, TN, 37996, USA, National Biological Survey at Great Smoky Mountains National Park, Gatlinburg, TN, 37738, USA, Division of Resource Management, Great Smoky Mountain National Park, Gatlinburg, TN, 37738, USA. Population status, genetics, and management of Southern Appalachian strain brook trout.

In attempts to restore declining native populations, most brook trout streams within the Great Smoky Mountains National Park were heavily stocked between 1932 and 1975 with hatchery strains of brook trout that were derived from northern populations. Protein and mtDNA examination show that surviving native Southern Appalachian brook trout are genetically distinct from these northern-derived hatchery strains. The effects of stocking on the survival and regional distribution of the native genotype within the Park has been examined using diagnostic gene markers. Native brook trout remain widespread despite past stocking. To date, of 53 populations examined, 35 show no apparent introgression of hatchery-derived genes, although many of the populations were stocked. A management strategy incorporating regulated fishing and control of non-native salmonids should lead to the continued survival of native Southern Appalachian brook trout.

MCEACHERN, A. KATHRYN. National Biological Survey, Channel Islands Field Station, Ventura, CA, 93001, USA. Disturbance dyanmics of Pitcher's thistle populations in Great Lakes dune systems.

Pitcher's thistle (Cirsium pitcheri) is a colonizing species endemic to the dunes of the western Great Lakes. Interactions among disturbance processes and thistle population dynamics were investigated at local and landscape levels in Great Lakes sand dunes, 1988-1993. Early-successional habitats nearest the shore support high thistle population growth rates. However, these sites are destroyed during cyclic high lake-levels. Populations in sheltered inland habitats have low to negative growth rates, although recruitment is increased during brief disturbance episodes. Highest thistle densities and population growth rates occur in other inland sites subject to chronic low-level disturbance, and these populations may function as local seed sources for repeated dune system colonization. Tradeoffs among habitat location and disturbance operate at local scales to affect fates of individual populations, while the persistence of metapopulations is structured by the disturbance pattern across dune systems.

MCGINLEY. MARK A. AND SHIVCHARN S. DHILLION. Texas Tech University, Lubbock, TX 79409, USA. Mycorrhizal infection the optimization of plant root:shoot ratios and leaf nitrogen content.

Arbuscular mycorrhizal fungi form associations with apprimately 2/3 of all plant species. Although these associations are typically thought mutualistic, in some cases mycorrhizal fungi may act parasitically or have no apparent effect on plant growth. Thus, the costs and benefits these interactions need to be examined in more detail. We suggest that an important effect of infection by mycorrhizal fungi may be alteratio in plant growth decisions. We present a model investigating how variation in soil nitrogen content and the level of mycorrhizal infection sh

influence plant growth and resource allocation decision. The model predicts (1) that there is an optimal level of mycorrhizal infection that maximizes plant relative growth rates in a particular environment and that the optimal infection level depends on soil fertility and the rates of fungal nitrogen uptake and carbon use and (2) that increasing levels of infection should increase leaf tissue nitrogen content and reduce the proportion of biomass invested in shoots. Thus, studies of how soil nutrient characteristics influnce plant growth decisions may be complic by variation in levels of mycorrhizal infection. Greenhouse experiments with little bluestem (*Schizachyrium scoparium*) provide qualitative support for some of these predictions.

MCGRADY-STEED, JILL and PETER J. MORIN. Rutgers University, Piscataway, NJ, 08855, USA. The paradox of the protozoa: disturbance, storage and diversity.

Ephemeral pools contain a diverse assemblage of protists, rotifers, and nematodes that compete for similar substrate and food resources. Prolonged coexistence of over 10 bacterivore species suggests that non-equilibrium processes may promote species richness in these pools. Using the cyst-containing mud from a well-characterized ephemeral pool, we conducted a replicated microcosm experiment in which drying regimes were manipulated in a controlled environment. An 'undisturbed' treatment involved replicated microcosms that experienced constant hydration. In a 'disturbed' treatment, periodic desiccation and rehydration were imposed on replicated microcosms. Daily monitoring permitted examination of differences in species richness and composition for corresponding time intervals between treatments. Cumulative species richness was significantly higher in the undisturbed microcosms, primarily because late-successional predator species failed to excyst in the disturbed microcosms. Richness was initially greater in the undisturbed microcosms compared to the second and third development episodes in disturbed systems. Species richness eventually became greater in the disturbed microcosms after five to seven periods of development. Species composition differed significantly between treatments, diverging after the first development episode due to different successional trajectories in undisturbed and disturbed microcosms. Non-equilibrium mechanisms contribute to diversity in this system, but their contribution only becomes apparent after many episodes of community development.

MCGRAW, J. B. and J. SWANEY. Department of Biology, West Virginia University, Morgantown, WV 26506-6057, USA. The propensity measure of fitness in analyses of natural selection.

Analyses of phenotypic selection via multiple regression or path analysis attempt to quantify the relationship between quantitative traits of an organism and individual Darwinian fitness. As the ultimate measure of individual success, the choice of a measure of fitness is therefore critical in such analyses. We show how to estimate the propensities for individuals to survive and reproduce, given their measured phenotype. These propensities are then integrated into a single measure of individual fitness. This is illustrated for a hypothetical organism with the life history of an annual plant, but the method is general, and applies to organisms with age-structured life histories as well. Computer simulations of selection analyses show that use of the propensity measure of fitness provides a more accurate depiction of the selection regime than analyses using components of fitness. For some selection regimes, the pattern of selection was incorrectly identified using components of selection: This was particularly evident where a trait influenced survival and fertility in opposite ways. These generalizations were confirmed with a selection analysis in a natural population of *Impatiens pallida*.

MCGUIRE, A. DAVID, JERRY M. MELILLO, LINDA A. JOYCE and DAVID W. KICKLIGHTER. Marine Biological Laboratory, Woods Hole, MA, 02543, USA and Rocky Mountain Forest and Range Experiment Station, Ft. Collins, CO, 80526, USA. Equilibrium responses of soil carbon to climate change: Issues of parameterization.

We use the Terrestrial Ecosystem Model (TEM) to investigate how assumptions about the active soil carbon at calibration sites influence estimates of global soil carbon response to climate change. When TEM is parameterized for "1 m" soil carbon at each of the calibration sites, it estimates global equilibrium soil carbon stocks to be 1301.5 Pg (10^{15} g) for contemporary climate at an atmospheric CO_2 concentration of 312.5 ppmv. For a 1 C^o warming applied across the terrestrial biosphere, TEM estimates a soil carbon release of 42.7 Pg. In contrast, when TEM is parameterized for "20 cm" soil carbon, it estimates global stocks of 837.2 Pg for contemporary climate and a release of 18.8 Pg for a 1 C^o warming. When we adjust the active soil layer at calibration sites so that transitions in soil carbon are smooth at ecosystem boundaries, the relative contribution of tropical ecosystems to the global response declines. We conclude that using a constant depth to define the active soil layer should be avoided.

MCKANE, ROBERT[1], EDWARD RASTETTER[1], GAIUS SHAVER[1], KNUTE NADELHOFFER[1], ANNE GIBLIN[1], JAMES LAUNDRE[1], and F. STUART CHAPIN, III[2]. [1]Marine Biological Laboratory, Woods Hole, MA, USA, and [2]Department of Integrative Biology, University of California, Berkeley, CA, USA. Effects of historical changes in climate on carbon storage in Alaskan arctic tundra.

Surface air temperature in Arctic regions has increased since pre-industrial times, raising concerns that warmer and drier conditions have increased soil decomposition rates, thereby stimulating the release to the atmosphere of the large stores of C in arctic soils. We used a model (MBL-GEM) of ecosystem C and N dynamics to predict and analyze historical (1829 to 1990) changes in C storage in a tussock tundra ecosystem in Alaska. We calibrated the model by deriving a single parameter set that closely simulated responses to decade-long manipulations of nutrients, temperature, light, and atmospheric CO_2. Based on the combined effects of reconstructed historical changes in atmospheric CO_2, mean growing-season temperature and two alternative soil moisture scenarios, the model predicts a -3.0 to +2.1 percent change in ecosystem C from 1829 to 1990. These results are consistent with field evidence that historically recent changes in C storage of tussock tundra have been relatively small. However, the model also predicts that relatively large transient losses of ecosystem C (50 to 120 g m^{-2} yr^{-1}) may frequently have occurred since the late 1800s, with one of the largest simulated C losses of the 20th century occurring from 1988 to 1990 (85, 92, 61 g C m^{-2} yr^{-1}, respectively). These simulated losses were at the low end of the range of losses measured in Alaskan tussock tundra from 1983 to 1990 (65 to 487 g C m^{-2} yr^{-1}), but nonetheless suggest that these recent losses may be transitory in nature.

MCKEE, D. Department of Biology, Imperial College, Silwood Park, Ascot, Berks. SL5 7PY, U.K. Videoing Daphnia to determine the effect of temperature on population dynamics and body-size structure.

A laboratory based study was undertaken to examine short term dynamics and body-size structure in populations of Daphnia magna maintained at 5°C, 15°C, 25°C, and under a varying temperature regime (9°-21°C, 12h:12h cycle). Video recording and image analysis were used to gather and process data. It was possible to distinguish four body-size classes and obtain accurate population counts using this method. Temperature had a large effect on population growth and development, but a lesser effect on individual body-sizes and proportions of animals in a given size class.

MCKEE, KAREN L. and CANDY FELLER. Louisiana State University, Baton Rouge, LA 70803, USA and Smithsonian Institution, Washington, DC 20560, USA. Effects of nutrients and shading on growth and architecture of mangroves in Belize.

Above- and below-ground growth responses of Rhizophora mangle L. (RM), Avicennia germinans (L.) Stearn. (AG), and Laguncularia racemosa (L.) Gaertn. f. (LR) to nutrient enrichment (NPK) and shading (50% full sunlight) were investigated in a completely randomized 3 x 2 x 2 factorial experiment conducted in a clear-cut mangrove forest at Twin Cays, Belize. After 1.5 yr, total (leaf + stem + root) biomass of RM, AG, and LR juveniles, respectively, was lowest in the low nutrient, unshaded (11.8 ± 2.0, 3.8 ± 1.6, 1.1 ± 0.4 g dry mass) or shaded (14.4 ± 2.0, 4.6 ± 1.6, 0.5 ± 0.1 g dry mass) treatments, intermediate in the enriched, unshaded treatment (20.5 ± 3.5, 26.4 ± 11.3, 21.9 ± 4.0 g dry mass), and highest in the enriched, shaded treatment (33.0 ± 4.6, 81.2 ± 16.2, 71.3 ± 10.1 g dry mass). The positive effect of shading on growth was attributed to amelioration of high soil temperatures, which develop in large light gaps in these island forests. Canopy and root system architecture and biomass partitioning patterns indicate interspecific differences in flexibility of response to environmental conditions and potential to succeed in large versus small light gaps in forests with different nutrient regimes. The results provide insight into how regeneration patterns in mangrove forests may be influenced by resource availability and non-resource stress factors.

MCKINNEY,KATHRYN K. AND EDWARD J. RYKIEL,JR. Texas A&M University, College Station, TX, 77843, USA. Redcedars Have Significant Impact on Post Oak Leaf Area in Hardwood-Redcedar Clusters.

The interaction between eastern redcedar (Juniperus virginiana) and post oak (Quercus stellata) in hardwood-redcedar clusters may be governed in part by shading of the lower leaves of the post oak center tree by redcedars growing beneath the canopy. We examined the change in leaf area from 1982 to 1993 for post oak center trees in 20 clusters. Allometric relationships were developed to estimate projected leaf area of post oak (LA (cm^2) = 58308 + 2077*DBH^2) and redcedar (LA = -51.813 + 2.05*Basal $Diameter^2$). In 1984, the under-canopy redcedar were removed from 4 of these clusters. The leaf area of post oaks without redcedars increased by 1.8 x 10^6 cm^2, while the area of oaks in clusters increased by 0.5 x 10^6 cm^2 over this period. Thus, leaf area growth rate of cluster oaks was lower than that of oaks without surrounding redcedars. We hypothesize that the leaf area growth rate of cluster post oaks will continue to decline as redcedar grow through the post oak canopies.

MCKINNEY LLOYD B., FRED E. SMEINS, and NOVA J. SILVY. Texas A&M University, College Station, Texas 77843-2135, USA. Influence of coastal prairie fragmentation on the endangered Attwater's Prairie Chicken.

Forty years of landscape change is documented for a 56,000 ha study area centered on a 3,240 ha national wildlife refuge historically occupied by Attwater's Prairie Chicken (Tympanuchus cupido attwateri) on Texas Coastal Prairie, Aerial photographs for 1952, 1964, 1982, and 1990 were interpreted and digitized into a geographic information system. Prairie habitat decreased from 52% of the area in 1952 to less than 17% in 1990. Mean prairie patch size decreased from 5,868 ha in 1952 (n=5) to 445 ha in 1990 (n=21) while mean nearest neighbor distance for prairie patch centroids was reduced from 4,534 m in 1952 to 2,306 m in 1990 indicating an overall reduction in the extent of potential habitat. Populations declined by nearly 90% from 600 in 1950 to 63 in 1991. Lek sites also mirrored population trend with locations falling from 34 in 1979 to 17 in 1990. Longterm loss and fragmentation of habitat appears to have had the major impact on Attwater's Prairie Chicken populations.

MCKINNEY, MICHAEL L. University of Tennessee, Knoxville, TN, 37996, USA. How do rare species avoid extinction?

A potentially important distinction of rare species is that they may be better at avoiding extinction at low abundances. This is difficult to directly test because rare species tend to have increased sampling error. However, there are ways to overcome such problems, including in the fossil record, which is rich in extinction and abundance data. One way is to examine the growing literature on extinction selectivity. This gives clues on which traits promote extinction resistance: lower trophic level, morphological and behavioral simplicity, eurytopy, and stable habitats are examples. Such clues are very general and must be supplemented by finer scales of intergroup comparisons, as by comparing traits and habitats among rare vs common species at different taxonomic levels. Initial results using foraminifera indicate that rare species tend to co-occur nonrandomly in the same genera, implying that rarity is a phylogenetically inherited trait.

MCLAUGHLIN, SAMUEL B., STAN D. WULLSCHLEGER and APRIL STONE. Environmental Sciences Division, Oak Ridge National Laboratory, Oak Ridge, TN 37831-6034, USA, and Graduate Program in Ecology, University of Tennessee, Knoxville, TN 37996, USA. Physiological diagnosis of the health of spruce and fir at high elevations in the Southern Appalachians

A sequence of field studies to evaluate causes of decreasing radial growth rates of red spruce at high elevations in the Great Smoky Mountains during the past 30 years has examined climatic signals, competition, xylem wood chemistry, soil chemistry, foliar nutrition and carbon allocation patterns. The resultant hypothesis that acid deposition alters red spruce growth through limiting calcium availability, and consequently net carbon assimilation, has now been tested in controlled greenhouse and field studies. Recent measurements of reduced respiration and increased photosynthesis of red spruce saplings in response to adding calcium in the field, provides additional evidence linking acid deposition to altered nutrition, physiology, and growth of red spruce. Initial data from physiological gradient analysis also support the occurrence of parallel elevational gradients in physiology of fraser fir.

MCLENDON, TERRY, DONALD A. KLEIN, MARK W. PASCHKE, AND EDWARD F. REDENTE. Colorado State University, Fort Collins, CO, 80523, USA. Above- and belowground characteristics along a chronosequence of abandoned cropland in a shortgrass plains ecosystem.

The role of nitrogen (N) availability in the recovery of abandoned cropland is being investigated in a multi-year study in semiarid northeastern Colorado. Three N-availability levels (high, intermediate, low) are experimentally maintained in four seral communities that represent a post-cultivation chronosequence. The seral communities include an annual-dominated early-seral community (4 years since cultivation), two grass-dominated mid-seral communities (one 12 years and one 38 years since cultivation), and an uncultivated late-seral community. Effects of the N-availability treatments on plant (above- and belowground components) and microbial (total and active bacteria and fungi) communities, decomposition rate, tissue N allocations, and soil N pools are being measured within each seral community. First-year data are presented that indicate distinct successional patterns for each of these components.

MCNULTY, STEVEN G., JAMES M. VOSE and WAYNE T. SWANK. USDA Forest Service, Coweeta Hydrologic Laboratory, Otto, NC, 28763, USA. Validation of landscape scale forest ecosystem model predictions of net primary productivity and run-off across the southern United States.

Potential climate change effects on landscape scale forest ecosystem processes (e.g., productivity and hydrology) could have important future social and economic implications. Numerous landscape scale models have been developed to examine ecosystem response to climate change, but model predictions are difficult to validate because data are rarely collected over large geographic regions. PnETII is a model which combines monthly climate variables with soil water holding capacity to predict monthly and annual forest productivity and hydrology. Through a careful screening of over 21,000 Forest Service, Forest Inventory Assessment plot growth data from 1961-1992, we have tested PnETII model predictions of southern pine NPP across the southern U.S. PnETII predictions of water drainage were also tested using USGA National Water Summary data of stream gauge run-off measures from 1951-1980. Our analysis shows that establishment of general patterns between predicted and measured ecosystem processes are possible at large spatial scales.

MEEDER, JOHN F., JOSEPH J. O'BRIEN, RONALD D. JONES and MICHAEL S. ROSS. Southeast Environmental Research Program, Florida International University, Miami, FL 33199, USA. Perturbation of the Thalassia ecosystem and effects on ecosystem dynamics caused by Hurricane Andrew, South Florida.

Bottom currents associated with Hurricane Andrew had significant, varied and often localized impacts on Thalassia-dominated meadows. Ecosystem processes documented are: 1) Thalassia detritus and fine grained sediments were winnowed, 2) water depth increased, 3) previously buried sediments and nutrients were made available at the water-sediment interface, 4) bottom habitat diversity and Thalassia edge were increased, and 5) mass export or turnover of stored organic organic carbon and nutrients occured. Spatial variability in the type and magnitude of hurricane impact was dependent upon: type and percent cover of bottom community, water depth, location in storm's path, and adjacent topography. In the deeper offshore areas Thalassia was undisturbed or experienced winnowing of detritus and fine grained sediments. In shallower areas, winnowing was more intense with living rhizomes eroded and expanded. In areas of extreme bottom turbulence, grass beds were frequently completely eroded. Expected burial of grass beds by siltation was not observed except in local, low energy areas indicating extensive onshore and offshore export. Although Thalassia beds are considered sediment (sinks) by most workers, Hurricane Andrew illustrated that the sediments stored over long periods of time (decades-to-centuries) should be considered mobile or in temporary storage. These processes are analogous to the effects of fires in terrestrial grasslands.

MEDEIROS, ARTHUR C., F. RUSSELL COLE, AND LLOYD L. LOOPE. National Biological Survey, Makawao, Maui, HI, 96768, USA and Colby College, Waterville, ME, 04901, USA. Patterns of expansion of an invading Argentine ant (Iridomyrmex humilis) population in Haleakala National Park, Maui, Hawaii.

The Argentine ant, Iridomyrmex humilis, a species with non-flighted queens, occupies two disjunct areas between 2070 m and 2850 m elevation in Haleakala National Park. This alien ant species negatively affects the locally endemic arthropod fauna, including pollinators, which evolved in the absence of ant predation. The Argentine ant was first noted in the lower elevation area in 1968, and in the higher area in 1982. Extremely vigorous ant populations occurred throughout the range in 1984-86. In 1988-89, a sharp decline (>90%) occurred in the lower elevation population, whereas

the newer, higher elevation population remained relatively vigorous. A marked expansion in the ant's range was noted in 1993, especially at the higher elevation area, perhaps related to consecutive mild (low rainfall) winters. Newly invaded areas characteristically have high ant populations, whereas previously occupied range is a mosaic of persistent and diminished populations, apparently depending on microhabitat. Unless this ant species is controlled, it appears capable of spreading widely, with potentially catastrophic effects on locally endemic biota. Experimental control efforts are underway with a hydromethylnon/protein bait, using techniques developed for Argentine ant control in agricultural sites in California.

MEDLEY, KIMBERLY E.[1], MICHAEL F. LUCAS[1], BRIAN W. OKEY[2], GARY W. BARRETT[1], AND CHRISTINE M. BUTALLA[1]. [1]Miami University, Oxford, OH 45056, USA and [2]University of Guelph, Guelph, ON, CANADA. Cultural and ecological influences on the functioning of forests in agricultural watersheds.

Land use patterns for 1935, 1956, and 1982 show an increase in total forest area from 2800 ha to 3400 ha in agricultural Upper Four-Mile Creek watershed, SW Ohio and significant changes in the positions of forest patches. Forest area is stable, but fragmented, in the upper watershed; it increases by 25% in the lower watershed. Water quality problems in Acton Lake, constructed at the base of the watershed in 1956, substantiate the need to examine factors influencing the functional role of forest buffers. Questionnaires, parcel data, and CRP claims are used to examine cultural processes that alter land-management decisions, and comparative measures of nutrient flows and forest structure are used to estimate landscape buffering capabilities. Results suggest that cultural forces, more than economic or environmental, influence farm-level forest management. We present a model that integrates our study of cultural-ecological processes at farm and landscape levels along seven first-order streams of Marshall Branch, a tributary basin.

MEGONIGAL, J. PATRICK and WILLIAM H. SCHLESINGER. Duke University, Durham, NC, 27708, USA. Methane oxidation in tidal freshwater swamps

Methane-oxidizing bacteria can significantly reduce fluxes of CH_4 from wetland soils, lowering the atmospheric burden of this greenhouse gas. We measured rates of methane oxidation in two swamp forests on a tidal freshwater river in North Carolina. Soils at the lower site are exposed for 5 hours twice a day while soils at the upper site may be exposed for periods of 12 hours or more. Rates of methane oxidation were estimated <u>in situ</u> with applications of CH_3F, an inhibitor of methane oxidation. At the upper site, methane fluxes increased from 2±1 (mean±sd) to 16±4 mg m^{-2} d^{-1} in September and from 1±0.7 to 3±2 mg m^{-2} d^{-1} in October with applications of CH_3F. In November there were no differences between treatments. At the lower site, the inhibitor had no effect on fluxes even though CH_4 flux rates were relatively high on control plots (24±15 mg m^{-2} d^{-1} in September). These preliminary results suggest that small changes in hydroperiod can significantly influence CH_4 fluxes from wetland ecosystems.

MEHLMAN, DAVID W. University of New Mexico, Albuquerque, NM, 87131, USA. Spatial variation in North American bird abundance.

Data from the Breeding Bird Survey were used to confirm hypotheses on the distribution of abundance within the range of a species. The frequency distribution of abundance was highly skewed, with all species relatively rare at most survey sites. Maximum abundance increased with increasing distance from the edge of range when distance was measured from interior range boundaries. The reverse pattern occurred when distance was measured from continental range boundaries. Low abundance sites were found throughout the range and their frequency increased as distance to the range edge decreased. High and low abundance sites were closer together in space to sites of similar abundance than to sites of different abundance. The spatial autocorrelation of abundance generally showed a U-shaped pattern, with high positive autocorrelation at small and large lag distances and zero or negative autocorrelation at intermediate distances. These results are consistent with the view that local abundance is determined by multiple niche factors with continental edges serving as "step" boundaries.

MEIER, CALVIN E., KUO-CHUAN LIN and PATRICIA MICKS. Texas A&M University, College Station, TX, 77843, USA. Nutrient release from decomposing needle litter in <u>Pinus taeda</u> plantations.

A 32-mo study was conducted in five East Texas <u>Pinus taeda</u> plantations (17-23 yr old) to evaluate the influence of substrate quality and climatic differences on nutrient release and litter decomposition patterns. Site AET ranged from 858-955 mm/yr with water deficits of 55-240 mm/yr. Using the litterbag technique, changes in needle mass, N, P, Ca, Mg, and K were determined through the study period. Decomposition constants, k, varied from 0.27-0.47. At the study's end, litter Mg and K capitals had declined by averages of 68 and 81%, respectively, with little significant difference among sites. In litter exhibiting greatest mass loss, Ca capital declined by 68% in contrast to an average of 35% in the other sites. On the site with significantly lower initial litter N concentration and lowest decomposition rate, net litter N content, after 32 mo, was 17% greater than initial content while other sites showed an average 7% net loss. Similarly P content declined by an average of 18% in three sites but had 6 and 23% net increases in the two plantations with significantly lower initial P levels.

MEINERS, SCOTT J. and DAVID L. GORCHOV. Department of Botany, Miami University, Oxford, OH, 45056, USA. Possible nurse tree effects of Juniperus virginiana on hardwood tree seedlings.

Juniperus virginiana has been hypothesized to be a nurse tree in secondary succession. To test this hypothesis, field sampling, microenvironmental measurements, and an experimental planting of Acer saccharum and Fraxinus americana were done in the summer of 1993. Field sampling of old fields showed that there were higher densities of woody seedlings near J. virginiana individuals. Plantings (in exclosures) and measurements were taken near (30 cm) and far (3.0 m) from central J. virginiana trees. Juniperus virginiana significantly reduced light, mean soil temperature, soil temperature fluctuations, evaporation, and soil moisture (near vs. far comparisons). Germination rates of both species were higher in the far treatment. There were no differences in distance treatments in biomass or root:shoot ratios in one year old Acer seedlings. Fraxinus seedlings showed decreased growth in near treatments. While there is a spatial association between J. virginiana and deciduous tree seedlings, our results suggest that this association is not due to higher survival or growth during the growing season.

MELLIN, THOMAS C., ALLEN, H. LEE, and THOMAS R. WENTWORTH. North Carolina State University, Raleigh, NC, 27695, USA. Effects of soil compaction and harvest removals on non-crop vegetation in a loblolly pine plantation.

A 55 to 60-year-old mixed pine hardwood stand in the coastal plain of North Carolina was clearcut and planted in one acre plots with loblolly pine. Experimental treatments were imposed on the plots as a 2 x 2 factorial including different levels of soil compaction and organic matter (OM) removal, two key factors in determining long term soil productivity. Soil compaction varied from none to severe and harvest removals varied from stemwood only to whole tree plus forest floor. Two years after treatment, vegetation regrowth was characterized using the quadrat method developed by the N.C. vegetation survey. In addition, 5 $1m^2$ clip plots were taken per plot. The imposed treatments greatly affected species richness, biomass, and species-area relationships. Greatest biomass was found in the low OM removal/no compaction plots with the lowest biomass occurring in the high OM removal/severe compaction plots. In contrast, greatest species richness was found on the low OM removal/severe compaction plots followed closely by the high OM removal/severe compaction plots while the low OM removal/no compaction plots had the lowest species diversity.

MESSIER, CHRISTIAN and NINKINMAA, EERO. Université du Québec à Montréal, Montréal, C.P. 8888, Succ. Centre Ville, H3C 3P8, Canada and University of Helsinki, 00170, Helsinki, Finland. Testing the effective compensation point idea for three shade tolerant broadleaf species in eastern Canada.

The growth vigour and above ground architecture of 30 to 550 cm tall yellow birch, sugar maple and american beech individuals were related to the light intensity reaching those individuals in a gradient of light from 0.5% to 47% of full sunlight in a mature birch-beech-sugar maple stand near Québec city, Canada. The main hypothesis (sensu Givnish) that understory tree seedlings increase their minimum light requirement as they grow larger, accounting for the proportional increase in non-photosynthetic tissue, was verified, i.e. the maximum seedling height found for all three species increased from 30 to 550 cm with increasing light intensity from 0.5 to 4% full sunlight. Above 4% full sunlight, seedlings of all species and all heights between 30 and 550 cm were found. Relative height growth rate was strongly affected by light, but not by seedling height. The three species showed different types of architectural plasticity with changes in light and total height.

METZGAR, LEE H. The University of Montana, Missoula, MT 59801-1002. Ecologists in K-12 education: Why? Why not? So what?

Reform of science education and renewed interest in environmental education proceed with little involvement of professional ecologists. However, efforts such as those described here show how ecologists can engage these trends positively. We celebrate these successes but also note that powerful barriers often foil and discourage such efforts. Chief among these, institutional values and reward processes focus on research productivity and devalue education, especially the education of non-majors. Pressing needs include: 1) Greater ESA leadership of and support for educational reform at all levels. 2) Broader criteria for academic success that reward participation in educational reforms. 3) Participation of professional ecologists in general education and teacher-preparation. Funding exists to support reform activities but changing academic value systems remains difficult. None-the-less, ecologists possess knowledge and skills desperately needed by those who hope to reform science education.

METZLER, KENNETH J. and JULIANA PANOS BARRETT, CT Geological and Natural History Survey, Hartford, CT, 06102, USA and The Nature Conservancy, CT Chapter, Middletown, CT, 06457, USA. An application of The Nature Conservancy version of Driscoll's Ecological Land Classification to classify and describe the vegetation of Connecticut, USA.

A hierarchical classification of vegetation is proposed for Connecticut following a regional framework developed by The Conservancy's Eastern Regional Office. In Connecticut, existing

literature and field data were used to describe the vegetation. Depending on the accuracy and completeness of the data, the vegetation was described at one of two levels: alliance or plant community. Currently, a total of 102 alliances and/or communities have been described: 32 - Terrestrial, 57 - Palustrine, and 13 - Estuarine. It is proposed that this classification be used to determine significant conservation priorities within Connecticut. This classification provides a framework for expansion into adjacent states and points to future research needs.

MEYER, GRETCHEN A. and MARK C. WITMER. Williams College, Williamstown, MA 01267 and Cornell University, Ithaca, NY 14853. Effects of gut treatment on germination success of bird-dispersed shrubs.

We fed fruits of Lindera benzoin, Prunus virginiana, and Viburnum dentatum to captive cedar waxwings (Bombycilla cedrorum) and thrushes (Turdus migratorious, Hylocichla mustelina, Catharus guttatus, and C. minimus). We compared total percent germination across the following treatments: seeds remaining in intact fruits, uningested seeds cleaned of the fruit pulp, seeds regurgitated by birds, seeds defecated by birds and cleaned of feces, and seeds defecated by birds and planted with feces. The presence of the fruit pulp virtually eliminated seed germination for Lindera and Viburnum. Germination was reduced for Prunus seeds planted in intact fruits, but this result was inconsistent across trials. In general, there were no effects of bird ingestion on seed germination as long as cleaned bird-ingested seeds were compared to cleaned control seeds. Planting defecated seeds with feces reduced total germination compared to cleaned seeds. We conclude that gut treatment by birds does not appear to be an important influence on the germination of these shrubs, although frugivorous birds do play an important role by cleaning the seeds of the fruit pulp. Defecated seeds are likely to suffer a reduced probability of germination compared to regurgitated seeds, but this effect is due to the presence of feces with defecated seeds rather than differences in gut treatment.

MEYER, SUSAN E., and BURTON K. PENDLETON. USDA Forest Service, Intermountain Research Station, Provo, UT 84606, USA. Factors affecting seedling recruitment success in blackbrush (Coleogyne ramosissima).

Blackbrush is a dominant shrub species along the Mojave Desert-cold desert interface. It is a wind-pollinated, mast-fruiting species whose seeds are dispersed by scatterhoarding heteromyid rodents. We followed seedling survival from natural caches at two Mojave and two Colorado Plateau sites from spring 1992 through two growing seasons following a year of mast seed production in 1991. Within each geographic area, a sandy site with apparently high rodent densities was compared with a rocky site. Seedling survival over the period varied from 1.4% to 90.2%. Sprout-grazing by rodents early the first season was the most important mortality factor, while apparent drought-related mortality was important later in the season. Survival was lowest at the sandy Mojave site and highest at the rocky Colorado Plateau site. Seedlings in small caches had a higher probability of survival than seedlings in large caches, but cache survival (at least one seedling) tended to be higher for larger caches. Proximity to adult blackbrush plants had no consistent effect. Survival was higher on small disturbances (natural gas pipeline corridors) than in mature blackbrush stands, particularly on the Mojave sites. Most mortality took place the first year. We conclude that blackbrush can successfully recruit from seed when mast years are followed by favorable establishment years, a scenario that may be more probable on the Colorado Plateau than in the Mojave Desert.

MIAO, S.L. and F.A. BAZZAZ. Harvard University, Cambridge, MA 02138. Physiological and phenological bases of decline in growth enhancement after long-term exposure to elevated CO_2.

We addressed the degree to which CO_2-induced growth enhancement in six temperate deciduous tree species is sustained, the physiological and phenological bases that underlie the growth response, and the effects of naturally occurring resource heterogeneity on seedling and sapling response to CO_2 after three years of growth. At the end of year three, CO_2 -induced growth enhancements declined with different degree among species and resource treatments. Photosynthetic rates as a function of intercellular CO_2 concentrations were greatly influenced by elevated CO_2, nutrients, light, and species. High CO_2 plants, however, showed higher photosynthetic rates than ambient CO_2 plants when both groups were measured in CO_2 concentrations *in situ*. The photosynthetic enhancement in elevated CO_2 largely resulted from higher intercellular CO_2 levels. In contrast to photosynthesis, stomatal conductance showed little variation. The effect of elevated CO_2 on leaf phenology was species-specific. In gray birch and yellow birch, ambient CO_2 plants had lower leaf bud mortality and a faster rate of leaf bud break than high CO_2 plants. In contrast, in red maple and striped maple, elevated CO_2 plants showed lower leaf bud mortality in some treatments and there was no statistical difference in leaf bud break between ambient and elevated CO_2 plants. These results show that beneficial effects of higher photosynthetic rates on growth in a high CO_2 environment may be negated in some species by changes in other plant traits. Differential responses of species to elevated CO_2 may have important implications for forest regeneration and species composition.

MICHELI, FIORENZA. University of North Carolina at Chapel Hill, Chapel Hill, NC 27599, USA. Effects of habitat structure and intraspecific interference on prey patch use by the blue crab, Callinectes sapidus.

Blue crabs, Callinectes sapidus, forage in both salt marsh and sand flat intertidal habitats. To determine what factors influence the use of these vegetated and unvegetated habitats by crabs, I manipulated prey distribution and crab density within 30 m^2 enclosures containing both habitats. Crabs spent more time and ate more prey (the hard clam Mercenaria mercenaria) within the salt marsh than in the sand flat when at low crab densities. At high crab densities, there was no difference in the proportion of prey eaten between habitats. Further experiments showed that interference and not exploitation competition explained the latter result. Large-scale field experiments comparing predation intensity in sand

flats and salt marshes during periods of high (summer) and low (fall) crab densities corroborated the results of the experiments within enclosures. These results indicate that crabs feed in less preferred (unvegetated) habitats when interference with conspecifics is most intense.

MICHENER, WILLIAM K., ROBERT N. SMITH, PAULA F. HOUHOULIS and J. LARRY LANDERS. J. W. Jones Ecological Research Center, Newton, GA, 31770, USA. Impact of habitat fragmentation and shrub-hardwood invasion on a Sherman's Fox Squirrel Population.

Fox squirrel (Sciurus niger) subspecies are declining throughout the eastern US and are beginning to receive special attention in conservation and multiple use resource management plans. Six 144-ha sampling plots located within continuously-forested areas of longleaf pine were sampled during spring 1993 employing a 12 X 12 matrix of traps, each separated by 100 m. A total of 475 fox squirrels and 1,656 other mammals (11+ spp.) were captured during 25,920 24-hour trapping periods. Vegetation sampling of canopy and groundcover, coupled with GIS-based analyses were used to quantify structural and compositional elements of the landscape that comprise suitable habitat for fox squirrels. S. niger distribution patterns were positively associated with longleaf pine basal area; moderately associated with live oak basal area; and inversely related to total oak basal area and scrub density. Based on these and additional results, we propose that fox squirrel populations (I) specialize in extensive two-layered habitat (pine canopy over herbaceous groundcover), and (II) give way to interspecific competition driven by hardwood-shrub proliferation; therefore, habitat suitability is (III) reduced by fragmentation, but (IV) enhanced by growing-season burning and other management practices which restore pine savanna structure.

MIDDLETON, BETH A. and KAREN L. MCKEE. Southern Illinois University, Carbondale, IL, 62901, USA and Louisiana State University, Baton Rouge, LA, 70803. Above- and below-ground leaf decomposition in mangrove swamps at Twin Caes, Belize.

Above-ground decomposition of species associated with mangrove islands in Belize is faster in shoreline zones dominated by *Rhizophora mangle* L. than in mixed woodland zones farther inland for leaves of *R. mangle, Avicennia germinans* (L.) Stearn., *Laguncularia racemosa* (L.) Gaertn. f., and *Thallassia testudinum* L. (k=9.30 and 1.01, 11.6 and 1.01, 1.79 and 1.01, and 76.5 and 1.01, respectively). Below-ground decomposition of *R. mangle* and *A. germinans* roots was much slower by comparison. Site differences in decomposition rates were attributed to differences in environmental conditions and biotic influences between shoreline and inland zones. The shoreline site was more frequently wetted by tidal action and characterized by lower salinity and more reducing soil conditions compared to the mixed forest zone. Herbivory studies also showed that the faster above-ground decomposition rates along the shoreline were partly attributable to initial processing of litter by crabs and other invertebrates, which were more abundant there compared to inland zones. The results will contribute to better understanding of peat-forming processes in these intertidal island forests.

MIDWOOD, ANDREW J., THOMAS W. BOUTTON, and STEVE ARCHER. Texas A&M University, College Station, TX, 77843, USA. Natural abundance of ^{2}H and ^{18}O in rainfall, soil moisture, and plants in a subtropical savanna: Implications for plant water use.

In the Rio Grande Plains (TX), subtropical woodland has replaced relatively open grassland/savanna during the past 200 yr. To investigate the hydrologic implications of this transformation, we determined the natural abundance of ^{2}H and ^{18}O in rainfall, ground-water, and soil and plant water in three habitats representing a successional chronosequence in the transition from grassland to woodland. Precipitation was isotopically identical to groundwater and fell on the meteoric water line with a weighted mean $\delta^{2}H$ of -22 ‰ and a weighted mean $\delta^{18}O$ of -4.3 ‰. $\delta^{2}H$ and $\delta^{18}O$ of precipitation did not vary seasonally, but showed a significant "amount effect". Correlations between $\delta^{2}H$ and $\delta^{18}O$ of soil water suggested higher evaporation rates in wooded areas than in grassland. However, we suggest this result does not reflect higher evaporation rates, but rapid drying of the soil via transpiration followed by kinetic fractionation associated with evaporation in dry soils. $\delta^{2}H$ and $\delta^{18}O$ of plant and soil water indicated that more recently established woody plants associated with earlier successsional stages had shallower root systems and obtained water from the upper 150 cm of the soil profile, whereas those associated with later successional stages had deeper root systems and acquired water below that depth. By reducing transpirational leaf area and root biomass in the grass layer, long-term grazing in this former grassland may have enhanced infiltration of soil water, creating an opportunity for development of a community dominated by more deeply rooted woody plant species capable of exploiting water in lower portions of the soil profile.

MIGNANO, JOANNA R. and H. LEE ALLEN. North Carolina State University, Raleigh, NC, 27695, USA. Effects of water and nutrient availability on fine root biomass of loblolly pine.

Monthly soil cores 10 cm in depth were taken for thirteen months in order to obtain estimates of fine root biomass and production in a nine year old loblolly pine stand in the Sandhills of North Carolina. Two classes of roots were identified: < 2 mm and 2-5 mm in diameter. Four treatments were applied including no treatment, irrigation, optimal nutrition, irrigation and optimal nutrition. Each of the four treatments were replicated four times. Twenty samples were taken from each plot per month for a total of 320 cores per sampling period. Monthly biomass data indicates there were no treatment effects. This contrasts with the dramatic response in the aboveground production, within the irrigation and optimal nutrition plots, which showed a one hundred percent increase.

MIKAN, CARL J. and MARC D. ABRAMS. The Pennsylvania State University, University Park, PA, 16802, USA. Edaphic properties relating to altered succession on historic charcoal hearths in southeastern Pennsylvania.

We related the age structure and composition of a forest to edaphic properties caused by the use of earthmound kilns for charcoal production by an iron furnace from 1771 to 1883. Physical and chemical properties of charcoal hearth soils were examined to understand floristic differences relative to surrounding sites after a century of secondary succession. Recolonization

of charcoal hearths was delayed by the elimination of stump sprouting and the soil seed bank, and an extreme soil chemical and physical environment. Hearth communities were significantly younger, with lower tree density, basal area, sapling and shrub abundance, and an increase in herbaceous cover. Quercus spp. and Acer rubrum were less important, but Liriodendron tulipifera was more important on charcoal hearths. Charcoal soils had lower bulk density, but higher organic matter, pore space, pH, and exchangeable base cations. Differences in foliar concentrations of N, P, K, Ca, Mg, Fe, Mn, Al, and Cu in plants growing on hearth and control sites suggest that lack of woody vegetation on charcoal hearths may be related to altered macro- and micro-nutrient availability.

MILCHUNAS, D. G. and W. K. LAUENROTH. Colorado State University, Ft. Collins, CO, 80535, USA. Consistency in plant community response to grazing and protection: patch, site, and landscape scales.

Only a few of the hundreds of 'fence-line' grazed-ungrazed studies in the literature utilize a well-replicated design, and their conclusions suggest a high degree of inconsistency in plant response from site-to-site. We examined long-term grazed and protected shortgrass steppe at seven paired sites up to 10 km apart in relation to soil texture, landscape position, and utilization by herbivores. Within-site variability in soil texture was as great as that between sites, and the small-scale patch-to-patch variability explained plant response better than variability in means from site to site. Greater plant diversity in patches of coarse soil in ungrazed treatments was not evident in grazed treatments; grazing tended to smooth small-scale environmental variability. Very few grazed-ungrazed comparisons were consistent from site to site, and the inconsistencies could not be explained by differences in attributes between sites or distance between sites. Similarity of grazed versus ungrazed communities at a particular site were often as great as that for one-half of an exclosure compared to the other half. Patch-to-patch variability in soil and utilization may be as important as site-to-site variability in determining grazing impacts.

MILLER, DEBORAH L., STEVE ARCHER AND STEPHEN F. ZITZER. Texas A&M University, College Station, TX 77843-2126 USA. Radial growth of an invasive arborescent (*Prosopis glandulosa*) in relation to annual rainfall, soils, topography and competition.

Although abundance of *Prosopis glandulosa* has increased in grasslands and savannas throughout the southwestern USA in recent history, little is known of the rates and dynamics of its stand development. We have monitored radial growth of *Prosopis* in contrasting landscape elements along 1-3% slopes in a savanna parkland in southern Texas for 5 y using dendrometer bands. Plants growing on upland soils with an argillic (B_t) horizon had the lowest annual growth rates (max =.58 cm/y) and were least responsive to variations in annual rainfall. Highest annual growth rates occurred among plants in lowland, intermittent drainages (max = 1.2 cm/y) and among upland plants growing where the B_t was absent (coarse-textured subsurface soils) (max =.75 cm/y). Plants in each of these habitats were highly responsive to rainfall (5-9x increase in radial expansion in wet vs dry years), but their growth rates varied significantly between replicated landscapes. Removal of understory shrubs whose ingress and/or establishment is facilitated by upland *Prosopis* plants elicited a 4-6 fold increase in its annual radial growth (max=2.01 cm/y). It thus appears that understory shrubs are significant competitors for soil resources with *Prosopis* plants. The magnitude of response of *Prosopis* to understory removal suggests that competition may be more important than soil type or topographic location in regulating *Prosopis* growth at this site. Implications for successional processes and stand dynamics will be discussed.

MILLER, PATSY M., DANIELA ROTH, and BOONE KAUFFMAN. Oregon State University, Corvallis, OR 97331, USA. Effects of slash-and-burn agriculture on seed banks, sprouts, and seedlings in a Mexican, tropical dry forest.

A high consumption burn in a slashed, tropical dry forest during May, 1993, reduced seed germination from 965 $\pm$ 81 seeds m^2 from pre-burned soils to 67 $\pm$ 24 seeds m^2 from post-burn soils (n = 72). Germination was greatest 8 to 10 days after watering began, no germination occurred after day 42. At least 38 species (dicots and monocots) germinated from pre-burn soils; only dicots germinated from post-burn soils. Four months after the burn, the average woody sprout originating from buried buds was significantly taller, had a larger crown area, more stems, and larger diameter stems than did the average seedling ($P < 0.01$, n = 99). Of the 55 species identified, 35 were present only as sprouts, 12 present only as seedlings, and 8 present as both sprouts and seedlings. Survival and growth of sprouts and seedlings with competition from planted corn and introduced C_4 grasses, cattle grazing, and seasonal drought was measured in April, 1994. Seed pools were estimated before and after a second burn in May, 1994. After slashing and burning, tropical dry forest regeneration appears to be primarily by sprouting. However, repeated burning greatly reduced the seed bank and sprout and seedling survival.

MILLER, RICHARD E. and LAURA F. HUENNEKE. New Mexico State University, Las Cruces, NM 88003, USA. Demographic variation in creosote bush.

In the recent history of the southwestern United States, large areas of grassland have been invaded by creosote bush (Larrea tridentata). However, the demographic characteristics of creosote bush are usually considered to be those of a stress tolerant shrub. We suggest that under certain conditions creosote bush has weedier characteristics. A study was undertaken to document demographic variation in a population of creosote bush that included areas dominated by creosote bush and also ecotonal areas where the shrubland contacted grasslands. Fifty plants in 40 randomly selected plots were censused (N = 2000). Creosote bushes growing in the ecotonal areas were larger in size, produced more fruits, and had canopies in better condition (less canopy mortality). However, demographic behavior was more highly correlated with creosote bush density, suggesting that much of the observed variation was largely attributable to density-dependent population regulation.

MILLER-WEEKS, M. Forest Health Protection, USDA Forest Service, Durham, NH, 03824. USA. Damage agents associated with visual symptoms on spruce and fir in the eastern United States.

Surveys to define crown symptoms and determine the trend in tree condition of red spruce, balsam fir, and Fraser fir were conducted in the eastern United States in the late 1980s. The surveys assessed crown symptoms and also identified symptoms which could be attributed to known damage agents. In the Northeast the most notable abiotic factor was chronic weather damage, causing branch dieback, mortality, and breakage. Winter injury, browning of the recent year's needles, was also prevalent in some years. Major biotic factors affecting stems and roots included bark beetles and root and stem rots. Damage to the branches was caused by various adelgids, eastern dwarf mistletoe, and cytospora canker. On the foliage, needlecast and rust diseases were noted, along with various defoliating insects and needle miners. The most significant factors noted in the Southeast were the effects of severe ice storms and the impact from the balsam woolly adelgid on Fraser fir.

MILLIKIN, CATHERINE and CAROLINE BLEDSOE. University of California, Davis CA 95616-8627, USA. Effects of a Mediterranean climate on root dynamics and soil water potential in deciduous blue oak woodland in Northern California.

Cool, wet winters and hot dry summers characterize Mediterranean climates. Above-ground growth occurs in spring, when optimal moisture and temperature conditions coincide, but little is known about timing of below-ground activity. Root growth and distribution of oak (deciduous blue oak, Quercus douglasii) and various annual grasses were studied in an oak woodland at the UC Sierra Foothill Field Station. Using a mini-rhizotron camera system and permanently installed access tubes, root activity was video-recorded and root density measured at 25, 50 and 75 cm. Spatial variability in root density was high, ranging from 0.5 to 11 roots/cm^2 and was not correlated with aspect or soil moisture. When root density was measured at 25, 50 and 75 cm, most of the roots were observed at 25 cm (59%), less at 50 cm (37%), and 5% at 75 cm. Seasonally, root density decreased 40% (from 4.7 roots/cm^2 in June 1993 to 2.9 in January 1994). Soil water potential, measured at similar soil depths, also decreased from June to January, as the soils dried out. In June, soil water potential was surprisingly moist lower in the soil profile (75 cm and deeper, - 0.1 M Pa), suggesting that deeper rooted species, such as the oaks, may be able to take up water during summers, when above-ground activities are minimal.

MILNE, BRUCE T. University of New Mexico, Albuquerque, NM 87131, USA.
The necessity for sampling at multiple scales.

Adequate characterization of nature is rarely achieved by sampling at a single temporal or spatial scale because measures such as organismal density are controlled by many environmental and biotic factors, each of which may operate over a finite range of scales. For instance, density of a small monocarpic perennial, *Lesquerella fendleri*, in the Sevilleta LTER site in New Mexico, USA is affected broadly by soil moisture conditions and locally by its association with the shrub *Larrea tridentata*. Autocorrelation analysis, in which plant density was assessed at multiple scales, was used to ensure independent sample units in a demographic study of *L. fendleri*. In a study of piñon-juniper woodland ecotones, tree density was purposefully assessed at multiple scales to estimate the value of a critical tree density used in a test of the theory of spatial phase transitions. Use of the theory to detect locations that are potentially sensitive to climate change may be restricted to a particular range of scales due to the interaction between local biotically mediated responses to water availability versus broad ranging topographic and latitudinal controls. Thus, research strategies can be devised to delineate the conditions under which a particular experimental design, or theory, may yield accurate inferences, or predictions, respectively.

MITCHELL[1], J.S., RICHARD W. KNAPTON[2], and ROBERT C. BAILEY[1]. [1]Department of Zoology, The University of Western Ontario, London, ONT., CANADA. N6A 5B7. [2]Long Point Bird Observatory, Box 160, Port Rowan, ONT., CANADA. Impact of waterfowl and fish predation on zebra and quagga mussel populations at Nanticoke, Lake Erie..

From fall 1992 to spring 1994 we used exclosures to examine the impact of waterfowl and fish predation on populations of Dreissena polymorpha, the zebra mussel, and Dreissena sp., the quagga mussel (of uncertain phylogeny) at Nanticoke, Lake Erie. Heated water discharges from a generating station at Nanticoke result in a plume of warmer water which is attractive to both staging and overwintering ducks. In years when there is extensive ice-cover along Lake Erie, overwintering ducks are restricted to this warm-water plume. The plume is also attractive to fish. Exclosure cages were placed both inside and outside the warm water plume. We used SCUBA collected mussels from rocks under and adjacent to exclosure cages in May, October, and December, 1993, and in May 1994. From each collection, the density, size distribution, species composition and total biomass of mussels present will be estimated to determine the impact of predators on the mussel population.

MITCHELL, ROBERT and MARY MILLER. Jones Ecological Research Center, Newton, Georgia 31770 and Department of Agronomy, Auburn University, Al. 36849. Shade and nutrient addition affects on wiregrass growth and demography.

Wiregrass (*Aristida stricta* Michx.) is a dominant component of the understory vegetation in longleaf pine savannas throughout much of the southeastern Coastal Plain. It appears to play a pivitol role in providing fuels to maintaining a frequent fire regime essential for sustaining these savvannas. The once common longleaf pine/wiregrass community is now scarce due to landuse changes across the landscape. Understanding the ecology of this species is critical to managing remaining stands properly and restoring former stands. To better understand the response of wiregrasss to resource availability we investigated the affects of shade and nutrient additions on the growth, reproduction, and demography. The area was burned in mid-July, and two weeks latter approximately 600 tillers of wiregrass

emerged. Fertilization initially increased tiller area by 12% while shading decreased tiller area by a similar magnitude. However, a month after the burn, shaded tillers averaged 30% more area than those in the open while no fertility response was observed. These trends were maintained through time. Demographic analysis of vegetative and reproductive development of wiregrass as affected by shading and nutrient additions will be discussed.

MITSCH, WILLIAM J. and XINYUAN WU. The Ohio State University, Columbus, OH 43210, USA. Constructing experimental wetlands on a major university campus—research and education potential.

The Olentangy River Wetland Research Park, located on a 10-ha site owned by Ohio State University in Columbus, is being developed to investigate the role of riparian wetlands in the landscape, to serve as a laboratory for wetland research, and serve as an aid to higher and public education on wetlands. Two 1.0-ha experimental marshes have been completed in early 1994 with pumps, piping and electrical supply to bring water from the river to the floodplain wetlands. The water will then be allowed to flow by gravity back to the Olentangy River through a swale and constructed stream system. One basin is being planted by introducing rootstock and the other by natural recruitment to investigate the relative importance of the two processes. Site hydrology includes significant groundwater-surface water interaction; groundwater flow shows seasonal patterns. Before-construction vegetation, water quality, soil, and fauna data provide a background for assessing functional changes to the landscape when the wetlands are introduced. Future plans call for experimental mesocosms, a public observation structure, and a wetland research building.

MIYANISHI, K. and A.M. BOYONOSKI. University of Guelph, Guelph, ON, N1G 2W1, CANADA. First year seedling dynamics of Lupinus perennis L. in a southern Ontario oak savanna.

The purpose of this study was to investigate the effect of date of emergence on first year seedling survivorship in the herbaceous perennial, Lupinus perennis L. Fourteen cohorts totalling 1126 seedlings were identified by date on which cotyledons were first observed. Seedlings were monitored Apr 9-Oct 30, 1990 and in May 1991. Survivorship was calculated for 4 cohorts ($145 > n > 392$) emerging Apr 9-May 2 using the life-table method and for 4 cohorts ($18 > n > 31$) emerging May 9-Jun 6 using the Kaplan-Meier Product Limit method. The last 6 cohorts emerging Jun 27-Sep 17 were too small for analysis. All 8 cohorts followed negative exponential survivorship functions, indicating no age-dependent hazard. The slopes (hazard rates) ranged from 0.006 to 0.01 and were not related to date of emergence. Fluctuations in hazard around these values for all cohorts were synchronous and correlated with a drought index. Date of emergence had no effect on rate of overwinter survival.

MLADENOFF, DAVID J.[1], GEORGE E. HOST [1], and THOMAS R. CROW[2]. [1]Natural Resources Research Institute, University of Minnesota, Duluth, MN 55811, and [2]USFS North Central Experiment Station, Forestry Sciences Lab, Rhinelander, WI 54501. LANDIS, A spatially explicit forest landscape succession model incorporating fire and windthrow disturbance.

LANDIS is a stochastic, spatially explicit model of forest landscape disturbance and succession for the northern Lake States. The model is raster-based and programmed in C++ using object-oriented data structures. To simulate Lake States forest dynamics, LANDIS contains interacting windthrow and fire disturbance regimes which we believe have not previously been modeled. Fire is a bottom-up disturbance in forests while windthrow is top-down, and susceptibility varies with tree age and species. We explored the dynamics of the model in simulating forest succession by varying windthrow and fire disturbances. Moderate windthrow has a greater affect on later fires than moderate fires do on windthrow. Once an area becomes dominated by a shade tolerant species (sugar maple), the predominant disturbance type (windthrow) changes age class but not species composition, since the understory becomes dominated by maple as well as the canopy. Severe fire following windthrow returns succession to aspen. Without disturbance landscapes become dominated by shade tolerant species 150 years sooner (200 vs. 350 yrs).

MOEGENBURG, SUSAN M. University of Florida, Gainesville, Florida, 32611. Sabal palmetto seed size: Causes of variation, choices of predators, and consequences for seedlings.

Intraspecific variation in seed size likely results from selection for large seeds which produce more vigorous seedlings, and selection for small seeds which may facilitate dispersal and avoid predation. On the proximate level, seed sizes produced by individual plants are determined by plant size and environmental variability. Sabal palmetto trees produce a wide size range of seeds, many of which are eaten by the bruchid beetle Caryobruchus gleditsiae. I tested four hypotheses regarding S. palmetto seed size: 1) seed size and tree leaf number are related; 2) seed size influences seedling vigor; 3) adult beetle size is a function of host seed size; and 4) adult beetles should show a preference to oviposit on large seeds. I found that seed size varies more among trees than within them, and is positively related to the number of leaves on palms. Larger seeds produce seedlings with greater leaf length, area, and mass, and greater root mass. Larger palm seeds are selected more often than small seeds by ovipositing beetles, and produce larger beetle offspring. As size-selective predators, beetles potentially influence not only the quantity but also the quality of seeds available for recruitment into palm populations.

MOLANO-FLORES, BRENDA, STEPHEN D. HENDRIX, and ROBERT W. CRUDEN. Department of Biological Sciences, University of Iowa, Iowa City, IA, 52242, USA. Effect of population size and density on reproduction in two prairie species

Population size and density can be limiting factors on the successful reproduction of plant species. In this study, the effect of population size and density on the reproductive characteristics of two congeneric prairie species, Anemone canadensis and A. cylindrica, were studied in Dickinson County, Iowa. For A. canadensis fruit set per stem (proportion of ovaries setting fruit) was significantly and positively related to population size. Higher fruit set in large populations of A. canadensis may be due to greater pollinator activity as indicated by greater pollen loads per stigma in large populations. The proportion of aborted fruits and undeveloped ovaries per stem was positively and significantly related to population density. In A. cylindrica, neither population and density was related to any reproductive characteristic measured because this species is self-pollinated.

MOLDENKE[1], ANDREW R., NANCY BAUMEISTER[1], BRUCE A. CALDWELL[1], ROBERT GRIFFITH[1], ELAINE R. INGHAM[1], MARK G. JOHNSON[2], PAUL T. RYGIEWICZ[3], DAVID T. TINGEY[3], and JAMES WERNZ[1]. [1]Oregon State University, Corvallis, OR, 97331 USA, [2]ManTech Envir. Technol. Inc., US EPA, [3]US Environmental Protection Agency, Corvallis, OR. 97333. Effects of CO_2 and climate change on forest trees: soil biology and enzymology.

Samples of Teracosm soils were analyzed shortly after initial setup to determine whether initial conditions were equivalent and matched expected values for local soils. Total and active fungal biomass, active bacterial biomass and protozoan numbers were reduced, with greatest decreases occurring in the A horizon. No effect was observed on total bacterial biomass, nematode or arthropod densities, but changes in nematode and arthropod species composition occurred. Significant differences in total density and species composition occurred between the enclosed Teracosms and the open controls. Arthropod and nematode community structure in the three altitudinal field sites had significantly diverged. No significant differences in activities of key soil enzymes in C- and N-cycling (acid phosphatase, protease, B-glucosidase, phenol oxidase and peroxidase) were found between initial samples relative to treatment, but all levels were significantly different relative to depth in soil profile. Activities were within ranges previously observed in forests of the Pacific Northwest.

MOLLES, MANUEL C., JR., CLIFFORD S. CRAWFORD, LISA M. ELLIS. University of New Mexico, Albuquerque, NM 87131, USA. Experimental flooding of a riparian forest along the Rio Grande: influences on populations and ecosystem processes.

Our treatment and reference study sites (3.1 ha) are at Bosque del Apache National Wildlife Refuge in mixed cottonwood (Populus fremontii) riparian forest, not flooded for 50 years. Study sites were monitored for two years before the first experimental flood. Timing of flooding matched peak flows in the 100-year hydrograph for the Rio Grande. Flooding raised groundwater levels 2 m, increased dissolved oxygen and dissolved organic carbon, but decreased ammonium concentrations in ground water. Flooding also increased cation exchange capacities of soil but decreased total phosphorus. Decomposition rates were higher at the flood site. Ground arthropod populations were reduced but small mammal populations were unaffected. We will asses responses to this long-term, large-scale experiment using randomized intervention analysis.

MOLOFSKY, JANE[1], RICHARD DURRETT[2], and SIMON LEVIN[1]. [1]Princeton University, Princeton, NJ, 08544, USA and [2]Cornell University, Ithaca, NY, 14853, USA. Frequency-dependence in a spatial context.

In sessile organisms like plants, interactions occur locally so that important ecological processes like frequency-dependence occur within local neighborhoods. We investigated how local frequency-dependent competition would influence whether two species would coexist using interacting particle system models. Individuals of the two species were randomly placed on a grid and the dynamics in the model developed from the application of local frequency-dependence rules. For four different frequency-dependent scenarios, the results indicated that over a broad parameter range the two species could coexist. Local measures of the correlation structure during invasion transients can serve as predictors of ultimate invasibility and coexistence.

MONZ, CHRISTOPHER A.[1], LISA A. JOHNSON [1,2], DAVID N. COLE [3] and DAVID R. SPILDIE [3]. [1] National Outdoor Leadership School, Lander, WY, 82520, USA, [2] University of Montana, Missoula, MT, 59807, USA, and [3]USFS AldoLeopold Research Institute, Missoula, MT. 59807. Vegetation response to trampling in five native plant communities in the Wind River Range, Wyoming, USA.

The response of five native vegetation types to two years of applied trampling was investigated. Sites were located between an elevation of 2800 and 3200m in the Wind River Range in central Wyoming, USA. Plant communities included both woody and herbaceous forest understories, a subalpine meadow dominated by graminoids, an alpine grass community and an alpine fellfield. Experimental plots (0.5m x

1.5m) were subjected to trampling mid growing season at the rate of 25, 75, 200 and 500 passes, with the exception of the alpine fellfield and the alpine grass community that, instead of 25 passes, received 800 and 1000 passes respectively. Alpine communities exhibited the least decrease in plant cover while both forest understory communities showed significant decreases with as little as 25 passes. Intense trampling (500 passes) resulted in nearly 100% vegetation loss in some forest understory plots. Soil penetration resistance increased significantly with 200 passes in both forest understory sites, but did not respond to trampling at the other sites. Species richness tended to decrease in all plots with increasing trampling intensity. Canonical discriminant analysis revealed significant changes in plant community structure in all vegetation types, with low levels of trampling (75-200 passes) affecting forest understory communities and higher levels affecting the subalpine meadow and alpine communities.

MOORE, JOHN C. University of Northern Colorado, Greeley, CO, 80639, USA Aboveground responses to disturbance of soil ecosystems.

Studies of disturbances on terrestrial ecosystems traditionally stress responses aboveground and ignore those within soil. Soils are often viewed as reserviors of plant limiting nutrients and not as a habitat that supports numerous species. Yet, it is the interactions among soil organisms and the linkages they form with plants that regulates either directly through symbiosis or indirectly via decomposition the availability of nutrients. Disturbances of different ecosystems (e.g., mining in a sagebrush steppe, agriculture worldwide, and tourist traffic in caves) illustrate the importance of soil biota to aboveground processes and have generated the following patterns. Comparisons of undisturbed and disturbed soils reveal changes in functional diversity, the pattern of material flow through the system, and in the spatial and temporal compartmentalization of biota and processes. These changes in the soil community structure are accompanied by changes in nutrient retention, decomposition rates and the structure of the aboveground community. Given the diversity of organisms and the complexity of interactions belowground and the high degree of coupling between the above and belowground communities it seems imparative that studies of disturbances ask how disturbance affects both the belowground and the aboveground communities.

MOORE, MONICA S.[1], B.G. LOCKABY[1], J.A. STANTURF[2], AND E. GUERTAL[1]. [1]Auburn University, Alabama, 36849, USA, [2]US Forest Service, Stoneville, MS, 38776, USA. Spatial relationships among hydrology, nutrient availability and vegetation productivity on a forested floodplain in central Georgia.

Relationships between spatial patterns of vegetation productivity, hydrology, and nutrient availability are under investigation on the Flint river floodplain in central Georgia. Study objectives include using kriging to describe and compare spatial relationships among vegetation productivity, hydroperiod, and nutrient availability. A system of grid points was established along an ecotone gradient (mesic to hydric) on the Flint River floodplain (24 point grid at 30 meter intervals). Soils range from a mesic, well drained mineral soil to a poorly drained soil with high organic content, while the vegetative communities on these soils are Quercus/Liquidambar and Nyssa/Magnolia, respectively. Littertraps, water wells, and ion exchange resins were installed at each point to estimate productivity (using litterfall as an index), hydrologic regime, and available NH_4 and PO_4, respectively. Litter and resin bags will be collected monthly and water table depths estimated biweekly. Semivariograms will be used to develop kriged estimates for each variable in order to estimate spatial patterns. Mean litterfall results for mesic sites and hydric sites were 122.92 g/m and 29.7 g/m, respectively, for late fall. Water tables depths ranged from 8.89 cm below ground on the mesic sites to 1.93 cm above ground on the hydric sites.

MOPPER, SUSAN[1], MICHAEL BECK[2], DANIEL SIMBERLOFF[2], and PETER STILING[3]. [1]University of Southwestern Louisiana, Lafayette, LA, 70504, USA, [2]Florida State University, Tallahassee, FL, 32306, USA, and [3]University of South Florida, Tampa, FL, 33620, USA. Local adaptation and agents of selection in a leafmining insect.

The deme formation hypothesis predicts that short-lived insects inhabiting long-lived plants can adapt to the unique traits of individual hosts. Such local adaptation should create a mosaic population of genetically distinct insect demes. We tested this prediction by transferring eggs of a mobile leafmining insect, Stilbosis quadricustatella to natal and novel oak trees. Larvae suffered significantly less host-plant-mediated mortality on natal than on novel trees, indicative of local adaptation. However, larvae also suffered significantly more natural-enemy mediated mortality on natal trees. Consequently, rates of successful mine completion did not differ on natal and novel trees. These results suggest that host plants and natural enemies may represent opposing forces of selection. In some insect systems there may be little selective advantage to adapting to plant traits.

MORAN, MATTHEW D. and L.E. HURD. University of Delaware, Newark, DE, 19716, USA and Washington and Lee University, Lexington, VA, 24450, USA. Short term behavioral and numerical response of an arthropod assemblage to experimentally elevated predator densities.

We investigated the short term response of an arthropod assemblage to increased generalist predator densities by experimentally introducing mantids (Tenodera sinensis) to field plots in a replicated, controlled experiment. Carnivorous arthropods were significantly reduced by mantids, while herbivores showed no detectable response. Cursorial spiders emigrated from treatment plots in greater numbers than from control plots. Initially, this emigration comprised only small spiders that were potential prey for mantids, while larger spiders began to leave later in the study, possibly as a numerical response to reduction in small spider abundance. Predator avoidance behavior must be considered together with intraguild predation and competition when interpreting the outcome of predator manipulations. Since the predator emigration occurred rapidly, short term experiments may be more valuable in detecting this effect.

MORAN-PALMA, P., and A. A. SNOW. Ohio State University, Columbus, OH, 43210. Effects of interplant distance on mating success of Lakeside daisy (Hymenoxis herbacea).

We investigated large and fine scale effects of distance on compatibility and seed set in a rare, self-incompatible perennial, Lakeside daisy (Hymenoxis herbacea = H. acaulis var. glabra). Plants from mapped locations were collected at the Marblehead Peninsula, Ohio, and transplanted to a greenhouse where they were hand-pollinated. For large scale analysis, 110 crosses were classified in three categories: near crosses (0.75-6.70 m), far crosses (17-72 m), and very far crosses (>300 m). There was no significant effect of distance on compatibility or seed set in these crosses. For fine scale analysis, 44 crosses were used and interplant distances ranged from 0.75 m to 10 m. There was no significant effect of compatibility at this scale, but interplant distance explained 13.6% of the variance of the ratio seed/florets, suggesting that local genetic structure may result in biparental inbreeding. For all distance classes, > 80 % of the crosses were compatible, indicating that lack of compatible mates is not likely to limit seed production in this population.

MORANZ, RAYMOND and LINCOLN P. BROWER. University of Florida, Gainesville, FL, 32611, USA. Host plant-mediated variability in the cardenolide anti-predator defenses of the queen butterfly (Danaus gilippus).

Many herbivorous insects are able to sequester plant secondary compounds for use as anti-predator defenses. For us to understand the effectiveness of these defenses in deterring predation, we must first learn if variation in host plant chemistry causes variation of insect chemical composition within and among populations. To test our prediction that butterfly chemical defenses in a given area are dependent on the host species present, we sampled D. gilippus adults and their milkweed host plants at numerous sites in northern Florida, and analyzed cardenolide composition of both butterflies and plants using thin-layer chromatography and spectrophotometry. We found that at least eight species of milkweeds in the region serve as host plants, and that these species differ greatly in cardenolide composition. Preliminary data suggest that plant chemical variability was reflected in the cardenolide composition of the adult butterflies. While some individuals of D. gilippus are well defended against predators, individuals from populations only a few kilometers away may be more vulnerable due to their utilization of hosts that possess lower concentrations of cardenolides.

MORON-RIOS, A. ; VICTOR JARAMILLO and RODOLFO DIRZO. Centro de Ecología,UNAM A.P. 70-275 C.P. 04510 México,D.F. MEXICO. Effects of simulated defoliation on aboveground biomass and root nitrogen concentration of two perennial bunchgrasses, in a pine forest in México.

We conducted a field experiment to asses the effects of periodic defoliation on two native bunchgrasses, Muhlenbergia quadridentata and Festuca tolucensis. Treatments were three levels of defoliation: no-defoliation, monthly defoliation removing 30 % (low level) and 70 % (high level) of plant height and three harvest dates in a full factorial design with 7 replicates per treatment. Defoliation treatments did not differ significantly between them (P > 0.25). Both species compensated the loss of aboveground biomass. Regrowth of both species was not affected by defoliation. On average, Muhlenbergia and Festuca decreased their aboveground biomass 36.2 % and 33.2 % respectively with defoliation, but such reductions were not statistically significant (P > 0.05). Root nitrogen concentration was not affected by defoliation. Muhlenbergia had a mean N concentration of 0.33 % and Festuca of 0.39 %.

MORRISON, JANET, A. State University of New York at Stony Brook, Stony Brook, NY 11794. USA. An indirect effect of interspecific plant competition on a plant-pathogen interaction.

In a field experiment I varied the ecological conditions under which I inoculated individuals of the host plant Juncus dichotomous with the smut fungus Cintractia junci. One of these ecological conditions was the intensity of interspecific competition experienced by the host plants. In both years of the experiment, competition directly affected host plants by reducing their size. In the first year, competition intensity did not significantly influence whether or not host plants became infected with the smut fungus. In the second year, however, host plants experiencing more interspecific competition were less likely to be infected than when competition was less. Interspecific plant competition not only has a direct negative effect on host plant growth, it also has an indirect positive effect on host plants by decreasing their probability of becoming infected by a fungal pathogen. Thus it is important to examine the wider biotic environmental context of plant-pathogen interactions; they can be influenced by other interactions in the community.

MOTTETHADKA, VENKATA M. and LINDA, L. WALLACE, University of Oklahoma, Norman, OK,73019, USA. Effects of clipping, photosynthetic pathway and soil sterilization on compensation and VAM colonization in grasses.

Four C_4 and two C_3 grasses were grown in the field in sterile and nonsterile soils to examine the effects of clipping on plant morphology, biomass and VAM colonization. In addition, the influence of nematodes and soil borne pathogenic fungi were examined. There was reduction in the percent root length colonization by VAM in the non sterile soil but it was higher in the clipped plants of both sterile and non sterile soils in relation to unclipped plants. There was compensatory

response to clipping in few species in the non sterile soil. Percent root length colonized by VAM was negatively correlated with nematodes and pathogenic fungi in the non sterile soil.

MOTZKIN, GLENN, ARTHUR ALLEN, JONATHAN HARROD, and DAVID R. FOSTER. Harvard Forest, Petersham, MA, 03166, USA. Vegetation dynamics and disturbance history of a New England pitch pine-scrub oak community.

Despite widespread conservation interest in sandplain communities throughout the northeastern United States, considerable uncertainty exists with respect to their origin and long-term history. Our investigation of a ~800 ha sandplain in central MA suggests that current vegetation and species distribution patterns are strongly related to historical land-use practices and, to a lesser extent, fire history. Age structure and GIS analyses document the persistent influence of historical human activities on subsequent vegetation and ecosystem characteristics for 50 to >100 years.

MOU, PU, R. H. JONES and R. J. MITCHELL. School of Forestry, Auburn University, Auburn, AL, 36849, USA. Root distribution of two tree species under heterogeneous nutrient environments.

In order to investigate how plant species use patchy soil environments, seedlings of sweetgum and loblolly pine were grown in sand with heterogeneously or evenly arranged nutrients in both shaded and open conditions for one growing season. Significant differences in root development were observed between the two nutrient arrangements and the two species. In the heterogeneous nutrient treatment, roots concentrated in the enriched soil. Loblolly pine was less sensitive to the spatial differences in nutrient availability than sweetgum and developed mycorrhizal roots in infertile soil. Significant species differences in branch angle and inter-branch length were also observed indicating a fundamental difference in rooting habit between the two species. However, the above ground development was unaffected by nutrient treatment, possibly due to sufficient supply. Shaded seedlings produced less total mass, and disproportionally less below-ground mass. The results demonstrated: 1) root development strongly reacts to its nutrient environment; 2) species differ in root plasticity, and 3) species differences in rooting habit were consistent across a variety of soil environments.

MOWRY, CHRISTOPHER B. and DONALD J. SHURE. Emory University, Atlanta, GA, 30322 USA. Factors influencing dietary choices of Tana River red colobus monkeys(*Colobus badius rufomitratus*).

A phytochemical survey of tree species growing within riverine forests of the Tana River in Kenya, Africa was conducted to better understand the feeding ecology of an endangered resident primate, *Colobus badius rufomitratus*. Young leaves, which make up a large percentage of this animals' diet, were significantly higher in nitrogen and lower in acid detergent fiber content than more abundant mature leaves. Phenolic chemistry had little inhibitory effect on *C. b. rufomitratus* feeding. Once an acceptable threshold of nitrogen and fiber is reached, choice among leaf species by *C. b. rufomitratus* appears to be largely influenced by leaf availability. When mature leaves were eaten, those species high in nitrogen and low in fiber content were selected, including two species of legumes. A significantly higher nitrogen content was found for the mature leaves of all leguminous versus non-leguminous tree species. Consequently, the availability of mature leaves of leguminous species during periods of preferred food scarcity may prove critical to groups of Tana River red colobus monkeys.

MUIR, ANGELA. Carleton University, Ottawa, ONTARIO, K1S 5B6, CANADA. Resource allocation to sexual and asexual reproduction in the perennial understorey herb Asarum canadense.

Asarum canadense is a common herbaceous perennial that reproduces both sexually and asexually. There is much support for the theory that energy allocated to sexual reproduction takes away from asexual reproduction and that energy can be shuttled from one form to another. However, in a study of 60 triplets of wild ginger consisting of a control plant, a plant with the flower bud removed, a plant with the vegetative bud removed, no significant difference in physical growth or storage occurred between treatments over the growing season. Thus, energy allocation to sexual reproduction may not limit vegetative propagation in Asarum canadense.

MULDER, CHRISTA P.H., and R.W. RUESS. University of Alaska, Fairbanks, AK 99775, USA. Effects of geese grazing on arrowgrass in a subarctic salt marsh.

We studied the effect of goose herbivory on arrowgrass (*Triglochin palustris*), a highly preferred forage species, on the Yukon-Kuskokwim Delta (SW Alaska). In one experiment, exclosed plots were compared with unexclosed (control) plots, and with unexclosed plots with feces removed. The second experiment consisted of a full-factorial design with three factors: 1) three levels of fertilization with goose feces; 2) two levels of clipping of arrowgrass; and 3) two levels of clipping of competitors. Plants in exclosed plots were taller, had a greater total biomass, greater allocation to leaves and roots, and greater mean and total leaf lengths than plants in unexclosed plots. Plants in plots with feces removed had greater allocation to bulbs and longer stolons than other plants. Fertilization and clipping of arrowgrass had a negative effect on arrowgrass biomass, while clipping competitors had a positive effect. When plants were fertilized and neighbours clipped, plant biomass increased and

allocation to leaves and roots decreased, but when plants were fertilized and neighbours not clipped, the opposite occurred. Results suggest that goose herbivory has a primarily negative effect on arrowgrass, but that this is highly dependent on goose selectivity for this species.

MULLER, MICHAEL R. and DAVID J. CURRIE. Ottawa-Carleton Institute of Biology, University of Ottawa, Ottawa, ON, K1N 6N5, CANADA. Relationships between avian species richness and various environmental and anthropogenic variables over southern Ontario.

Species richness is an important descriptor of ecosystems and, as a component of biodiversity, may be useful for conservation planning. While global and local patterns of richness have been described, with moderate success, by climatic and habitat parameters respectively, regional scale predictors are scarce. Using satellite imagery, a GIS and a quadrat resolution of of 10km^2, we tested hypotheses relating the spatial variation in avian species richness over southern Ontario to characteristics of the environment. Of the climatic factors examined, mean annual temperature explained the most of the varience in richness (35%). Quadrats containing protected areas (e.g. parks and conservation areas) had significantly more species than those without, yet species richness was not related to the amount of the park area in a quadrat. A NOAA land cover image, human population and measures of building density are being related to avian species richness.

MUNGER, JAMES C., MARTHA-ANN CAUGHLIN, AND STEVEN KNICK. Boise State University, Boise, ID, 83725, USA. Density and thermal regime of harvester ant colonies: effects of sagebrush.

Our previous work showed that colonies of Pogonomyrmex salinus are found in open microhabitats where soil temperatures are sufficient for brood production. Can this result be extrapolated to a macrohabitat scale, i.e., does vegetation determine colony density? On 82 400m transects we measured colony density and vegetation, as well as soil characteristics and mating site proximity. Shrub density was negatively correlated with colony density, but explained only 6% of the variation in colony density. Even less variation was explained by soil and mating site, indicating that other factors must be important. Workers are sensitive to the thermal regime of the colony and will protect it. By excavating colonies we found that workers move brood in a daily cycle over a depth range of up to ca. 40 cm to utilize appropriate temperatures. Fifteen of 26 artificially shaded colonies moved to a new location; none of 28 unshaded controls moved. Sagebrush seedlings we planted near colonies were quickly defoliated by workers.

MURPHY, A.L., B.G. LOCKABY, AND D.A. BROWN. Auburn University, AL, 36849, USA. Influences of flooding on decomposition dynamics in a forested floodplain of a blackwater river in southeast Georgia.

The influence of flooding regimes and floodwater nutrient status on litter decomposition processes and soil immobilization in a forested floodplain of a blackwater river have been investigated. In this two year study, field microcosms were installed permitting realistic simulation of flooding. Litter mass and N and P dynamics were measured over a two year period. Mass loss was slowest in the non-flooded treatment throughout the two year study. Elevated P stimulated mass loss more than the other flooded treatments. N and P immobilization-mineralization patterns in litter were strongly influenced by flooding regime. The flooded treatments exhibited a P mineralization pulse after each cessation of flooding. Soil N and P immobilization were measured once at six months. Elevated N and P inflow enhanced N and P immobilization in the soil. Flooding without elevated nutrient inflow also enhanced N immobilization. Flooding without nutrient inflow elevation depressed soil P immobilization.

MURRAY, ROBERT E., YVETTE S. FEIG AND JAMES M. TIEDJE. Appalachian State University, Boone, NC, 28608, USA and Michigan State University, East Lansing, MI, 48824, USA. Specific activity of denitrifying bacteria in artificial denitrification activity centers.

Denitrification activity centers were established in 6 soil cores by placing a small section of dried plant leaf, which had been saturated with a solution of glucose and nitrate, in the lower portion of each core. Denitrifying enzyme activity in activity centers averaged 3 fold greater than in the bulk soil. Denitrifier biomass (most-probable-number counts) was between 1 and 4 orders of magnitude greater in activity centers. Denitrifier specific activity (the maximum potential rate of nitrogen utilization per cell) was lower in activity centers and more similar to specific activity values reported for pure cultures of denitrifying bacteria added to soil. Estimates of denitrifier activity and biomass carried out on a homogeneous subsample derived from a soil core containing a denitrification activity center will not adequately reflect the biomass or the activity of denitrifying bacteria within the activity center.

MURTHY, RAMESH and PHILLIP.M.DOUGHERTY. North Carolina State University, Raleigh, NC, 27695, USA. Effects of Longterm Elevated Carbon dioxide concentration, Nitrogen and Water availability on the Physiology of loblolly pine (Pinus taeda) branches.

The objective of this study was to determine to what extent elevated CO_2 alters carbon fixation of loblolly pine when water and nutrition are limiting. Three branches per tree were enclosed in polytene chambers and exposed to ambient, 1.5*ambient and 2*ambient levels of CO_2 respectively for a 12 month period. A 2*2 factorial of nutrition and water was employed. Monthly instantaneous measures of maximum photosynthesis(amax), stomatal conductance and other

physiological parameters were taken on needles. Branches exposed to 2*ambient CO_2 in the fertilized and irrigated plots showed significantly higher amax values compared to the other treatment level combinations and showed no signs of acclimation. Results suggest that response to elevated CO_2 levels depends greatly on whether nutrition and water are limiting.

MUSICK[1], H. BRAD, GERALD G. SCHABER[2], AND CAROL S. BREED[2]. [1]University of New Mexico, Albuquerque NM 87131, USA, and [2]U. S. Geological Survey, Flagstaff AZ 86001 USA. Use of AIRSAR to identify woody shrub invasion and other indicators of desertification in the Jornada LTER.

Polarimetric Airborne Synthetic Aperture Radar (AIRSAR) signatures acquired of the Jornada Long-Term Ecological Research (LTER) site in south-central New Mexico at C-band (6-cm wavelength), L-band (25-cm) and P-band (68-cm) were compared with ground observations of vegetation type and other land-surface characteristics. Each band appeared to be most responsive to plant structural components in a particular size class, which increased with wavelength. Cross-polarized L-band images were effective in detecting woody shrub cover. This type of vegetation is a key indicator of desertification, but is typically difficult to discriminate from desert grassland on the basis of spectral characteristics in the visible and infrared bands (as, for example, on Landsat or SPOT images). The surface roughness and volume-scattering characteristics of the shrubs versus that of the grassland produced a distinctive signature on AIRSAR images. Other indicators of desertification detectable by their unique signatures were (1) large coppice dunes resulting from severe wind erosion and (2) barren silty flats resulting from fluvial erosion.

MUTCH, LINDA S. Sequoia National Park, Three Rivers, CA, 93271, USA. Growth response patterns of giant sequoia to different levels of fire severity in Sequoia and Kings Canyon National Parks, California.

The radial growth response of giant sequoias (Sequoiadendron giganteum) to fire was investigated in prescribed burn areas in Sequoia and Kings Canyon National Parks. Increment cores were taken from sequoias in seven burn sites and four unburned control sites. I used mean ring-width indices to compare pre- and post-burn growth between burn and control and between four different fire severity levels. Changes in mean ring-width indices indicated that growth increased at all study sites for the post-burn periods relative to pre-burn periods. Favorable climate conditions in the early 1980s contributed to the growth increased observed at all these sites. Post-fire mean growth for four out of seven burn sites, however, was significantly higher than that on control sites for the same time periods. In general, lower severity fire resulted in lower magnitude growth increases than those observed after moderate to higher severity fire, perhaps due to less post-fire soil nutrient increase and less reduction in inter-tree competition. Fire severe enough to cause extensive foliage damage resulted in growth suppressions for one to several post-burn years. The correspondence of specific post-fire growth response patterns to different levels of fire severity on recent prescribed burns may allow estimation of pre-settlement fire severities from analysis of radial growth patterns associated with known fire scar dates.

MUZIKA, R.M. Northeast Forest Experiment Station, Morgantown, WV, 26505, USA. Defoliation and thinning effects on woody understory in Mid-Appalachian Forests.

In advance of gypsy moth defoliation, eight stands (10-12 ha each) were thinned with the objectives of reducing susceptibility and vulnerability. Four of these stands were primarily oak (*Quercus*) and four were mixed hardwoods, dominated by *Quercus*, *Carya*, and *Lirodendron*. Stands were thinned in 1989 and several were defoliated severely in 1991 and 1992. Understory vegetation was surveyed for three years following thinning. Regardless of defoliation severity and thinning, the mixed hardwood understory was more diverse than the oak understory. In the thinned and defoliated mixed hardwood stands, *Acer rubrum*, *Prunus serotina*, and *Liridendron tulipifera* dominated the woody regeneration. Woody regeneration on oak stands was almost exclusively *Acer rubrum*. In the mixed hardwood stands, defoliation alone increased species richness, but defoliation and thinning reduced the richness. After two years of heavy defoliation in the oak stands, species diversity dropped substantially, but species richness remained the same.

MYERS, CHRISTOPHER A. AND HAYS R. CUMMINS. School of Interdisciplinary Studies, Miami University, Oxford, OH, 45056, USA. Can Students Teach Themselves Science?

We present an unusual model of science education in which students create their own scientific community. With faculty guidance, students conduct their own research, write laboratories, consult tutors in a Peer Science Center, review the work of other student investigators, report results in a public Natural Systems Database, and lead classmates in research to explore ecological questions of common interest. This NSF-funded project advances discovery-oriented and constructivist approaches to undergraduate science education. Strategies for alleviating the significant problems that can occur with student-centered, hands-on research are discussed.

NADELHOFFER, K., G. MURRAY, A. GIBLIN, G. SHAVER, J. LAUNDRE, L. JOHNSON, A. STANLEY[1] and J. SCHIMEL[2]. [1]Marine Biological Laboratory, Woods Hole, MA, 02543 and [2]University of Alaska, Fairbanks, AK, 99775. Effects of chronic warming and nutrient additions on ecosystem respiration and methane fluxes along a tundra moisture gradient.

We measured ecosystem respiration (ER: or CO_2 flux), methane (CH_4) fluxes and net ecosystem production (NEP) near Toolik Lake, Alaska to compare effects of temperature, moisture and nutrients on tundra C balances. We measured fluxes using closed chambers in control, warmed and fertilized plots in wet, moist and dry tundra. ER rankings of tundra types differed between years. In 1992 ER was ~70 g C m^{-2} y^{-1} in wet and moist tundra and was 50% lower in dry tundra. In 1993 ER was >150 g C m^{-2} y^{-1} in moist tundra and ~55 g C m^{-2} y^{-1} in wet and dry tundra. CH_4 emissions ranged from 3.5 to 7 g C m^{-2} y^{-1} in wet and from 0.6 to 2.8 g C m^{-2} y^{-1} in moist tundra. Dry tundra consumed about 0.1 g CH_4-C m^{-2} y^{-1}. In wet tundra ER increased slightly with warming but dramatically with fertilization. Wet tundra NEP increased with fertilization but not with warming. CH_4 emissions from wet tundra increased with warming but decreased with fertilization. Warming and fertilization increased ER but neither treatment affected NEP in moist tundra. CH_4 emissions from moist tundra responded similarly but less dramatically to treatments than did wet tundra CH_4 fluxes. Warming did not affect ER or NEP in try tundra, but fertilization increased both processes. Consumption of CH_4 in dry tundra increased with warming but decreased with fertilization.

NAEEM, SHAHID, L. J. THOMPSON, SHARON P. LAWLER, JOHN H. LAWTON, and RICHARD M. WOODFIN. NERC Centre for Population Biology, Imperial College at Silwood Park, Ascot, Berks SL5-7PY, U. K. Does biodiversity matter? A test of the association between diversity and ecosystem functioning.

Theories disagree on how anthropogenic declines in biodiversity may affect global biogeochemical processes. We tested these theories by experimentally manipulating biodiversity among 14 microcosms, each modelling a terrestrial ecosystem. Six microcosms contained 31 species of plants and animals (high diversity), while 4 others contained 15 species (medium diversity) and 4 others contained 9 species (low diversity). Although species richness varied, all microcosms had 4 trophic levels, the same initial densities of organisms, and received identical environmental conditions for 206 days. We monitored 5 ecosystem functions; (1) community respiration, (2) productivity, (3) decomposition, and (4) nutrient and (5) water retention. Ecosystems of different diversities differed significantly in their biogeochemical performance. We discuss a possible mechanistic explanation for these differences and their implications for community, ecosystem, and conservation biology.

NAIDU, SHAWNA L. and EVAN H. DeLUCIA. University of Illinois, Urbana, IL, 61801, USA. Photoinhibition and acclimation of shade-developed saplings to late-season canopy gaps.

We hypothesized that acclimation of shade-developed saplings to late-season canopy gaps would depend partially on their ability to minimize the magnitude and duration of photoinhibition. After 8 wks of growth (3 wks after leaf expansion) in the forest understory, shade-developed *Acer saccharum* (sugar maple) and *Quercus rubra* (red oak) saplings were transferred to a gap. Photoinhibition was then monitored for 30 days using chlorophyll fluorescence analysis. Non-photochemical fluorescence quenching and minimum fluorescence increased (30%,45%) in transferred leaves of maple (oak changed little) upon exposure to the gap, indicating possible damage to light-harvesting pigments as well as possible down-regulation of photosynthesis in maple. Photoinhibitory damage to photosynthetic reaction centers was evident in both species as an immediate reduction in the ratio of variable-to-maximum fluorescence of dark-adapted leaves (F_v/F_m), which is proportional to the efficiency of Photosystem II. Damage was greater in magnitude and duration (max. decrease 20%, d 7; 50% recovery, d 17) for maple than oak (max. decrease, 17%, d 4; 50% recovery, d 14) and recovered to within 5% of controls by day 28 in both species. Results indicate shade-developed oak leaves are less susceptible to photoinhibitory damage and recover more quickly than maple, suggesting that oak may out-compete maple through increased carbon gain during the acclimation period upon exposure to a canopy gap.

NAKAMURA, ROBERT R. California State University, Los Angeles, CA 90032-8201, USA. Reproductive ecology of California poppy, Eschscholzia californica.

The relationship between floral traits and reproductive success was studied in interior populations of California poppy, Eschscholzia californica. The nectarless flowers were large (62.3 mg dry mass) and varied in corolla diameter (1.6 to 7.6 cm) and stamen number (16 to 32). At both study sites beetles in the genus Eschatocrepis were the main floral visitors. Beetles were observed eating pollen and remaining overnight inside flowers. Flower size and stamen number were not correlated with beetle abundance per flower. At one site insect herbivory in 1992 and mammalian herbivory in 1993 prevented almost all seed maturation. Seed production at the other site was not pollen limited. Pollen addition had no significant effect on seed number per fruit and total seed mass.

NAROG, M.G., R.C. WILSON and T.E. PAYSEN. USDA Forest Service, Pacific Southwest Research Station, Riverside CA 92507 and Cal State University, San Bernardino, CA 92415-0730, USA. Invertebrate community dynamics in a thinned and burned oak forest.

Invertebrate community dynamics were studied in a closed canopy canyon live oak (Quercus chrysolepsis Liebm.) forest on the San Bernardino National Forest in southern California. Invertebrates collected from pitfall traps varied among three treatments (control, thin, thin/burn). Thin/burn treatment populations decreased in absolute numbers of individuals collected and remained depressed 1 year after burning. But, species diversity in the thin/burn treatment recovered to pretreatment levels by this same period. Thinned-only plots "re-established" population numbers and species diversities similar to that of controls by 1 year after thinning. During the

study, fluctuations were observed in population numbers and in number of species collected in control plots. This demonstrates the importance of using controls for damping background level noise from population changes--especially when studies involve organisms sensitive to environmental fluctuations. Relative abundance and relative species diversity proved significant in revealing community level trends. Biodiversity indexes showed no significant loss of invertebrate biodiversity 1 year after thinning and burning this canyon live oak forest.

NASH, C.H. and E.A. JOHNSON. Dept. of Biological Sciences and Kananaskis Field Stations, University of Calgary, Calgary, AB, T2N 1N4, CANADA. Lightning-caused forest fires in west-central Canada.

The fire regime of the subalpine and boreal forests is dependent on lightning-caused forest fires. The spatial pattern of lightning strike density is characterised by a band of high strike density in the foothills of the Canadian Rocky Mountains, 150 km from the continental divide. Low strike densities are observed in the mountains and on the plains. The diurnal peak in strike density occurs between 1600 and 2200 local time. At all times and at all locations, the number of strikes exceeds the number of forest fires, suggesting that fire occurrence is not dependent on strike density. Instead, ignition by lightning is dependent on fuel moisture and can be predicted from fuel moisture code values. Synoptic scale fuel drying processes, such as persistent high pressure systems, combined with localized storms best explain fire occurrence due to lightning.

NAVARRETE, SERGIO A. and BRUCE A. MENGE. Oregon State University, Corvallis, OR 97331, USA. Keystone predation: testing interaction strengths between two predators and their main prey.

While the keystone predation hypothesis is a major ecological paradigm, rigorous experimental tests of the hypothesis, requiring manipulations of the suspected keystone and alternative predators, are rare. We determined the relative predator-prey interaction strengths for a keystone and a subordinate predator in rocky intertidal habitats on the Oregon coast. Seastar (s) and whelk (w) abundances were manipulated to determine their separate and joint predatory effects on small mussels. We used a split-plot design (+s+w, +s-w, -s+w, -s-w) that also tested for effects of wave exposure (exposed vs protected) and sites (low vs high productivity). Overall, seastar predation was high in all localities and habitats, regardless of the presence of whelks. Predation by seastars was higher in the locality with higher productivity. Predation by whelks was significant in the absence, but not in the presence of seastars. Seastar removal led to increased whelk density in some site/exposure conditions. Pairwise manipulations (one-predator/one-prey) overestimated the joint predatory effects. Per capita interaction strengths were more variable for seastars than whelks and more variable between exposures and sites than population-based estimates. Seastars have a clear keystone effect on mussels, while whelks can be locally important if the keystone predator is scarce.

NEILL[1], C., J. M. MELILLO[1], P. A. STEUDLER[1], M. C. PICCOLO[2], J. L. MORAES[2] AND C. C. CERRI[2]. [1]Marine Biological Laboratory, Woods Hole, MA, 02543, USA and [2]Centro de Energia Nuclear na Agricultura, Piracicaba, SP, Brazil. Changes to soil carbon and nitrogen stocks and cycling rates following forest conversion to pasture in the Brazilian Amazon Basin.

We examined soil carbon and nitrogen stocks, soil organic matter turnover and nitrogen mineralization and nitrification rates along chronosequences of moist tropical forest and pastures in Rondônia, Brazil, to examine how forest conversion to pasture affects soil C and N stocks and C and N cycling rates. Total C and N stocks in the surface 30 cm generally increased with pasture age. A large, stable pool of refractory forest-derived (C_3) carbon remained in pasture soils. Pasture soil C stocks increased as grass-derived (C_4) carbon was added to a slowly-declining forest-derived C pool. Net N mineralization and net nitrification rates were higher in forest than in pastures. Gross N mineralization rates measured by ^{15}N dilution were more than 3 times greater than net rates and were also higher in the forest. A lower gross N mineralization rate in older pasture suggested that nitrogen cycling rates and N availability may decrease as pastures age. These results are from one region of the Amazon Basin. Soil C and N responses to deforestation will likely vary with soil type, climate and land-use history. Greater regional specificity and more detailed categorization of agricultural use and management will be important in future models of the effects of land-use change on C and N stocks of tropical soils.

NELSON, SUZANNE C. and ROBERT H. ROBICHAUX. University of Arizona, Tucson, AZ, 85721, USA. The potential for improving cowpea yield under intercropping with pearl millet.

Genotype X environment interactions have often been implicated in the analysis of plant responses to varying environments. Of particular importance is the interaction between crop genotypes and the cropping systems in which they are grown. This interaction is evident in comparing genotypes bred for conventional, high-input, sole cropping systems with genotypes selected by farmers for traditional, low-input, intercropping systems. The potential for genotype X cropping system interactions suggests that crop breeding objectives be designed with specific cropping systems in mind. The objective of this study was to identify traits leading to increased yield of cowpea (Vigna unguiculata) in a cowpea/pearl millet (Pennisetum americanum) intercropping system. F_2 cowpea populations were produced from crosses of three genotypes that differed in architectural traits, times to maturity, and yield potential. The populations were intercropped with millet and analyzed for characteristics such as branching pattern, node number, and length of internodes. The results suggest that traits promoting increased cowpea yield in intercropping differ from those in sole cropping.

NEPSTAD, DANIEL C., SIMONE A. VIEIRA, PETER JIPP, CLAUDIO R. DE CARVALHO, GUSTAVO H. NEGREIROS. Woods Hole Research Center, Woods Hole, MA 02543 USA, School of the Environment, Duke University, Durham, NC 27708 and EMBRAPA/CPATU, Belém, PA 66.001 Brasil. Canopy water relations and leaf phenology in deep-rooted forest and pasture, eastern Amazonia.

Forests in eastern Amazonia retain leaf canopies during prolonged seasonal drought by extracting roughly one third of annual transpirational flux from deep (1-8 m) soil. However, forest plant species also depend on drought tolerance for leaf retention. As pre-dawn xylem pressure potential declined to an average of -1.8 MPa for 10 canopies species during the 5-month drought of the 1992 ENSO, leaf area dropped by only 15%. In contrast, XPPpre of pasture vegetation declined to -0.8 MPa as leaf area dropped by 50%. Xylem pressure potential at the turgor loss point ranged from -3.2 to -1.5 MPa in the forest and -1.6 to -1.0 in the pasture. Based on superimposed maps of NDVI seasonality and rainfall, we estimate that one third of the closed-canopy forests of Brazilian Amazonia depend on both deep-rooting and leaf drought tolerance for the maintenance of leaf area and evapotranspiration during seasonal drought.

NEUFELD, HOWARD S.[1], C. SCOTT CLARK[2] and JAMES A. WEBER[3]. [1]Appalachian State University, Boone, NC 28608, [2]Mantech Env. Tech. Inc., Corvallis, OR 97333 and [3]U.S. EPA, Corvallis, OR 97333. **A 25 cuvette automated gas exchange system for the study of plant responses to ozone.**

Attempts at linking ozone altered growth responses to reductions in stomatal conductance and photosynthesis in the field have been hampered by difficulty in obtaining sufficient concurrent gas exchange data in multiple exposure chambers. Single cuvette systems take too long to obtain data when there are two or more ozone treatments, resulting in the confounding of treatment and time effects. Single cuvette systems are also expensive because of labor costs. We describe herein an automated gas exchange system that overcomes many of these limitations. The system can measure gas exchange in each of 25 cuvettes four times per hour, 24 hours per day. Each clamp-on cuvette has light and temperature sensors, plus an internal fan for mixing. Cuvette sampling and data storage are controlled by a datalogger. Cuvettes have been left on leaves of tulip poplar and black cherry for 3-4 days, and on ponderosa pine for 1-2 weeks, without any apparent deleterious effects. Data obtained can be analyzed for instantaneous and hourly trends, or for patterns integrated over the entire day. Diurnal responses of CO_2 exchange for different canopy positions and ozone exposures show the system is useful for comparing responses and integrating net carbon gain.

NICHOLS-ORIANS[1], COLIN and ROBERT S. FRITZ[2]. [1]Williams College, Williamstown, MA 01267, USA and [2]Vassar College, Poughkeepsie, NY 12601, USA. The relative susceptibility of hybrid and parental willow species, varies with nutrient fertilization.

The relative susceptibility of hybrid and parental plants is known to vary among herbivore species, but may depend upon environmental conditions as well. To test this we placed potted plants of 5 clones each of silky willow (*Salix sericea*), marsh willow (*S. eriocephala*) and hybrids of the two in a common garden plot, and manipulated soil nutrient levels with 20-20-20 fertilizer. There were three replicate plants per clone in each of three nutrient regimes. They were fertilized weekly. At the end of the tenth week we counted the number of leaf-miners and leaf-folding sawflies, and determined the proportion of leaves damaged by japanese beetles, mites and a pathogenic rust. We found significant taxa, fertilization and taxa by fertilization effects on susceptibility. Most responded positively to fertilization. Some were more common on *S. eriocephala*, others more common on *Salix sericea*, and others more common on hybrids, but the relative differences often depended upon soil nutrient levels. Thus patterns of hybrid resistance varies among phytophages and soil nutrient conditions.

NICOTRA, ADRIENNE B. and ROBIN L. CHAZDON. University of Connecticut, Storrs, CT, 06269, USA. Spatial heterogeneity in light availability in primary and secondary tropical rain forest.

Spatial heterogeneity in the light environment of tropical rain forest seedlings may be greater in structurally complex, old-growth stands compared to relatively even-aged, successional stands within a chronosequence. We assessed light availability by measuring leaf area index (LAI, using a LICOR LAI-2000 Plant Canopy Analyzer) in an old-growth rain forest stand and two secondary stands (17 & 23 years regrowth) along replicated 160m transects at La Selva Biological Station in Costa Rica. Along the transects, LAI values were highly correlated with PAR measured simultaneously by adjacent quantum sensors ($n=36$, $R^2=0.814$). Although neither mean nor median differed among stands, the range was considerably greater in the old-growth stand (6.09) than in the secondary stands (3.45 & 3.84). The standard deviation was 1.7 times higher in the old-growth stand. The grain of patchiness of light availability can be described by the spatial scale of autocorrelation. LAI values in all three stands were autocorrelated at distances less than 15 m (Moran's I, $p< .000$). In the old-growth forest, the majority of LAI values were positively autocorrelated at points less than 40m apart ($p < 0.000$), whereas positive autocorrelation extended less than 30m in the secondary forest stands. In the old-growth stand only, most points more than 40 m apart were negatively autocorrelated ($p<.000$). The results suggest that old-growth rain forest stands have larger patches of light availability and greater LAI difference among patches than successional stands. Differences in the spatial scale of heterogeneity are probably due to tree-fall gaps.

NIESENBAUM, RICHARD A. Muhlenberg College, Allentown, PA, 18104-5586, USA. The effects of defoliation on fruit abortion rates and on selective fruit maturation in Lindera benzoin.

According to theory, a plant should selectively mature fruit from flowers in which there has been the most intense pollen tube competition. The degree of this "selectivity" should increase as resources become more constrained and fruit abortion rates increase. This was tested by examining fruit set and pollen tube numbers in naturally pollinated flowers on

defoliated and control branches of Lindera benzoin which is a dioecious, understory shrub that typically exhibits low fruit set. Defoliating branches after fruits were initiated significantly increased subsequent fruit abortion. Flowers that matured fruit had significantly more pollen tubes per stigma and style, than those that initiated but then aborted. Pollen tube numbers in flowers that matured fruit were only slightly greater on defoliated than on control branches. This result suggests that "selectivity" does not increase as local resources become more constraining. When resources are depleted at the branch level, relative position becomes an important determinant of which ovaries mature.

NILES, ROBERT K., DIANA W. FRECKMAN, and ERICHA M. COURTRIGHT. Colorado State University, Fort Collins, CO 80523. Changing morphology and identification heroics: constraints on the measurement of nematode biodiversity.

Given the nematode's highly conserved morphology, identification proceeds by alternative methods using different information: humans make intuitive judgments based on morphologic variation; image analysis, when coupled with statistical inference, uses morphologic data from many characters; the arbitrarily-primed polymerase chain reaction (ap-PCR) enables determinations based on genotype. We compared the identifications made by humans, image analysis, and ap-PCR to distinguish Acrobeloides obliquus and A. uberrinus. Identifications by all methods were on the same specimens, raised with resource abundance (in culture on agar plates) or resource scarcity (in cones of blow sand). Logistic regression models, based on image analysis data, included explanatory characters related to body lengths, width at the anus, and position of anus and vulva. However, morphology of both species changed with resource availability (confirmed by t-test comparisons on individual characters). Greatest discrepancies in identification among the three methods occurred with juveniles from blow sand. These results indicate that the trade-offs in measuring nematode biodiversity are related to the nematode's morphologic response to resource quality and the effort required to make an accurate identification.

NILSEN, ERIK T. Biology Department, Virginia Tech, Blacksburg, VA 24061, USA. Acclimation of stem photosynthesis to changes in seasonal climate in four legumes from the coast and desert of California.

Photosynthetic responses of stems to light, vapor pressure, tissue temperature, and carbon dioxide concentration were measured on four microphyllous legumes with prominent green stems during the spring and mid summer. Only the species from the Mojave desert (high elevation) indicated acclimation to summer temperature. But the thermal optimum for all species was close to the maximum spring temperatures. All species had a high light saturation point (>1000 $\mu E\ m^{-2}\ s^{-1}$ of PAR). Stem photosynthesis of the low desert species was inhibited by low vapor pressure and high temperature during the summer months. There was no change in stem photosynthetic response to vapor pressure gradient in any species among seasons. However the two coastal species were more sensitive to vapor pressure than the two desert species. These comparisons indicated that stem photosynthesis does adapt to regional climatic conditions, but does not acclimate to seasonal changes in climatic conditions.

NODVIN, S.C., H. VAN MIEGROET, S.E. LINDBERG, E.M. WILLIAMS, E.F. PAULEY, N.S. NICHOLAS, AND D.W. JOHNSON. USDI, National Biological Survey-Cooperative Park Studies Unit, The University of Tennessee, Knoxville, TN, 37910, USA. Factors regulating watershed export from Southern Appalachian spruce-fir systems.

The mountain-top Southern Appalachian red spruce-Fraser fir forests: 1) receive some of the highest rates of atmospheric deposition measured in North America, 2) contain old-growth forests, 3) have declined in red spruce crown condition and radial increment, 4) have recent major insect-caused mortality of mature Fraser fir, and 5) contain poorly buffered soils and stream systems. For three years, we have monitored precipitation, throughfall, and stream hydrology and chemistries from a 17.4 ha watershed (1676-1920m elevation). In addition we have assessed canopy biomass and nutrient components and completed a detailed soil survey. Results show that atmospheric deposition and throughfall processes are spatially heterogeneous and affected by canopy and topographic factors. Nitrate was the predominant anion in the two streamlets (weighted concentrations: 47 and 54 μeq/L NO_3^- compared to 31 and 43 μeq/L SO_4^{2-}). Watershed nitrate export is extremely high (~1000 eq/ha/yr), which facilitates significant base cation exports both chronic and episodic stream acidification. Watershed deposition, export, and internal cycling studies demonstrate that this system is highly nitrogen saturated.

NOEL, JILL M., ANDY MAXWELL, WILLIAM J. PLATT, and LINDA PACE. Louisiana State University, Baton Rouge, LA 70809, USA. Distribution of damage by Hurricane Andrew to cypress (*Taxodium distichum* var. *nutans*) of south Florida.

In March 1993, hurricane damage was surveyed in 16 cypress (*Taxodium distichum* var. *nutans*) domes located along a transect extending in a north-south direction, perpendicular to the direction of movement of the eye of Hurricane Andrew across south Florida. Cypress was very resilient; major damage (trunk snapped) and mortality was low (≤4%). However, defoliation, loss of branches, and damage to bark occurred in most (>80%) trees. Largest diameter trees experienced the greatest bark and branch damage. Damage occurred in ≥20% of trees which were 15-20 cm diameter. The severity and extent of damage decreased with distance from the eye, tapering to low levels within 40 km of the center of the eye. Damaged trees sprouted

epicormically, and were beginning to exhibit a "flat-topped" structure typical in areas that are subject to frequent hurricanes. Similar patterns of cypress damage have been noted after other hurricanes in this region, particularly Camille and Hugo.

NOHARA, S. and KIMURA, M. National Inst. Envir. Stud., Tsukuba, Ibaraki 305, JAPAN and Tokyo Metropolitan Univ., Hachiohji, Tokyo 192-03, JAPAN. Allocation to emergent versus floating leaves in Nelumbo nucifera in responce to flooding and water depth.

Experiments on the effect of water depth and flooding on N. nucifera in the artificial environment of ponds to explore the following two questions; 1. What is the maximum water depth at which N. nucifera can grow? and 2. What is the effect of the degree and timing of flooding on the growth of N. nucifera? Growth responces of N. nucifera under the continuous water levels were investigated. The petiole dry weight per unit length of emergent leaves rose with increasing water depth. In contrast, that of floating leaves was constant at about 10 mg dry weight per cm. The LAI of floating leaves increased with water depth. There was a marked increase in the ratio of above- to under-ground biomass with increasing water depth. Petiole expansion responces to amplitude of flooding were investigated. The maximum rate of elongation of petiole was 25 cm per day at a sudden flooding. Effects of timing of flooding on growth were investigated. The effect on final crop was most severe when flooding occurred during late August.

NORBY, RICHARD J. Environmental Sciences Division, Oak Ridge National Laboratory, Oak Ridge, TN, 37831-6034, USA. Tree growth in elevated CO_2 — Fitting seedling and sapling data to ecosystem questions.

Tree growth above and below the ground is an important component of global carbon storage and a prime determinant of forest ecosystem response to environmental change. Hence, measurement of growth is an obvious objective of experimental studies on the response of trees to atmospheric CO_2 enrichment. Many experiments with tree seedlings have demonstrated that total growth increases in elevated CO_2, the average response being a 32% increase in dry mass when the ambient CO_2 concentration is doubled. Several multi-year exposures of trees to elevated CO_2 in field experiments, however, have produced widely divergent results with respect to final tree biomass. Much of this variability can be explained by differences in leaf area production, and the expression of growth as the annual stem mass increment per unit leaf area (growth efficiency) reveals a uniformity in response across sites and species. Root growth also is an important component of ecosystem function and carbon storage, but its measurement and interpretation are problematic. While the data on tree growth demonstrate the *potential* for forest trees to grow faster and sequester more carbon in a CO_2-enriched atmosphere, to be relevant to questions concerning forest ecosystem responses the existing experimental data must be interpreted in relation to patterns of forest canopy and root system development.

NUNGESSER, MARTHA K. University of Virginia, Charlottesville, VA, 22901, USA. Ecological and physical processes in hummocks and hollows in raised bogs.

The surfaces of boreal peatlands frequently exhibit a microtopography of hummocks and hollows. These forms tend to remain stable for long periods of time and over broad climate variations, implying an internal feedback system between the biological and physical environments. A dynamic simulation model is being developed to test a hypothesis regarding stability and resilience of raised bogs, focusing on growth and decomposition of the common Sphagnum mosses, surface hydrology, and physical properties of peat. The model grows Sphagnum using species responses to moisture, temperature, and light regimes. Decomposition and peat accumulation result from and reinforce differences in the microhabitats. Unique thermal and hydrologic attributes of peat also reinforce differences between hummocks and hollows. Interactions of these aspects of peatland ecosystems appear to lead to long-term stability in these bog surface features.

OBERBAUER, STEVEN F., KURT VON KLEIST III, KEVIN WHELAN, and SUZANNE KOPTUR. Florida International University, Miami, FL 33199, USA. Effects of Hurricane Andrew on epiphyte communities within cypress domes of Everglades National Park

Hurricanes have historically been a common disturbance to South Florida forests, and undoubtedly have been an important force in determining plant community structure. The epiphyte community in particular, because of its canopy attachment, should be strongly affected by hurricanes. The passage of Hurricane Andrew on 24 August 1992 across our study sites in cypress domes in Everglades National Park provided a rare opportunity to examine the effects of a major hurricane on the epiphyte community. Epiphyte communities in cypress domes are among the most strongly developed in the Everglades. In this report we document the short-term community responses of epiphytes in three cypress domes to Hurricane Andrew. Overall, losses of adult epiphytes averaged 0.5 plants m^{-2}. However, a very large number of new recruits entering the population following Hurricane Andrew has lead to an overall increase in epiphyte density of 1.6 plants m^{-2}. No changes in species composition were found in our study plots, although different species of bromeliads showed different susceptibility to hurricane-force winds.

ODE, PETER R. and BARBARA L. PECKARSKY. Cornell University, Ithaca, NY, 14850, USA. The role of food limitation and competitor density in larval mayfly ecology (Insecta: Ephemeroptera).

Herbivorous mayfly larvae commonly share their algal resource with high densities of many species of other grazers in streams. We determined the role of food limitation and competitor crowding in the larval ecologies of two mayfly species (Baetis bicaudatis Baetidae and Epeorus deceptivus Heptageniidae) by measuring the influence of these factors on short-term fitness measures. Mayflies were reared under four treatments manipulating food levels and density. Forty replicate 10 cm circular flow-through streams were stocked with either: 1) 4 mayflies + low algae levels, 2) 4 mayflies + high food levels, 3) 16 mayflies + low algae levels, and 4) 16 mayflies and high algae levels. Mayflies were reared from middle instar larvae until just before their adult emergence (≈3wks). We measured feeding rates, growth rates, time to emergence, and size at emergence in males and females, and female fecundity in females. Low algal levels and crowding reduced Baetis and Epeorus feeding rates, survivorship, and fecundity. Low food levels reduced growth rates for both species, but crowding only affected allocation to egg mass.

OHGUSHI, TAKAYUKI Institute of Low Temperature Science, Hokkaido University, Sapporo o6o, Japan. Adaptive behavior produces population stability: a case study of the herbivorous lady beetle.

The herbivorous lady beetle *Epilachna niponica*, which feeds exclusively on thistle plants, exhibited a high stability of population densities in terms of host plant abundance; less than two-fold variations in two local populations during a five-year study period. Field experiments revealed that reproductive females resorbed eggs in the ovary in response to host plant deterioration. This physiological response was more likely to lead to a density-dependent reduction in realized eggs per female. Also, females showed careful oviposition site selection: they tended to lay eggs on plants with less egg load. These specified oviposition tactics resulted in a remarkable resource tracking of populations, through density-dependent reduction in reproductive rate. Lifetime fitness of offspring decreased with increasing egg density. Offspring fitness decreased even at a low egg density, which was identical with the equilibrium population density. This implies that oviposition on plants with less egg density improves lifetime reproductive success of an ovipositing female. Also, resorption of eggs could have adaptive significance when offspring fitness drops considerably due to resource deterioration late in the reproductive season or habitat disturbance such as inundation. Consequently, the oviposition behavior of reproductive females in time and space is highly correlated with lifetime fitness of their offspring.

OHLHORST, SHARON L. and STEVE ARCHIBALD. Utah State University, Logan, Utah 84322 USA. Improving ecology education in Utah: strategies, successes and challenges.

The Utah team decided to focus on improving ecology education through strengthening and expansion of currently existing networks and activities. Both the elementary and secondary education science core curricula are currently under revision and ecologists have been incorporated into the planning and review process. A network designed to bring ecologists together with teachers is in progress. A twelve page newspaper supplement on schoolyard ecology will be published in March. This publication will be received by teachers for use in their classroom and includes suggestions on partnership activities with ecologists. Ecologists are involved in a number of teacher education workshops. The primary challenge is institutional support for these activities, which currently are viewed as peripheral to the mission of research institutions.

OHLHORST, SHARON L. and W. DAVID LIDDELL. Utah State University, Logan, Utah 84322, USA. Simulation- and field-based evaluation of benthic community sampling methods: implications for biodiversity and monitoring programs.

A number of sampling methodologies have been developed for quantitative evaluation of sessile biotas, including both plot and plotless techniques. The methods differ considerably in time efficiency and in "quality" of data gathered. For example, depending upon sampling methods employed, one community may be perceived as two very different communities with different species abundance and diversity. We have evaluated commonly-used sampling methods through use of computer simulations and field studies. Simulations allow the sampling of numerous replicates of "known" communities exhibiting different population and community parameters. Our results indicate that no one census method is universally applicable to all community types. The appropriate method depends upon population and community attributes such as organism density, size, spatial pattern, and diversity. Preliminary evaluation of population and community parameters is therefore essential to the development of optimal census strategies.

OLIVER, J. DOUGLAS. Dept. Env. Protec., Bur. Mine Recl., Tallahassee, FL 32310, USA. Mile-a-minute weed and Vossia cuspidata, potential invasives of U.S. natural and restoration sites.

Mile-a-minute weed (Polygonum perfoliatum), from eastern Asia, has been spreading through wild and disturbed areas of the mid-Atlantic U.S. It is a vine with tolerance for shade, sunlight, dry, and wet conditions. The southward direction of spread and the warm native habitat suggest

that mile-a-minute would probably proliferate after entering Florida. Mechanical control is not likely to be completely effective because seeds are often left behind. No appropriate biocontrols are known. The plant poses a threat to natural and restored ecosystems because of its capacity to grow rapidly and overgrow other species. V. cuspidata, a nearshore and deeper freshwater plant, has spread through warm areas of Asia and Africa. Mechanical control is not likely to be effective and prospects for herbicidal and biological control are largely unknown. If the plant enters the U.S., it could dominate large areas in south Florida and replace native plants. It could also invade restoration sites, such as those on spoils. Mile-a-minute and V. cuspidata are expected to cover large areas of the U.S. unless they are continually excluded or controlled.

OLSON, E.J. University of Pennsylvania, Philadelphia, PA 19104. Phytochemistry, predators, and season determine suitability of nonhost plants for Rothschildia lebeau (Lepidoptera: Saturniidae) larvae.

Ecological factors in addition to plant chemistry may define the variety of plants suitable for use by an herbivorous insect. I tested Rothschildia lebeau, a polyphagous caterpillar, against 70 tropical dry forest nonhost woody plants, all native to this insect's habitat. In no-choice lab trials, 86% of these plants did not support larval development through the first instar, while 4 (6%) supported development of full-sized adults with normal to near-normal female egg number and viability. I call these 4 plants novel hosts. In the field I placed sets of all 5 larval instars on 2 of the 4 novel and one normal host species and censused survivors every 2 days. Larvae placed on Annona purpurea grew nearly as fast as larvae on the control, but significantly more were predated in 1991 and 1992. Larvae placed on Erythroxylon havanense early in the rainy season in 1992 were killed at the same rate as on the control, but they grew very slowly, leading to significantly higher predation losses. Larvae placed on E. havanense later in the rainy season could not grow at all, due to changes in foliar quality. Neither novel host served as a secure refuge from a specialist ichneumonid parasitoid. These results suggest that predators can narrow the range of suitable host plants for this insect, both directly and in combination with slow larval growth. However, most nonhost plants are not suitable because this insect will not or cannot feed on them.

OLSON, MARK H. University of Wisconsin, Madison, WI, 53706, USA. Ontogenetic niche shifts in largemouth bass: variability and consequences for first year growth.

Ontogenetic niche shifts are a critical feature in the ecology of many size-structured organisms. In largemouth bass, there is a diet shift from littoral invertebrates to fish that typically occurs sometime in their first year. I examined factors that influenced this shift by tracking diet and growth trajectories of young-of-year (YOY) bass cohorts in 4 Michigan lakes over 2 years. The timing of the niche shift was highly variable among lakes and years. A successful shift to piscivory depended, in large part, on growth rates of bass during the 1-2 month window before bluegill (their primary fish prey) spawned. Rapid growth in the invertebrate feeding stage gave bass a size advantage over YOY bluegill which enabled them to switch to piscivory as soon as YOY bluegill became available. As well, favorable climatic conditions enhanced early growth rates of bass and increased the size advantage of bass over bluegill. Bass experienced a jump in growth rates after switching to the piscivorous stage. Consequently, they finished their first growing season substantially larger when conditions facilitated a niche shift. Since overwinter survival is strongly size-dependent, factors which affect early growth rates and thus the shift to piscivory can potentially have important effects on the dynamics of the population as a whole.

OLSZYK[1], DAVID M., CLAUDIA M. WISE[1], DAVID T. TINGEY[1], PAUL T. RYGIEWICZ[1], AND RONALD S. WASCHMANN[2]. [1]U.S. Environmental Protection Agency, Corvallis, OR, 97333 and [2]ManTech Environmental Technology, Inc., Corvallis, OR, 97333. Effects of CO_2 and climate change on forest trees: shoot growth and gas flux responses.

Critical questions regarding effects of rising atmospheric CO_2 and climate change on forested systems include: Will shoot growth change in response to elevated CO_2 and temperature?. Will net carbon and water fluxes change in response to elevated CO_2 and temperature? Initial shoot growth and gas flux data are presented for *Pseudotsuga menziesii* seedlings continuously exposed for one year to target environments of ambient or ambient + 200 ppm CO_2, and ambient or ambient + 4°C air temperature in closed chambers. Changes in stem diameter, height, terminal shoot and bud length, are reported. Whole canopy and single branch level gas flux data used to calculate photosynthetic, respiration, and transpiration rates also are reported. The experiment is continuing so that longer-term impacts of CO_2 and temperature on the seedlings can be determined and data obtained for process-based modeling of tree growth. The aboveground effects will be related to belowground processes to evaluate whole system responses to atmospheric CO_2 and climate change.

ORIANS, GORDON H. University of Washington, Seattle WA, 98195,USA. Evolved consequences of rarity.

Species that have been rare for a long time should evolve traits that improve survival and reproductive success of individuals under those conditions. Two important components of rarity are geographic range and local population density. I have used animal-pollinated plants as subjects for my research on evolved consequences of rarity because local population density is a major determinant of pollinator behavior and probability of success in transfer of pollen. Species in the genus Eremophila (family Myoporaceae) with low local population densities differ, on average, from more common congeners in having more zygomorphic flowers and being more likely to be pollinated by birds than by insects. Very few species have both small ranges and low population densities. Rare species in the genus Psychotria (family Rubiaceae) are more likely than common species to deviate from heterostyly, the basic condition in the genus and family. Such differences suggest that newly-rare species may face more difficulties than species with evolutionary experience of rarity. Management strategies should reflect these differences.

ORWIG, DAVID A. AND MARC D. ABRAMS. Penn State University, University Park, PA, 16802, USA. Contrasting radial growth and canopy recruitment patterns in Liriodendron tulipifera and Nyssa sylvatica: gap-obligate versus gap-facultative tree species.

Radial growth, canopy recruitment, and disturbance histories were examined in co-occurring Nyssa sylvatica, and Liriodendron tulipifera, to determine the influence of canopy gaps in species with contrasting life histories. Trees were sampled from mixed-Quercus forests in northern Virginia. Many N. sylvatica became established prior to 1850 and experienced multiple release and suppression periods coinciding with logging during the late 1800s and early 1900s. L. tulipifera became established during the early 1900s following logging and only a low percentage experienced prolonged suppression. Ring width patterns indicate that both species utilized different strategies following disturbance. N. sylvatica persisted in sub-canopy positions for extended periods of time capable of responding to release even after 170 years, indicating small gap utilization. In contrast, L. tulipifera relied on a strategy of becoming established following large disturbances by maintaining rapid height and radial growth for canopy accession in gaps.

OSTERTAG, REBECCA. Dept. of Botany, University of Florida, Gainesville, FL, 32611, USA. Root gaps in a lowland neotropical rain forest.

Volumes of soil with diminished root length densities (i.e., root gaps) represent regions of putative reduced below-ground competition. I examined the formation and consequences of root gaps in two light environments (canopy gaps and intact forest) and two soil fertilities (fertile and less fertile) found at La Selva Biological Station, Costa Rica. There was significantly less total and fine (<1 mm) root length density in canopy gaps than in adjacent understory sites, suggesting that canopy gaps create root gaps. The consequences of root gaps were investigated by experimentally creating root gaps in these two soil and light environments. Into each root gap treatment I planted a 5 mo old seedling of *Hampea appendiculata* (Malvaceae) and monitored relative growth rate for 7 mo. After 2 and 7 mo there were no differences in growth rates of the seedlings between different root gap treatments or soil types, but the plants in canopy gaps grew significantly faster than those in the understory. Although natural disturbance creates both above-ground and below-ground gaps in this forest, such root gaps may offer soil resources that are either unavailable or inconsequential for established plant growth, and are therefore unlikely to alter competitive interactions between plants.

OTT, JAMES R.[1], ANDREA F. HUBERTY[2], GALEN P. DIVELY[2], and ROBERT F. DENNO[2]. [1]Southwest Texas State University, San Marcos, TX, 78666, USA, and [2]University of Maryland, College Park, MD, 20742, USA. The genetic basis of host range expansion in the Silver-spotted skipper.

Larvae of the Silver-spotted skipper, Epargyreus clarus, (Lepidoptera: Hesperiidae) are polyphagous but feed primarily on Black Locust, Robinia pseudoacacia (Leguminosae) along the USA's eastern seaboard. Recently some E. clarus populations in this region have begun to expand their host range to include Soybean, Glycine max, an introduced legume. The genetic basis of this host range expansion was examined by rearing both parental and offspring generations of E. clarus on both host plants in the laboratory. We estimated: 1) host plant effects on larval performance (i.e., survivorship, growth rate, and pupal weight); 2) additive genetic variance for these characters; and 3) the magnitude and direction of genetic correlations in performance both within and between host plants. We found: 1) only minor (generally <5%) differences in performance between the two host plants, with the exception of survivorship; 2) significant heritable variation for larval performance; and 3) positive or nonzero genetic correlations in performance both within and between host plants. These results suggest that the amount and structure of genetic variation for larval performance characters in the sampled E. clarus population should not constrain further adaptation to the novel hostplant.

OUTCALT, KENNETH W. USDA For. Serv., P.O. 14524, Gainesville, FL 32604. The effect of within-gap position on precipitation and seedling survival in Longleaf pine forests

Natural regeneration of longleaf pine (Pinus palustris) is normally concentrated in the center of tree fall gaps and is surrounded by a conspicuous zone without seedlings. Precipitation and seedling survival were monitored at 1, 4, 8, and 12 m from gap edges along lines oriented in the four cardinal directions within 90-year-old longleaf pine stands on the Ocala National Forest in Central Florida. In March seedlings were evenly distributed across gaps with a mean density of 11/m^2. At the end of May, seedling survival was significantly lower at 45% 1m from the edge compared to 4, 8, and 12m survival of 66, 70, and 70% respectively. Survival was also lower for seedlings growing on the north and west sides of gaps at 48%, versus 78% for the south and east areas. Precipitation from March to May followed similar patterns with lesser amount received at 1 and 4m from gap edges and in the west area. Additional mortality from May to October lowered overall seedling survival but it was still lowest near edges and increased toward the center of gaps and in the south and east quadrants as did precipitation. Therefore, the lack of longleaf reproduction near gap edges did not result from differences in seedling establishment but rather from high mortality. Differences in precipitation across gaps was likely at least partially responsible for this differential seedling survival.

OVERTON, JACOB McC. Princeton University, Princeton, NJ, 08544-1003 USA. Species distributions along gradients in particle system models: the influence of dispersal distance.

The influence of dispersal distance on several aspects of a species local distribution is investigated using a one-dimensional, discrete time contact model. The model contains an array of sites that are either occupied or vacant. In each time period,

occupied sites have a probability of becoming vacant or contributing colonists to neighbors within a dispersal distance. The model is first investigated on arrays in which colonization and extinction probabilities are spatially constant. Both the existence and size of a positive equilibrium occupancy are influenced by dispersal distance. Gradients are imposed on the array by making either the colonization or vacation probabilities a function of position along the array. The distribution of species along these gradients is then compared to the distributions on uniform arrays. For large dispersal distance, individuals occupy more of the gradient than is predicted from uniform arrays. For near-neighbor dispersal, individuals do not occur in all parts of the gradient for which uniform gradients predict existence. This result is qualitatively different than analogous results from diffusion models.

PACE, MICHAEL L. Institute of Ecosystem Studies, Box AB, Millbrook, New York 12545, USA. An Invasive Species Alters the Temporal and Spatial Patterns of Plankton Blooms in the Hudson Estuary II. Zooplankton

Invasion of the Hudson River Estuary by the zebra mussel, Dreissena polymorpha, has reduced substantially reduced phytoplankton biomass. Coincident with this change we have observed reductions of tintinnids, rotifers, copepod nauplii, and the cladoceran Bosmina longirostris. In addition, the spatial and temporal dynamics of zooplankton population appear to have been altered. Typically, the Bosmina population increases each June from < 0.1 individual L^{-1} to 100-1000 individual L^{-1} over an 80 km zone in the estuary. The Bosmina population increase was antenuated in 1993 and shifted down the estuary reflecting the differential development of phytoplankton in response to zebra mussel grazing. Changes in zooplankton have important food web implications as resident and anadromous fishes exploit zooplankton during critical life history phases. The zebra mussel is clearly altering ecosystem productivity in the Hudson which may in turn have strong impacts on fish population dynamics.

PAEZ, ALEJANDRA, G. MICHAEL GEBRE, and TIMOTHY J. TSCHAPLINSKI. Universidad del Zulia, Maracaibo, Venezuela and Oak Ridge National Laboratory, Oak Ridge, TN 37831 USA. The relationship between growth and soluble sugar concentration of *Aloe vera* plants grown under three levels of irradiance.

The CAM plant *Aloe vera* was vegetatively propagated and grown under three irradiances: full sun, partial and deep shade (30% and 10% of ambient light, respectively) to determine the effect on growth, biomass allocation, and sugar concentration. After one year, the plants were harvested to determine final dry weight and the sugar concentration of the leaf mucilaginous gel. Plants grown under full sun produced twice the total dry weight of those grown under partial shade, with the difference equally partitioned between the shoot and root. Plants grown under full sun also produced thicker leaves, and more numerous and larger auxiliary shoots. The dry weight of plants grown under deep shade was 8.6% that of plants grown under full sun, which was directly proportional to the irradiance received. Partial shade increased the number and length of leaves produced on the primary shoot, but the allocation of carbon to roots was the lowest of all treatments. Partial shade reduced the total sugar concentration of the leaf gel matrix to 34% that of plants under full sun, due to reductions in all sugars measured. Glucose was the most abundant soluble sugar, with its relative contribution to the total pool increasing under shade. In summary, the proportional effects of partial shading were greater on soluble sugar concentrations than on the total plant biomass produced.

PALIK, BRIAN J. and NEIL PEDERSON. Joseph W. Jones Ecological Research Center, Newton, GA, 31770, USA. Landscape variation in overstory mortality in longleaf pine ecosystems.

Mortality of longleaf pine and slash pine was studied within an 11,000 ha landscape in the Gulf Coastal Plain. The study site contains primarily 60-80 year old second-growth stands that span a hydrologic gradient ranging from wet-mesic to xeric. Objectives for the study included 1) quantifying rate of mortality for the study population over the last six years and 2) assessing relationships between spatial variation in rate and cause of mortality and stand and site conditions that influence disturbance regimes. Lightning was the apparent cause of mortality of most overstory pines. Windthrow accounted for the next largest percentage of total mortality, followed by fire. Most deaths occurred in isolation, with only a small percentage of total deaths occurring in groups of trees. There was substantial spatial variation in cause and frequency of mortality, with windthrow being more frequent on wetter sites than the study area as a whole and group deaths being more frequent in higher density stands. The latter may reflect the ability of bark beetles or pathogens to spread from trees directly killed by lightning, wind, or fire to neighboring trees weakened by the same agents. Substantial spatial variation of mortality patterns in these ecosystems argues for taking a landscape-level approach to developing a conceptual understanding of stand dynamics.

PALLANT, ERIC and LISA M. HILSTER. Allegheny College, Meadville, PA, 16335, USA. Improving the health of earthworms on acid mine spoils with sewage sludge and lime.

Reclamation of acid mine spoils could be enhanced by the addition of common earthworms, Lumbricus terrestris. Pots containing acid mine spoils and three worms apiece were treated with two levels of lime, pH 5.3 or 6.5, and either sewage sludge or no sludge. After 11 weeks, mean worm weight in the sludge treated pots significantly increased 7.9%, while mean worm weight in the pots with no sludge decreased 11.6%. The total weight of worms per pot

followed the same trend as worm specific weight: sludge helped. The total weight of worms per pot was greater for pH 5.3 than pH 6.5. Mortality was greater at the lower pH, but the weight of each surviving worm was greater for the smaller populations. The worms, especially those in the sludge, created numerous channels. Our results suggest, if treated right, worms could improve soil structure and be used to stimulate reclamation of acid mine spoils.

PAN, YUDE, DAVID W. KICKLIGHTER, JERRY M. MELILLO and A. DAVID MCGUIRE. Marine Biological Laboratory, Woods Hole, MA 02543, USA. The climatic sensitivity of NPP estimates by the Terrestrial Ecosystem Model for the coterminous United States.

The Vegetation/Ecosystem Model Analysis Project (VEMAP), which was initiated to compare models of biogeochemistry and vegetation distribution, has developed climatic data sets for the coterminous United States. We ran the Terrestrial Ecosystem Model (TEM) at 0.5° resolution using the VEMAP monthly temperature and precipitation data and compared the NPP estimates with those using the climatic data of Legates and Willmott (L&W). For the coterminous U.S., TEM calculates 3.7% less NPP with the VEMAP data than with the L&W climate. Decreases in NPP generally occur in moist ecosystems and are associated with lower temperature; temperate conifer forest has 10.5% less NPP with a 3.3 C° decrease in temperature. However, increases in NPP generally occur in dry ecosystems and are associated with higher precipitation; xeromorphic woodland has 6.2% higher NPP with 80 mm more precipitation. We conclude that estimates of NPP are more sensitive to differences in climatic inputs at regional than at continental scales.

PARDO, L. H., P. E. MURDOCH, M. J. MITCHELL, C. T. DRISCOLL, G. E. LIKENS. USDA Forest Service, Burlington, VT 05402. Growing season loss of nitrate at three northeastern hardwood forests: a regional indicator of nitrogen saturation?

Nitrogen is typically tightly retained in terrestrial ecosystems in the Northeast. In ecosystems with episodic nitrogen losses, nitrate export during the summer period of high biotic demand remains low. Increasing nitrate loss during the growing season is an early indicator of ecosystems shifting from episodic to chronic nitrogen loss (nitrogen saturation). Studies of nitrogen cycling from Biscuit Brook, Catskills, NY, Huntington Forest, Adirondacks, NY and Hubbard Brook Experimental Forest, White Mountains, NH, showed high nitrate loss at each site during the summer of 1990. This regional pattern may be caused by anthropogenic (higher nitrogen deposition), climatic (temperature and weather interactions), and/or natural (eg. pest outbreaks) disturbance. High nitrate loss causes surface water quality deterioration and may be linked to forest decline. The pattern also demonstrates the need for surface water monitoring on a regional scale to assess the effects of air pollution emissions legislation.

PARÉ, DAVID[1-2] and YVES BERGERON[1], 1: GREF, Université du Québec à Montréal, C.P. 8888, Succ A. Montréal, Québec, Canada, H3C 3P8; 2: Biodôme de Montréal, 4777 Ave Pierre-de-Coubertin, Montréal, Qc, Canada, H1V 1B3.
Influence of colonizing tree species on chemical and biological soil properties following fire in the Canadian southern boreal forest.

We studied the properties of the forest floor and the mineral soil found under three tree species (*Betula Papyrifera*, *Populus tremuloides*, *Picea glauca*) that regenerated after wildfire in the southern boreal forest of eastern Canada. The following analysis were performed: standard soil analysis, the estimation of the pools of available, total and microbial nitrogen (N) and the estimation of *in situ* and *in vitro* net N mineralization rates. The trees were 30, 44, 75 and 120-year-old and had regenerated in the year following a wildfire as confirmed by tree ring counting. The most significant differences between species were reserves of exchangeable calcium and pH which were greater under the influence of *Populus tremuloides*. Although no significant difference was found between species for N availability, species could indirectly affect nitrogen cycling rates via a pH effect.

PARENT, SYLVAIN AND CHRISTIAN MESSIER. Université du Québec à Montréal, Montréal, Québec, H3C 3P8, Canada. Effets of light on growth and acclimatation of balsam fir, at the southern limit of the boreal forest, Quebec, Canada.

Clearcutting methods in much of Quebec have been modified recently to protect advanced growth. Vigorous advanced regeneration is more likely to survive forest operations and in the understorey, light would be one of the most limiting factors for growth and vigor. Our goal was to characterize growth, vigor and architecture of advanced regeneration of balsam fir (Abies balsamea L. Mill.) in relation to a light gradient of 2% to 83%. Light contributes to more than 70% of growth and acclimatation variations. With light levels greater than 25% of light we noted a transfer from sympodial to monopodial growth. The number of branches and the specific leaf weight area of seedlings seems to increase with increasing light. These results will give us a better understanding of the autoecology of tolerant species.

PARKER, AMANDA K. and KAREN G. PORTER. Institute of Ecology, University of Georgia, Athens, GA 30602-2202, USA. Seasonal succession of phytoplankton in a small, warm-monomictic, southeastern lake (Lake Oglethorpe, GA).

Phytoplankton community structure in a small, warm-monomictic Piedmont lake, Lake Oglethorpe,GA, was studied over a two year period. Species assemblages, cell numbers, biovolume estimates, and pigment analysis were determined weekly. During winter mixis (Nov-March) chrysophytes (*Synura caroliniana* and *Dinobryon bavaricum*) and diatoms (*Asterionella* sp.) dominated the phytoplankton in number and biovolume. Species number (11-19 sp.) and total abundance (7.3×10^3 cells$\cdot$ml^{-1}) were lowest in January. In late winter mixis, there was a brief period of chlorophyte (*Ankistrodesmus spiralis* and*Gloeocystis gigas*) dominance with an increase in species number (24-29 sp.). During the spring transition (April-May) chrysophytes (*Uroglenopsis americana* and *Chyroschromulina* sp.) dominated once again and species number was highest (30-39 sp.) with an increase in chlorophytes and small cyanobacteria. During stratification (late May-Sept) the summer assemblage was dominated by filamentous cyanobacteria, a small *Cosmarium* sp., and large euglenoids and dinoflagellates. Cell numbers were highest in summer (2.9×10^5 cells$\cdot$ml^{-1} in July). Fall destratification was characterized by a decline in summer species and a return to dominance by chrysophytes and diatoms. These patterns differ significantly from classic seasonal succession in northern dimictic lakes by lacking the diverse flagellate assemblage found during ice cover, the extended spring clear water phase, and high diatom and chlorophyte abundances. Lake Oglethorpe also had higher annual total abundance, biovolumes, and chlorophyll than has been found in northern dimictic lakes (Wetzel 1983).

PARKER, GEOFFREY G. and PETER J. STONE. Smithsonian Environmental Research Center, P.O. Box 28, Edgewater, MD, 21037, USA. Three-dimensional light environment in a deciduous forest canopy.

Limitations of canopy access often restrict observations of forest radiation environments to ground-based or remotely-sensed vantages; the distribution of light is rarely assessable in three dimensions of canopy space. To understand the variation in radiation within a tall, deciduous forest on the Maryland coastal plain, we measured photosynthetically active radiation (PAR) with sensors mounted on a custom-built helium balloon. The balloon provides a stable platform for small environmental sensors in the middle and upper canopy. To illustrate the variation in forest light environments, we investigated spatial variability in vertical profiles of visible light in several stands of differing age and structure. In one of these stands, we examined: 1.) the spatially-averaged extinction coefficient for global PAR, 2.) the representativeness of measurements made from a fixed vertical transect of light sensors, and, 3) the three-dimensional light field in a large canopy gap.

PARKINSON, JONATHAN M. University of North Carolina, Chapel Hill, NC, 27599-3280. Maintaining the multitudes on mushrooms: A field test of patch dynamics coexistence models.

I employed a new method of investigating mycophagous insect communities (exposure of live, lab-cultured indigenous mushrooms), to test a prediction common to most 'patch dynamics coexistence models'. These models suggest that the subdivision of resources in space and/or time can promote the coexistence of species which might otherwise exclude each other. I exposed Pleurotus ostreatus mycelium and fruiting bodies to insect colonization and growth on the forest floor for four weeks on the forest floor. The three spatial patchiness treatments consisted of 1 kg of mycelium divided into 1 1 kg, 4 250 g, or 16 62.5 g blocks in a square grid array. Each treatment was located at the points of a triangle 100 m from the others, and the set of three treatments was replicated at five different sites near Highlands, NC. Greater mushroom production attracted greater numbers of insects. However, when the replicates with the best fruiting success are analyzed, the data show that richness, diversity (H'), and the number of unique taxa within the replicate and the experiment as a whole all increased with increasing patchiness. These results show that resource spatial and temporal distribution alone alone can play an important role in structuring insect communities and perhaps in the origin and persistence of species as well.

PARMELEE, ROBERT W., JOHN M. BLAIR, PATRICK J. BOHLEN, SCOTT SUBLER AND MICHAEL F. ALLEN. Ohio State University, Columbus, OH, 43210, USA. Effects of earthworms on nitrogen cycling processes in agroecosystems.

Soil nitrogen pools were examined in corn agroecosystems with manipulated earthworm populations (reduction, ambient, addition) and different sources of nitrogen (legume, manure, inorganic). We report on soil extractable N, microbial biomass N and N-mineralization rates following three years of earthworm manipulations. We observed distinct seasonal effects corresponding with periods of high earthworm activity, and significant earthworm-nitrogen source interactions. Concentrations of extractable N have been consistently greater in earthworm addition plots, particularly in the inorganic N treatment. The effect of increasing N availability extends throughout the soil profile. The increase in N availability may be partially explained by the effects of earthworms on microbial biomass N; microbial biomass N has been consistently higher in the earthworm reduction plots compared to ambient and addition plots. Earthworms also appear to increase net nitrification rates seasonally in the inorganic treatment, with higher rates in the earthworm addition plots during the spring and fall. Our results demonstrate that earthworms can significantly influence the availability of N, and suggest that earthworms are key facilitators of nitrogen transformations in agroecosystems.

PARUELO, J.M.[1] and W.K. LAUENROTH. Dept. of Rangeland Ecosystem Sciences, Colorado State University, Fort Collins, CO 80532.[1] Permanent address: Dpto. Ecología, Fac. Agronomía, Universidad de Buenos Aires. Argentina. Functional characteristics of North American shrublands and grasslands at a regional scale.

We evaluated the functional characteristics of 43 grassland and shrubland sites using the seasonal dynamics of the Normalized Difference Vegetation Index (NDVI), derived from AVHRR/NOAA data. Average annual NDVI accounted for 65% of the variability of the SITExDATE matrix, and 15% was accounted for by the difference between the NDVI during the warmest and coldest months. Annual average NDVI is an estimate of primary production, and the difference between the NDVI of the warmest and coldest months is an estimate of the seasonality of the vegetation. Mean annual precipitation explained 65% of the variability in the annual average NDVI ($p < 10^{-4}$). Seasonality was related to both the mean annual temperature and precipitation ($r^2 = 0.65$, $p < 10^{-4}$).

PASCARELLA, JOHN B. University of Miami, Coral Gables, FL, 33124, USA. The effects of hurricane disturbance on reproduction in the tropical understory shrub Ardisia escallonioides.

The impact of hurricane disturbance on reproduction in the tropical understory shrub Ardisia escallonioides (Myrsinaceae) was examined using four populations in south Florida that experienced differential hurricane disturbance from Hurricane Andrew (Aug. 24, 1992). There was no reproduction in an undamaged forest population while reproductive activity (% stems flowering, # inflorescences produced) increased significantly over 1991 (prehurricane) and 1992 (immediate post-hurricane) levels in three damaged forest populations. Seed predation from a specialist insect predator decreased significantly from prehurricane levels due to temporal and spatial escape. Seed production increased fifteen to ninety times prehurricane levels. The demographic effect of increased seed production will be examined using matrix models of population dynamics.

PATHEJA, MANMEET K. and NORMAN L. CHRISTENSEN JR. USDA Forest Service, Cadillac, MI, 49601, and Duke University, Durham, NC, 27705. Spatial and temporal distribution of mortality of American chestnut sprouts in the understory of an upland oak-history forest in Virginia.

The change in structure of American chestnut (***Castanea dentata*** [Marsh.] Borkh.) populations was estimated from 1987 to 1992 at the University of Virginia Mountain Lake Biological Station. Population changes were measured in terms of stems per hectare, clumps per hectare, and importance value, measured as chestnut basal area over total basal area. Spatial distribution of clumps and mortality of clumps between 1987 and 1992 was analyzed by mapping clumps on an X-Y grid and testing for deviation from a random distribution with chi-square analysis. Net mortality of stems equaled 36 percent of the total population, with the greatest net change occurrring in the largest and smallest diameter classes. Living clumps in 1987 were randomly distributed while living clumps in 1992 were aggregated. Total number of clumps per hectare decreased 16 percent. Clump mortality was localized and non-random. Total chestnut basal area decreased from 2.4 meters sq. per hectare in 1987 to 0.8 meters sq. per hectare in 1992.

PATRICK, PAUL H., ANTHONIE M. HOLTHUIJZEN, NARAYAN RAMANI, RON SHEEHAN, WILLIAM G. HANSON and JOHN W. HUCKABEE. Ontario Hydro, Toronto, Ontario M8Z 5S4, Canada, Idaho Power Company, Boise, ID 83707, USA, and Electric Power Research Institute, Palo Alto, CA 94303, USA. Biodiversity monitoring using an Intelligent Automated Monitoring System.

Biodiversity monitoring is a crucial aspect of environmental monitoring. Collecting data on rare or difficult to survey organisms is labor intensive and expensive. To collect consistent, high-quality auditory wildlife data an Automated Intelligent Monitoring System is being developed. The proto-type recorder is an intelligent, multi-channel audio-band recorder. Acoustic data are stored digitally on the computer's hard disk. Pattern recognition software analyzes data in both time history and frequency domain, extracts pertinent statistical information, and reduces and verifies data. Field trials in both temperate and tropical environments have been successful. Auditory signals can be collected consistently and at lower cost than using human observers. System development will include relative abundance estimation of calling organisms, incorporation of an ultrasonic band, refinement of software, and miniaturization of hardware.

PATTEN, DUNCAN T., JULIET C. STROMBERG, JANA FRY, MILTON R. SOMMERFELD and CHRISTINE KRAMER. Arizona State University, Tempe, AZ 85287 USA. Interrelationships among land use, water use, riparian communities and water quality on an effluent dominated river in the Southwest.

The Santa Cruz River in southern Arizona originates in the United States in ranching country, flows through ranching and agricultural land in Mexico, returns into the United States adjacent to an urban/industrial area and then flows into an area

being rapidly developed as a resort/residential complex. Models have been developed that demonstrate the interrelationships among land use, water management, water quality and riparian vegetation. Water quality of the river is influenced by water diversion, groundwater withdrawal and inflow, agricultural inflow, urban effluent discharge and riverine/riparian nutrient uptake or sequestering. Water management and agriculture have negatively influenced riparian vegetation recruitment and maintenance, thus reducing the potential for riparian "cleansing" of the river. Increased urban development has increased groundwater withdrawal which has reduced riparian communities, but has also increased effluent discharge which has stimulated growth of riparian vegetation. Increasing urbanization has accentuated the contamination of the river, thus emphasizing the need to maintain a fully functional riparian ecosystem to improve and maintain water quality.

PATTERSON, C. STUART, C. R. LEE and D. L. BRANDON. AScI Corporation and U. S. Army Corps of Engineers Waterways Experiment Station, Vicksburg, MS, 39180, USA. Dredged material acceptability based on relationships among sediment characteristics and test results.

Sediment characteristics and test results for three dredging projects in San Francisco Bay have been evaluated to develop relationships to predict contaminant migration in aquatic environments. Sediment characteristics included particle size, organic carbon, volatile solids, oil and grease, metals, butyltins, PAH's, PCB's and pesticides. Test results included survival (6 species) and bioaccumulation of butyltins, metals, PAH's, PCB's and pesticides (Macoma nasuta and Nephtys caecoides), and these variables were related to the sediment variables using multivariate statistical techniques. PAH's comprised the first variate pair in canonical correlations for both M. nasuta and N. caecoides. Multiple regressions predicting survival and tissue contaminant concentrations from sediment variables had R-square values ranging from 0.07-0.59 and 0.13-0.89, respectively.

PAULEY, E.F., S.C. NODVIN, T.B. COFFEY, A.K. ROSE, and N.S. NICHOLAS. NBS-Cooperative Park Studies Unit, Univ. of Tennessee, Knoxville, TN, 37910, USA. Vegetation, biomass, and nitrogen pools in a Great Smoky Mountains watershed.

Unlike most forest systems, high-elevation spruce-fir forests in the Great Smoky Mountains are N saturated. Most mature fir have been recently killed by an exotic insect pest. Here we document species composition, biomass, and standing N pools of the forest overstory in an un-logged 17.4 ha watershed. Fir, formerly abundant, is now minor overstory component (mostly of small individuals at high elevations). Spruce comprised 77% of live basal area, 48% of live density, and 79% of total live biomass. Spruce biomass was high on south-facing slopes but showed local peaks throughout the watershed. Yellow birch biomass was high on low-elevation east-facing slopes near streams. Spruce contained 71% of the total live overstory N, while fir contained less than 2%. Although spruce foliage comprised less than 6% of total live biomass, 37% of the total N content was in spruce needles. The spatial distribution of overstory N corresponded strongly to peaks of spruce and/or birch. Overall, some species distributions reflected well-known landscape patterns (e.g., increasing fir importance with elevation), while distributions of other species (e.g., spruce and birch) more closely reflected smaller-scale topographic and possibly disturbance-oriented patterns. Thus, vegetation patterns at several spatial scales influenced the amount and spatial distribution of N in the overstory.

PEARSON, SCOTT M. and MONICA G. TURNER. University of Tennessee, Knoxville, TN, 37996, USA and Oak Ridge National Laboratory, Oak Ridge, TN, 37831, USA. Impacts of land-cover change on native species in a Southern Appalachian watershed.

Anthropogenic land-cover changes can alter the abundance and spatial pattern of natural habitats. Changes in habitats have consequences for native plant and animal populations. A land-cover change model has been developed for the Little Tennessee River Watershed. In this model, land-cover change is driven by social, economic, and ecological characteristics of the landscape. We developed a species-impact module to monitor the effects on native species of landscape changes projected by the land-cover change model under different socioeconomic scenarios. The species-impact module utilizes species characteristics, such as habitat needs, area requirements, sensitivity to edge, survivorship, and dispersal capability, to project the effect of landscape changes on population size and persistence. The module projects the impact on a diverse group of species, ranging from annual plants to large vertebrates. To explore the effects of habitat changes more generally, the species-impact module was used to estimate effects on populations for a broad range of landscape-level changes that would not be realistic for the Little Tennessee River Watershed.

PEART, D.. Dartmouth College, Hanover, NH 0375. USA. Evaluating forest decline at the population and community levels.

Forest decline implies community-level changes in total biomass, density and/or size structure. Species decline implies changes in survival, reproduction and/or growth. Demographic and time-series data for rigorous assessment of decline are sparse for most forests, including the spruce-fir forest and red spruce populations in the northern Appalachians. No clear decline is apparent from demographic data, which are mostly post-1985. The status of spruce-fir and red spruce has been assessed mainly from short-term studies of standing dead trees, age structure, and changes in basal area. While standing dead trees are visually striking, they provide no hard evidence for decline. Simple basal area re-measurements of species and stands in permanently marked plots provide the main evidence for red spruce decline in the Northeast. These studies are few in number (four), predate the intensive research effort of recent years, and represent a tiny fraction of that effort. Recent investment in more intensive monitoring will greatly improve future assessments.

PECHMANN, JOSEPH H.K. Duke University, Durham, NC, 27708, USA and Savannah River Ecology Laboratory, Aiken, SC, 29802, USA. Population regulation in complex life cycles: aquatic and terrestrial density-dependence in the narrow-mouthed toad, *Gastrophryne carolinensis*.

I manipulated densities of the narrow-mouthed toad at both stages of its life cycle to test where density-dependence occurred. My experiment was a 2 x 2 factorial design having four treatments: low aquatic density followed by low terrestrial density, low aquatic density followed by high terrestrial density, high-low, and high-high. Densities were 150 or 600 tadpoles per 1000 L pond and 60 or 240 metamorphs per 100-m^2 terrestrial pen. Survival to and size at metamorphosis were lower and date of metamorphosis later at high aquatic density than at low. Aquatic density also affected terrestrial survival; no individuals raised at high aquatic density survived to first reproduction. For toads from the low aquatic density treatment, size at and terrestrial survival to first reproduction was lower and male age at first reproduction later at high terrestrial density than low. These results suggest that populations of *Gastrophryne carolinensis* may be regulated in both stages of its life cycle.

PECK, STEVEN L. North Carolina State University, Raleigh, NC, 27606, USA. Spatial aspects of the population biology of insecticide resistant alleles in large inhomogeneous regions: a 2D cellular automata model.

Insecticide resistance has occurred in over 400 species of insects. Resistance is a genetic phenomenon and several factors influence the rate, persistence and general population dynamics of resistant alleles in insect populations. Most investigations of the evolution of insecticide resistance have been limited to small spatial scales and concerned with the frequency of the resistant alleles through time of the entire population, rather than the spatial mosaic and patterns found in the constituent metapopulations. Using object-oriented programming, I have developed a deterministic 2D cellular automata model on a 250X250 lattice. Each cell in the lattice represents an agricultural field containing a density dependent pest population with non-overlapping generations, of which a certain proportion migrate to adjacent fields at every time step. Several operational strategies, such as pesticide effectiveness and crop rotation, are considered in the model. Genetic aspects explored include the effect of the mode of inheritance, dominance relationships, initial gene frequencies, and the fitness of the resistant allele. The model demonstrates rich dynamics, including spatial limit cycles and chaos. The model has implications for how pests are managed on a regional scale.

PEDLAR, JOHN H. Carleton University, Ottawa, ON, KIS 5B6, CANADA. Reproportioning of a mid-sized mammal assemblage as a result of landscape alteration.

Self-registered tracking data for raccoons and skunks were collected from 112 sampling points distributed in non-cultivated areas throughout a 100 km x 40 km block of farmland. Vegetation data were collected at each track station and multiple logistic regression was used to model the relationship between woody vegetation and mid-sized mammal occurrence. Raccoon presence was significantly related to woody fencerows and increasing woody vegetation, particularly canopy trees. In contrast, presence of skunks was related to shrubby vegetation in more open areas. Based on these results, I predict that vegetation changes at the landscape level will reproportion this assemblage of mid-sized mammals. This prediction is in the process of being tested.

PEET, ROBERT K. University of North Carolina, Chapel Hill, NC 27599-3280, USA. Restoration of plant community structure: the importance of old-growth systems.

Southeastern ecosystems can be strikingly different in structure from those found in other regions. Deciduous forests of the Southeastern piedmont are distinctive in that their soils are highly infertile and species composition and diversity are strongly correlated with subtle variations in soil chemistry. The fire-maintained longleaf pine woodlands of the infertile Southeastern coastal plain can have small-scale species diversity as high as that found anywhere in the world. In both these cases, the distinctive features are easily lost through human activities and are difficult to restore. Where soils have been profoundly altered, both determination of the original vegetation structure and its restoration are difficult if not impossible. To guide restoration, a system of old-growth reserves is required in which not only old trees, but all components of the structure and dynamics of these systems are maintained. No old-growth reserve system can be viewed as adequate until comprehensive descriptive studies have identified the variation that needs to be included.

PEIRCE, ANDREA and KATHY S. WILLIAMS. San Diego State University, San Diego, CA, 92182, USA. Nutritional ecology of three subspecies of the checkerspot butterfly, Euphydryas chalcedona.

This study examined differences in larval behavior and digestive physiology among three subspecies of a southern California checkerspot butterfly. Two subspecies are monophagous and the third subspecies uses three related foodplants. Larval growth, survival, and consumption rates were compared among subspecies on all plants. Plants were assayed for nitrogen and water content. Performance of traditionally monophagous forms was greatest on their normal host and the closest

taxonomically related novel host. Performance of oligophagous forms was greatest on plants with highest nitrogen and water contents. Results are related to secondary (iridoid) chemistry.

PELTON, MICHAEL R. and JOSEPH D. CLARK. University of Tennessee, Knoxville, TN 37901, USA and National Biological Survey, Knoxville, TN, 37901, USA. Management of a wide-ranging species: black bear.

Great Smoky Mountains National Park (GSMNP) has served as a protected core of the Southern Appalachian black bear (*Ursus americanus*) population and the focus of 25 years of intensive research on this carnivore. The research has established demographic and habitat parameters for bears as a baseline for comparison and use throughout the rest of the occupied bear habitat in the Appalachians. Information on reproductive and mortality rates, denning ecology, movements, activities, foraging ecology, habitat use, and human-bear interactions has been gathered. The characteristics of this species (e.g., large size, use of habitats on a landscape scale, sensitivity to human perturbations, and potential for human interactions) necessitates a regional approach to resolve management conflicts and issues. To facilitate that coordination, a technical working group was established in 1976 which meets biennially. This group represents 4 state wildlife agencies, 4 national forests, and 1 national park with the University serving as team coordinator. The team functions to bring together regional habitat and population data for synthesis and analysis including hunter harvest, road kills, depredation reports, mast surveys, and bait-station survey results. This presentation summarizes results of this long term effort to manage a valuable regional wildlife resource.

PENIX, STEVE L. and KATHY S. WILLIAMS. San Diego State University, San Diego, CA, 92182. Interactions of Pacific peach tree borer larvae, Aegeria opalescens, (Lepidoptera: Sesiidae) and Agrilus quadriguttatus niveiventris larvae (Coleoptera: Buprestidae)on arroyo willow, Salix lasiolepis.

Many species of beetles are attracted to trees damaged by mechanical injury. Attacks from Pacific peach tree borer moth larvae Aegeria and buprestid beetle larvae Agrilus were widespread on arroyo willow at a revegetated riparian site in Santee, CA. This study examined whether buprestid beetles were attracted to arroyo willow damaged by moth boring. The damage that occurs from sesiid moth larvae was simulated, and injured branches were monitored for Agrilus larvae attack. Agrilus attack occurred significantly more to damaged, dying branches than to healthy, undamaged branches. Other types of damages which lowered willow branch health significantly increased Agrilus attack. This study suggests that some buprestid beetle species may serve as indicators of tree health, which would aid silviculture and the management of forest ecosystems.

PEREZ, CECILIA, A.[1,2], LARS O. HEDIN[2], and JUAN J. ARMESTO[3]. [1]Universidad de Chile, Santiago, Chile, and [2]Cornell University, Ithaca, NY 14853, USA. Patterns of nitrogen mineralization in unpolluted, old-growth temperate forests of southern Chile.

Old-growth temperate forests are thought to be characterized by a lack of limitation of nitrogen relative to light. Internal supplies of inorganic nitrogen from soil mineralization are expected to be relatively high in such old-growth forests. We here report on rates and spatial variations in nitrogen mineralization and nitrification in soils of old-growth forests which have not been subject to atmospheric nitrogen deposition. We evaluated whether patterns of nitrogen transformations in the soil can explain the apparent lack of internal supply of nitrate in these ecosystems. In addition, we examined differences in nitrogen transformations between forest communities dominated by gymnosperms (*Fitzroya cupressoides*), and angiosperms (e.g., *Nothofagus nitida*). Our preliminary results do not suggest any lack or inhibition of nitrification in soils, indicating that microbial and/or plant uptake may be important for reducing levels of nitrate.

PERIERA, JASON and SWIFT, C. Whittier College, Whittier, CA, 90608. Land conversion in Merced County, California.

Approximately one sixth of California's remaining wetland habitats can be found in Merced County, in the heart of the San Joaquin Valley. These wetlands support a wide array of wildlife , including migratory waterfowl using the Pacific flyway. Over the years, agriculture and urban development in Merced County have had a profound impact on wetland habitats in the area and consequently, the birds and animals closely associated with them. This study looks at the years 1946 and 1990 in Merced County. Using aerial photographs from these years, maps showing wetland, agricultural and urban areas were created using a geographic information system to document the changes in land use. From these maps, the trends that have led to changes in wetland habitat betwenn 1946 and 1990 can be identified. Although the study shows a decline in wetland extent over this time period, the decline is not a result of the conversion of wetlands to agricultural uses, but appears to correspond to an increase in conversion to urban land use. Conversion of wetlands to agricultural use is limited by the suitability of these areas for crop growth. The recent trend to convert agricultural land back to wetland habitat for the purpose of increasing waterfowl habitat for hunting may prove to be an important conservation tool in an area facing increasing pressure by development.

PERONI, PATRICIA A., TONIA KORVES, and MILES SILMAN. Davidson College, Davidson, NC, 28036, USA and Mountain Lake Biological Station, Pembroke, VA 24136, USA. Spatial patterning of age and size structure in striped maple (*Acer pensylvanicum L).*

In order to investigate spatial patterning of age and size structure in striped maple, an understory tree, we mapped all striped maple > 60 cm in height in a 20 X 100 m plot, determined the age, height, and basal diameter of each tree, and subjected these data to

analysis of semivariance. Pairs of trees separated by distances of < 8 m showed the greatest similarity in age and height, and these patterns may result from limited seed dispersal or coarse grained environmental variation. Pairs of striped maples showed the greatest similarity in diameter when separated by intermediate distances (12-18 m), and were least similar in diameter at distances of <12 m. In a sample of twenty-five 5 X 5 m quadrants randomly located in the study plot, density correlated positively with both the coefficient of variation for diameter and the mean height/diameter ratio, but showed no significant correlation with mean height. These results suggest that the spatial patterns observed for diameter reflect the results of intraspecific competition and that intraspecific competition in striped maple results in variation in diameter rather than height.

PERRY, DAVID A., MARLA L. GILLHAM, PETER HOMANN, and ROBERT GRIFFITHS. Oregon State University, Corvallis, OR, 97331. Effects of CO_2, temperature, and seedlings on soil organic matter contents, and C and N mineralization, in forest soils.

Soils from 500-year-old old-growth Douglas-fir forests in the Oregon Cascade Mtns. (900 m and 1200 m sites) were 'incubated' for 32 weeks in controlled-environment chambers. This factorial experiment had two levels each of atmospheric CO_2 (350/700 ppm), soil temperature (13/17°C), soil N (1200 m soils contained twice as much C and N than soils from 900 m), and vegetation (with/without seedlings). Exchangeable NH_4 was greater in the 900 m soils than in the 1200 m soils for all treatments except elevated CO_2, and net mineralized NH_4 was greater in 900 m soils for all treatments. Extractable NO_3 decreased from ambient (350 ppm CO_2, 13°C) in all treatments and in both soil types, and was greater in 1200 m soils. Total net N mineralized was greater in the 1200 m soils, at higher temperature, roughly following the pattern of net mineralized NO_3 which was greater in the 1200 m soils at higher CO_2, temperature, or both. These results suggest greater proportional NO_3 uptake in seedlings grown in the lower elevation, N-limited soils, and/or that soil C quality is higher in 900 m soils.

PESCADOR, ALFONSO R., FRANCISCO J. ESPINOSA-GARCIA and JIAN CHEN. Centro de Ecología, Universidad Nacional Autónoma de México, A.P. 70-275, México, D.F., C.P. 04510, México. Larval responses of a highly polyphagous caterpillar (Hylesia lineata) to intrapopulation variability of one of its natural hosts (Casearia corymbosa).

When H. lineata larvae switch hosts early in their development the previous feeding experience does not affect further growth. Moreover, females allocate more resources to egg production when fed a low quality host than when fed on a high quality one. These traits appear to select against feeding specialization. In addition, other sources of variation may contribute to polyphagy. For instance, intraspecific variation in host quality may prevent larval specialization if insect genotypes differ in performance across host individuals. In a field experiment using full-sib larval families and C. corymbosa trees we examined whether this performance variability occurred in a tropical deciduous forest in Jalisco, México. We enclosed 10 to 12 days-old larvae from each of three families in branches of 10 trees; we repeated the same design simultaneously with other three families and other 10 trees. Relative growth and survival after the first month were recorded. We found extensive variation in host quality among trees and significant family by tree interactions. Also, the observed larval performance range overlapped with that obtained in previous experiments with lower quality host species. Thus, for some H. lineata genotypes, low quality C. corymbosa trees are comparable to other tree species of lower quality. Therefore, wide and overlapping host quality ranges and insect genotype by tree interactions may favor polyphagy.

PETERSON, MERRILL A. and ROBERT F. DENNO. University of Maryland, College Park, MD, 20742, USA. Differentiation in migratory and sedentary populations of Prokelisia planthoppers.

Life history theory predicts that the dispersal strategies of phytophagous insects are shaped by the persistence and isolation of their host plant patches. These strategies may in turn influence levels of gene flow among populations, but this link is poorly documented. Populations of both Prokelisia marginata and P. dolus vary in dispersal capability with the persistence of their local saltmarsh habitats. In sites where the quality of their Spartina hostplants declines frequently, populations are more predominately long-winged than in highly persistent habitats. We examined the relationship between these habitat-mediated dispersal strategies and gene flow among Florida populations of both species using allozyme electrophoresis. Along the Atlantic Coast, where habitats are less persistent, populations of both planthoppers exhibit greater gene flow than among populations in the relatively persistent Gulf Coast habitats. Furthermore, gene flow across Florida is greater in P. marginata, which tends to be more prevalently long-winged than P. dolus.

PETREN, KENNETH, and TED J. CASE. University of California at San Diego. La Jolla, CA 92093-0116, USA. An experimental investigation into the manifold mechanisms of interspecific and intraspecific competition in a non equilibrium community.

We have documented the displacement of a native asexual gecko by an invading sexual gecko in urban/suburban habitats throughout the Pacific. Previous work shows the competitive displacement is asymmetric, occurs rapidly, and is facilitated by dense aggregations of insects around lights. A mechanism of interference was implicated whereby subordinate individuals of the displaced species avoided individuals of the invading species foraging near lights in the absence of directed agonistic interference. Here we test for other mechanisms, both interspecifically and intraspecifically, using a factorial replicated design which closely mimics natural conditions. We found significant effects on condition, survivorship and fecundity, and all detectable mechanisms involve food resource acquisition. Competition did not differentially effect individuals based on social status, as predicted by the subordinate avoidance mechanism. Direct measurement of insect abundance and harvest rates suggest that exploitation mechanisms may be operating. Significant differences in intraspecific agonism between species suggests that intraspecific interference may affect per capita foraging rates, and play a role in the mechanism of exploitation. This system presents an opportunity to study community-shaping competition in detail as it occurs, which may differ in mechanism and magnitude from competition observed in equilibrium communities.

PETTY, WILLIAM H. University of Tennessee, Knoxville, TN 37996, USA. Holocene vegetation history and Lake Michigan lake-level fluctuations on the southern shore of the Upper Peninsula of Michigan.

A 250-cm sediment core with a basal radiocarbon date of 7960 yrs BP was collected in June of 1993 from Elbow Lake, Mackinac Co., Michigan. Radiocarbon dates and fossil pollen preserved in lake sediments indicate that changes in vegetation are related to changes in climate and proximity to the Lake Michigan shoreline. Basal radiocarbon dates on sediment cores from a transect of ponds combined with tree-ring cores and GLO surveyor notes of a shipwreck reveal an average late-Holocene rate of regression of 3 feet per year. The pollen record, sediment stratigraphy, and sediment accumulation rates show that this general retreat of the shoreline was punctuated by periodic high stands. Radiocarbon dates of ~6900 yrs BP indicate a high stand of Lake Michigan during the late-Chippewa stage of Lake Michigan, prior to the classically recognized Nipissing-I high stand at ~4500 yrs BP. Pollen percentages for *Tsuga canadensis* and *Fagus grandifolia* both reach >1% by 5500 yrs BP, indicating that the northern shore of Lake Michigan provided suitable habitat for colonization by these species. Establishment of *F. grandifolia* at this time is associated with a rise in water table and is ~2000 years prior to its expansion into the interior of the Upper Peninsula after 3500 yrs BP. A further increase in mesic hardwoods along with *T. canadensis* to their modern level by 2200yrs BP is associated with an increase in sediment accumulation rate, indicative of a rising lake level and moister climate.

PFITSCH, WILLIAM A.[1], ERIK C. P. WARDENAAR[2], and DAVID TILMAN[2]. [1]Hamilton College, Clinton, NY, 13323 USA and [2]University of Minnesota, St. Paul, MN, 55108, USA. Water and nitrogen relations of three common tallgrass prairie perennials in response to experimental drought.

What attributes are most helpful for explaining differences in performance during severe drought? A six-week drought was imposed with rainout shelters over plots in an oldfield plant community. The average predawn water potential of rainout individuals declined to -1.8, -0.7, and -0.35 MPa for *Aster azureus*, *Solidago nemoralis*, and *Sorghastrum nutans* respectively. In contrast, the daily maximum photosynthesis of rainout plants of all three species declined to 40% of controls. The C_4 grass *Sorghastrum* had much higher water (WUE) and nitrogen (NUE) use efficiencies than the C_3 herbs. *Aster* and *Solidago* had a tradeoff between WUE and NUE. The success of *Sorghastrum* during drought is due to the resource efficiency of C_4 photosynthesis and access to deep soil moisture. Differences in drought performance of *Solidago* and *Aster* cannot be attributed to gas exchange physiology, but may reflect differences in rooting depth.

PHILIPPI, THOMAS E., and ROBERT K. PEET. University of North Carolina, Chapel Hill, NC 27599 USA. A model of optimal life-histories for tree seedlings: allocation to growth versus belowground reserves.

We start with the observation that tree seedlings in the Piedmont of North Carolina grow very slowly: taking 20 to 30 years to attain even 1m height. Further, a substantial number of seedlings appear to die back and resprout from ground level in subsequent years. Our model attempts to determine if such life-history patterns could have evolved as a response to infrequent disturbances such as heavy browsing or ground fires. Seedlings acquire resources in direct proportion to their aboveground biomass. Each year, seedlings allocate new resources between aboveground biomass, which increases future resource acquisition, and belowground reserves, which increase the probability of surviving to resprout. Disturbance events, occurring with a constant probability each year, remove all aboveground biomass and potentially kill seedlings smaller than a threshold size. The optimality criterion is the probability of surviving to reach an arbitrary safe aboveground size. A simplified, mathematically-tractable version and a biologically reasonable version requiring simulation produce similar results. Under some conditions, slow growth and allocation to reserves is the optimal life history. Increasing frequency of disturbance and reducing maximum potential growth rates increase the optimal allocation to reserves.

PHILLIPS, DONALD L.[1] and DANNY G. MARKS[2]. [1]U.S. Environmental Protection Agency and [2]U.S. Geological Survey, USEPA Environmental Research Laboratory, Corvallis, OR, 97333, USA. Spatial uncertainty analysis of a potential evapotranspiration (PET) model.

In simulation modelling, it is desirable to quantify model uncertainties and provide not only point estimates for output variables but confidence intervals as well. Spatially distributed physical and ecological process models are becoming widely used, with runs being made over a grid of points that represent the landscape. This requires input values at each grid point, which often have to be interpolated from irregularly scattered measurement sites, e.g., weather stations. Interpolation introduces spatially varying errors which propagate through the model. We modelled PET for 3 time periods in water year 1990 as a function of temperature (T_a), humidity (e_a), and wind (u) on a 10 km grid across the U.S. portion of the Columbia River Basin. T_a, e_a, and u were interpolated using kriging from 700-1000 supporting data points. Kriging standard deviations (SD) were used to quantify the spatially varying interpolation uncertainties. For each of 5693 grid points, 100 Monte Carlo simulations were done, using the kriged values of T_a, e_a, and u, plus random error terms determined by the kriging SDs and the correlations of interpolation errors among the 3 variables. Maps of PET means and SDs showed the spatial patterns of PET with a measure of its uncertainty due to interpolation of the input variables. This methodology should be applicable to a variety of spatially distributed models using interpolated inputs.

PICKER, MIKE D. University of Cape town, Rondebosch 7700, RSA. Adaptive cannibalism in Xenopus (Anura: Pipidae).

To determine if larval cannibalism is an adaptive component of the life cycle of Xenopus, I used a stomach lavage to examine the diet of the endangered X. gilli in relation to prey availability. Conspecific larvae were a dominant component of the female diet, whereas males consumed a greater diversity of smaller items. Prior to the first spawning, females preyed heavily on another species of tadpole. Selectivity indices showed that X. gilli larvae are taken in proportion to their natural abundance, whereas insect larvae are 'avoided'. The

greater prevalence of cannibalism in females is probably related to nutritive requirements of the developing ovaries. It is suggested that adults broadcast numerous filter feeding larvae to collect nutrients from a source unavailable to the adults (nanoplankton). Surplus tadpoles thus provide adults with nutrients from waterbodies having limiting amounts of animal protein.

PIER, P.A.[1], F.C. THORNTON[1], H. NEUFELD[2], J.R. SEILER[3], and J.D. HUTCHERSON[2]. [1]Tennessee Valley Authority, AL, 35660; [2]Appalachian State University, NC, 28608; [3]VPI and SU, VA, 24061-0324.
Cloudwater and O_3 Effects on Red Spruce at Whitetop Mt., VA: Physiological Response.

Results of studies on red spruce (Picea rubens Sarg.) at Whitetop Mountain (elevation 1689 m) were assessed to evaluate whether acidic cloudwater deposition and O_3 contribute to reported high elevation red spruce ecosystem decline. Studies were conducted using seedling exclusion chambers, mature tree branch exclusion chambers, and field experiments with seedlings, saplings, and mature trees. Ozone had minimal effects on the measured parameters. Photosynthetic response to cloudwater varied, dependent on tree age. Seedling respiration tended to decrease with cloudwater removal, although biomass accumulation was not affected. A 3° to 5° C increase in cold tolerance was measured in seedlings with cloudwater excluded. Chlorophyll and epicuticular wax concentrations were not significantly affected. Physiological responses to cloudwater may be caused by the observed depletion of needle cations, particularly Ca, which appear to be due to foliar leaching and to increased soil Al concentrations, which can interfere with cation uptake by roots.

PIERSON, ELIZABETH A. and JOSEPH R. McAULIFFE. U.S. Geological Survey, Tucson, AZ, 85754, USA and Desert Botanical Garden, Phoenix, AZ, 85008, USA. Ecological processes and consequences of invasion by the South African shrub Euryops multifidus in the southwestern United States.

Euryops multifidus (Asteraceae) was introduced to Arizona from South Africa by the USDA Soil Conservation Service in the mid-1930's. The spread of this shrub represents one of the most serious threats to the ecological integrity and economic value of several ecosystems in the American Southwest. In southern Arizona, this shrub readily invades vegetationally intact, semi-arid grasslands and eventually forms virtually uninterrupted monocultures from which native grasses, shrubs, and succulents are almost completely excluded. Study of plant responses at the advancing front of an area occupied by Euryops indicated that mortality and exclusion of native species are due to a competitive mechanism. These dramatic vegetation alterations are persistent and lead to a variety of additional detrimental changes, including marked increases in soil erosion.

PIETERS, ALEJANDRO and ZDRAVKO BARUCH. Universidad Simón Bolívar. Dpt. Estudios Ambientales. Aptdo. 89000, Caracas 1080. VENEZUELA. Effect of soil depth and fertility on growth, biomass and nutrient allocation of the invader grass Hyparrhenia rufa in a Neotropical savanna.

The African grass Hyparrhenia rufa has invaded the savannas of Venezuela except in sites with a superficial lithoplinthic hardpan. To study this, we designed an experiment where fertilization and fracture of the hardpan were applied to plots sown with H. rufa. Only fertilization was significant promoting growth, it also increased total and organ biomass ~ 1000 % with the highest proportion allocated to reproductive tillers. In unfertilized plants, leaves had the highest proportion (~ 40%) whereas the root / shoot ratio was 0.25 - 0.30 under all treatments. Fertilized plants also had the highest content of N, P, K due to increased biomass. N concentration was ~ 50 % higher in roots of all treatments whereas leaves of unfertilized plants had the highest N concentration. P and K concentrations were similar among vegetative organs but ~ 400% higher in the reproductive tillers of fertilized plants. Soil fertility but not depth limits the invasion and growth of H. rufa in savannas with superficial lithoplinthic hardpan. H. rufa showed plasticity in phenology, architecture, production and nutrient and biomass allocation in response to fertility. This, and its high growth potential and oportunistic water use, are partially responsible for the success of H. rufa.

PILMANIS, ADRIENNE. Duke University, Durham, NC, 27706, USA. **Post-glacial vegetation and fire history of a northwestern Ontario lake.**

Few paleoecological studies of pollen and charcoal deposition in annually varved lakes have been done in northwestern northern Ontario. Reconstruction of Holocene vegetation and fire history in this area is incomplete. A 4-meter sediment core was taken from "Northwest Lake", Ontario, a small varved lake. Pollen analysis results indicate that the early vegetation community in the area was herbaceous, and was followed by first spruce parkland and then by spruce forest. Subsequent communities were pine-dominated until an important mid-to-late-Holocene increase in the abundance of *Thuja* (cedar), which parallels Cupressaceae increases elsewhere in northern Ontario. *Thuja* remained abundant in the community through the present. The current community is dominated by *Picea mariana* (black spruce) and *Pinus banksiana* (jack pine). Analysis of charcoal accumulation is in progress. The results of this study provide valuable information regarding Holocene paleoecology in a remote and largely inaccessible region.

PILSON, D. University of Nebraska, Lincoln, NE, 68588, USA. Multiple herbivores and natural selection for resistance to herbivory in *Brassica campestris*.

Theory suggests that the effect on plant fitness of multiple herbivores feeding simultaneously may not be predictable by examining each herbivore in isolation. Two mechanisms through which multiple herbivores may affect the outcome of natural selection for plant

resistance, indirect interactions between herbivores and non-additive effects of herbivory on fitness, were evaluated for *Brassica campestris* (wild mustard). I performed a 3-way factorial experiment that included seven full-sib plant families, the presence or absence of flea beetles (*Phyllotreta cruciferae* Coleoptera: Chrysomelidae) and the presence or absence of diamondback moths (*Plutella xylostella* Lepidoptera: Plutellidae). Indirect interactions between herbivores occur when resistance to a later-feeding herbivore (diamondback moth) depends on whether or not an earlier-feeding herbivore (flea beetle) was present. ANOVA detected no indirect interactions. Non-additive effects of herbivory occur when the effect of feeding by one herbivore on plant fitness depends on the amount of herbivory by a second herbivore. Strong non-additive effects were detected by multiple regression. Further, the form of the non-additive effect varies among plant families. Thus, which families are favored by natural selection depends critically on the relative frequency of these two herbivores. These results indicate that the evolution of resistance to flea beetles and diamondback moths does not proceed independently in this *Brassica campestris* population.

PLATT, WILLIAM J. Louisiana State University, Baton Rouge, LA, 70803, USA. The importance of evolutionary models of plant population and community dynamics in conservation biology.

Models of change over time within plant communities traditionally have been based on concepts of succession. When disturbances occur frequently, they have been suggested to result in adaptations to withstand those disturbances, producing a "disclimax" state. If species influence the nature of the disturbance or modify the disturbance regime, however, evolutionary histories become unique pathways dependent on the species and their interactions with the disturbance. Disruption of such systems by man can easily remove unique environments created by "co-evolution" of plants and disturbances. Reconstruction of these unique environments, critical for conservation of such habitats, requires knowledge of evolutionary relationships between plants and recurrent disturbances. Conservation of southeastern habitats, such as longleaf and south Florida slash pine savannas, which are characterized by frequent growing season fires fueled by pyrogenic needles and other flammable vegetation, will require such evolutionary models. Study of old-growth habitats and effects of variation in disturbance regimes on vegetation dynamics will facilitate development of models for such systems.

POCKMAN, W. T. and J. S. SPERRY. Department of Biology, University of Utah, Salt Lake City, UT 84112, USA. The relationship between vulnerability to cavitation and the annual range of soil water potential in woody perennial vegetation of the Sonoran desert.

Vulnerability to cavitation, plant and soil water potential and xylem embolism were measured in stems of a riparian tree (*Salix gooddingii*), a desert tree (*Prosopis velutina*) and a desert shrub (*Larrea tridentata*) in the Sonoran desert to test the prediction that vulnerability to cavitation is related to the annual range of soil water potential encountered by a species. *Salix gooddingii* exhibited high and constant water potentials and was most vulnerable to cavitation while *L. tridentata* showed a large variance in water potential and was the most resistant to cavitation and *P. velutina* was intermediate in both parameters. Both *P. velutina* and *L. tridentata* cavitate over a broad range of xylem pressures suggesting they maintain water transport during periods of extended drought but *S. gooddingii* cavitated completely over a narrow range of high xylem pressures suggesting that it cannot tolerate substantial soil drying. None of the species studied exhibited a detectable increase in native embolism levels during the period April - November, 1993.

PODNIESINSKI, GREG S. and DONALD J. LEOPOLD. SUNY-College of Environmental Science and Forestry. Syracuse, NY, 13210. Vegetation organization in forested sapric peatlands along hydrology, microtopography and water chemistry gradients.

Forested, sapric peatlands in Central New York State are currently a focus of conflict between regulatory agencies and peatland-dependent agricultural interests. Resolution of this conflict is hampered by a poor understanding of the physical and ecological processes of these systems. The purpose of this study was to examine plant community organization along existing environmental gradients in five forested sapric peatlands as a first step towards developing a knowledge-based advisory model for peatland impact assessment, management, and restoration. pH, specific conductivity and calcium ion concentration indicate moderate to strongly minerotrophic conditions over all or most of each peatland site; and that local and site-wide differences in hydrology and microtopography have a greater influence on community composition than water chemistry. Hummock and hollow microtopography is positively correlated with plant species diversity, reflecting increased microhabitat diversity.

POLGREEN, GRETCHEN J., JAMES S. COLEMAN, and RICHARD L. HALLBERG. Syracuse University, Syracuse, NY, 13244, USA. Plant nutrient availability and thermotolerance: linking ecological and molecular approaches.

Acute increases in temperature can induce the production of heat shock proteins (HSPs) in seedlings and these HSPs may be necessary for seedling survival. Yet, there have been no ecological studies of whether inter-plant variation in HSPs relates to differential plant performance under fluctuating temperatures. In this study, we asked whether corn plants growing in high or low nutrients exhibit different patterns of HSP60 accumulation when exposed to acute heat stress, and whether variation in HSP60 accumulation correlates with recovery of plant growth and photosynthesis after heat shock. We found: 1) HSP60 was induced to similar levels regardless of nutrient conditions. However, HSP60 reached maximum levels 24 hr after heat shock in

low nutrient plants but not until 48 hr in high nutrient plants. 2) Following heat shock, high nutrient plants generally recovered growth and photosynthetic rates more slowly, and to a lesser extent, than low nutrient plants. This correlated with the overall pattern of HSP60 accumulation. Thus, by linking ecological and molecular approaches, we showed that plant nutrient availability can affect the pattern of HSP induction after acute heat stress and that changes in this pattern may relate to changes in thermotolerance.

POLIS, GARY A. and STEPHEN HURD. Vanderbilt University, Nashville, TN 37235, USA. High densities of spiders, scorpions and lizards on islands in the Gulf of California: flow of energy from the marine to terrestrial food webs and the absence of predation.

Some small islands support high densities of spiders (Metepiera, Argiope, Latrodectus), scorpions (Centruroides) and lizards (Cnemidophorus, Uta), 2->100x greater than on large islands or the adjacent mainland. In most years, most energy for these populations comes from the ocean, not in situ productivity by land plants. Marine energy enters terrestrial food webs via two conduits: marine birds and shore drift (carrion and algal detritus). On small islands, such input is several orders of magnitude greater than in situ productivity. We explicitly connect the marine and terrestrial systems to show that insular webs are one endpoint of the marine web. Although productivity sets the maximal potential densities realized abundance is limited by predation (e.g., spider abundance by scorpion predation). Thus prey availability and predation act in concert to set insular spider abundance.

POLLEY, H. WAYNE, HYRUM B. JOHNSON and HERMAN S. MAYEUX. USDA-ARS, Temple, TX, 76502, USA. Increasing CO_2 from glacial to present concentrations alters nitrogen and water requirements of C_3 plants.

Nitrogen and water use efficiencies were measured for three C_3 species, annual grasses Bromus tectorum (cheatgrass) and Triticum aestivum (wheat; two cultivars) and a woody perennial Prosopis glandulosa (mesquite), grown at daytime CO_2 concentrations that spanned glacial to present atmospheric levels. Changes in nitrogen and water use efficiencies were used to investigate effects of increasing [CO_2] on the relative requirements of C_3 plants for these resources. Whole-plant water use efficiency (WUE) increased at higher [CO_2] in all species and treatments (water availability, competition), but proportional changes in WUE were variable. Leaf intrinsic WUE, calculated from stable carbon isotopes in plants, increased by about the same fraction as [CO_2] in all species. Plant nitrogen use efficiency (NUE) rose at higher [CO_2] in only two of eight species and treatment combinations. The more consistent increase in WUE than NUE in these species at higher [CO_2] implies that in the past, plants were relatively more water-limited or required less nitrogen per unit of water than today. Plant response to rising [CO_2] therefore may have been less constrained by nitrogen availability in the past than it will be in the future.

POLLOCK, MICHAEL M. and ROBERT J. NAIMAN. Center for Streamside Studies, AR-10, University of Washington, Seattle, WA, 98195, USA. Response of plant species richness to changes in flooding regimes in a pristine Alaskan watershed - the intermediate variability hypothesis.

We have examined local patterns of floristic richness in a southeast Alaskan watershed to determine which communities are most diverse. Collectively, wetlands contain 94% of all plant species found in the watershed, while all uplands contain 38%. Riparian wetlands occupy less than 5% of the watershed, yet contain 74% of all species. Beaver impoundments within riparian communities, occupying less than 0.5% of the watershed, contain 41% of all species. We hypothesized that at the community level, species richness in wetlands was correlated to the variability of the flooding regime, and that increased variability should be correlated with increased species richness. Preliminary results indicate that species richness increases with increased daily variability of the flooding regime, but at high levels of variability, richness declines, suggesting that an intermediate level of variability is optimal for maintaining high floristic species richness in these wetland communities.

POPE, SHEALAGH E., LENORE FAHRIG, JOHN H. PEDLAR, PHILIP D. TAYLOR and JOHN F. WEGNER. Carleton University, Ottawa, ON, K1S 5B6, CANADA. Effect of Road Traffic on Amphibian Density.

We studied the effect of traffic density on local abundance of anurans (frogs and toads). We counted dead and live frogs and toads per km and estimated frog and toad local abundances using breeding chorus intensities, on similar roads through similar habitats with different levels of traffic intensity. After correcting for effects of date, local habitat, time and region, our analyses demonstrated that (i) the number of dead and live frogs and toads per km decreased with increasing traffic intensity, (ii) the proportion of frogs and toads dead increased with increasing traffic intensity, and (iii) the frog and toad density, as measured by chorus intensity, decreased with increasing traffic intensity. Taken together, our results indicate that traffic mortality has a significant negative effect on local density of anurans. Our results suggest that recent increases in traffic volumes worldwide are probably contributing to observed declines in amphibian populations, particularly in populated areas.

PORAZINSKA, DOROTA; DAVID C. COLEMAN; C. RONALD CARROLL and SUSAN ANDREWS. University of Georgia, Athens, GA 30602-2202, USA. Plant/animal interaction in the belowground system.

There are suggestions that some secondary compounds secreted from roots into the rhizosphere act as inhibitors of belowground fauna. To investigate the effect of some of these exudates on organisms present within the soil community, various species of plants in the Cucurbitaceae were used (C. maxima and C. andreana). The plants are characterized by various concentrations of triterpenoid cucurbitacins. Populations responses of genera of bacterivorous (Acrobeloides) as well as fungivorous (Aphelenchus) nematodes were assessed. The survival of nematodes was significantly decreased in soils with larger amounts of cucurbitacins.

PORTER, JAMES W., OUIDA W. MEIER, JENNIFER I. TOUGAS, and SARAH K. LEWIS. Institute of Ecology, University of Georgia, Athens, GA 30602, USA. Modification of the South Florida hydroscape and its effect on coral reef survival in the Florida Keys.

Tropical coral reefs require water of high clarity (shallow irradiances of up to 2,500 $\mu E\ m^{-2}s^{-1}$), high oxygen content (5.0 - 6.0 mg O_2/l), low turbidity (0.1 mg/l), low nutrients (0.01 - 1.0 μm N and P), stable temperatures (22- 30 °C), and stable salinities (33-36 ppt). Reefs in the Florida Keys are losing live coral cover at rates between 4% and 10% per year. After ten years of monitoring coral populations in the Florida Keys, we present evidence to connect accelerating coral mortality with the interruption of historical flows of nutrient-poor freshwater from the Everglades into Florida Bay. Specifically, we demonstrate the presence of hypersaline Florida Bay water on offshore coral reefs (the frequency and duration of these episodes is as yet unknown). Further, we show delayed mortality of bleached coral following periods of abnormally elevated sea surface temperature. Finally, we demonstrate the deletrious effect of Mississippi River flood water on coral pyhsiology. We contrast the startlingly minor damage to coral reefs caused by Hurricane Andrew with the previous decade of coral loss, which occurred in the absence of physical disturbances in the Florida Keys.

PORTER, JOHN H. and JAMES L. DOOLEY, JR. University of Virginia, Charlottesville, VA 22903, USA. Spatial sampling designs for detecting animal movements.

The ideal spatial sampling design for collecting movement data would sample movements equally across distances. Unfortunately, many of the designs used by ecologists have been far from ideal in this respect. Examination of designs drawn from the ecological literature using a Monte-Carlo simulation model indicates that raw movement data can be profoundly affected by the underlying distribution of sampling points. Several methods of reducing bias have been used. These either apply a weighting scheme to a theoretical distribution being compared to the data, or weight data based on the probability of observation at each distance. Using the latter method, the binomial distribution can be used to obtain both estimates of central tendency and variance for each distance class. We use a Monte-Carlo simulation model to assess the degree of distortion of movement distributions and efficiency of sampling for a variety of field sampling designs based on: shape of the sampling area (circular, square, rectangular, linear), pattern of sampling points within that area (random, regular, web), and density of sampling points. We also examine how selecting of subsets of observed movements can be used to eliminate distance-based sampling bias in these designs.

PORTER, KAREN G. Institute of Ecology, University of Georgia, Athens, GA, 30602-2202, USA. Integrating the "microbial loop" into the classic planktonic "food chain": insights into food web theory from a small, southeastern monomictic lake, Lake Oglethorpe, GA

Daphnia are considered keystone species, making both algal and bacterial production available to higher trophic levels (Stockner and Porter 1988, Pace 1993). However, during summer stratification in Lake Oglethorpe, a bacteria-flagellate-ciliate-rotifer community dominates, cladocerans are rare, and predatory *Chaoborus* and larval fish are both abundant, feeding on rotifers and ciliates. Microbially based consumers can therefore exert both top-down and bottom up control on cladocerans: bacteria and flagellates are food resources while ciliates and rotifers are competitors and also food resources that promote high abundance of invertebrate and vertebrate predators. Polis' food web model of consumer subsidy via "different channel omnivory" is the best theoretical description of this integrated pelagic food web. It is predicted to also occur in late summer, in eutrophic northern lakes and ponds.

PORTER, WARREN P., KENT HATCH, ISABEL TREICHEL, MARK COOK and RICHARD K. DWELLE. University of Wisconsin, Madison, WI, 53706, USA. A new technology for determining food intake and anabolic vs catabolic status of free ranging animals in the field.

We have developed and tested a new approach to determining energetic status of animals in the lab or field. It allows researchers to determine catabolic or anabolic status and the duration of that status from instantaneously, to the last three days, to the last three months, to longer periods of time. It does not require the injection of substances. The method can be used non-invasively, it is non-radioactive, inexpensive and field portable. It can be used to determine whether an organism is initiating a response to an infection as

the response is being initiated. The method can be used to monitor large numbers of organisms of virtually any size. It is a patent applied for process and utilizes state of the art technology.

PORTH, ADAM, NANCY HUNTLY, and JAY E. ANDERSON. Idaho State University, Pocatello, ID, 83209, USA. Effects of cyclically high populations of black-tailed jackrabbits (Lepus californicus) on sage-steppe vegetation and nitrogen budget.

Black-tailed jackrabbit density peaks ca. every decade in sage-steppe habitat of western North America. We studied black-tailed jackrabbits during a population high in Idaho and found they congregated during winter in areas of taller sagebrush. We estimated two such concentrations to contain 2000 animals over 4 km^2. Overwinter mortality was ca. 100%, resulting in 0.5 and 0.2 carcasses/m^2 in the two sites. Patches of urine and fecal pellets were abundant, with fecal pellets averaging 49 g/m^2 vs 1 g/m^2 in concentrations vs controls. Total N concentration of the snowpack in these areas was 17.4 mg/l as opposed to 4 mg/l in adjacent control sites ($p<.001$). Total soil nitrogen was 0.19% vs 0.11% in control areas ($p <.001$). Plant tissue nitrogen also was significantly higher in concentration areas. These results suggest that jackrabbits may influence mesoscale patterns of vegetation and nitrogen dynamics in sage-steppe.

POST, W. M., A. W. KING, and S. D. WULLSCHLEGER. Oak Ridge National Laboratory, Oak Ridge, TN, 37831, USA. The response of global carbon storage in soils and net ecosystem production to changes in climate and atmospheric CO_2.

Globally, soils contain two or three times as much carbon as living biomass. The amount of carbon in soil is determined by two biotic processes — productivity of terrestrial vegetation and decomposition of organic matter. Decomposition processes have strong physical and biological controlling factors. A modified version of the Rothamsted Turnover model was used to evaluate response of soil carbon, globally, to changes in atmospheric CO_2 and climate. Using information on climate and soil texture, computing soil moisture and organic matter inputs, we employed the model model at a grid scale of 0.5° latitude and longitude. With no change in climate, increased litter inputs due to a doubling of atmospheric CO_2 resulted in increases of 11-22% in soil carbon depending on the choice of CO_2 response function. Using current CO_2 concentration, changes in climate from a set of five atmospheric GCMs yield 5-10% decreases in soil carbon despite general increases in litter inputs. Soil carbon increases 6-18% as a result of combined climate and atmospheric CO_2 changes. Our models project changes in total terrestrial ecosystem carbon of 13-24% as a result of the potential global changes. We present maps of these altered global carbon distributions.

POTTER, DONALD A. USDA Forest Service, Stanislaus National Forest, Sonora, CA 95370, USA. Classification of upper montane forests in the central and southern Sierra Nevada mountains of California.

Classification of upper montane forests is one of several projects currently underway in the California Region of the Forest Service. This project covers an area of approximately 3 million acres in the central and southern sierras between Lake Tahoe and Kern County. Twenty-seven plant associations have been identified, and together they form the vegetation patterns viewed across the landscape of these upper montane forests. Plant associations are combinations of potential natural vegetation as defined by plant species composition, structure, and environmental setting. They differ from one another in their ability to produce plant communities and respond to treatment. The plant associations are compared at a series level to illustrate basic environmental and productivity differences between them. The associations provide a framework for understanding the vegetative patterns in the Sierra Nevada landscape, for integrating research findings with management of resources, and for providing managers with access to information that is useful in developing prescriptions and predicting long term response to management.

POULSON, THOMAS L. University of Illinois, Chicago, IL 60607-7060. Using natural experiments to test predictions from models of primary dunes succession at the Miller Dunes unit of the Indiana Dunes National Lakeshore.

Cowles and Olson did some of their classic work at Miller Dunes, IN. I agree with both that there are different successional paths and I show that allogenic factors have important influences on initial conditions, on establishment of pioneers on the beach, and on both speed and direction of succession. Whether allogenic or autogenic, sand blowing and deposition are much more important than availability of water and nutrients. In contrast to Olson, I find no evidence for the textbook facilitation model of marram grass to cottonwood to jack pine to black oak. Nor do my data fit the tolerance model. At a scale of species by species replacement my data fit a mix of the inhibition model (e.g. by marram and by pine) and an oft-neglected individualistic model. At a community or ecosystem scale there is inhibition by promotion of fire by black oak and other species, not recognized by either Cowles or Olson, and facilitation through all sequences by accumulation of humus, which Cowles emphasized as being very important.

POWELL, DOUGLAS S. U.S. Forest Service, Washington, DC, 20090-6090, USA. Inventory and analyses of forest vegetation--an integral need of ecosystem management.

Ecosystem management, a concept increasingly studied and adopted by land management agencies and landowners, requires information about ecosystems on all lands. Knowledge of the vegetation composition, structure, and processes at species, community, and landscape scales, is a logical

starting point. The Forest Inventory and Analysis (FIA) program of the U.S. Forest Service surveys a grid of over 400,000 permanent plots on private and public land in the USA. These points have been established since the 1930s, and data collected and analyzed from them in periodic inventories provide information such as the diversity of tree species; size distribution of trees; dynamics of land use change; and trends in growth amd mortality across a continuum of spatial and temporal scales. An initiative is underway to demonstrate the potential of FIA to address critical ecological questions. FIA can fill a data gap and provide ecosystem analyses to help meet the needs of a diverse clientele and provide the necessary foundation for building a program of forest ecosystem stewardship and sustainability.

POWERS, LAURA E.[1], DIANA W. FRECKMAN[1], and ROSS A. VIRGINIA[2]. [1]Natural Resource Ecology Laboratory, Colorado State University, Ft. Collins, CO 80523, USA, and [2]Environmental Studies Program, Dartmouth College, Hanover, NH 03755, USA.
Nematode biodiversity and community structure in Antarctic Polar Desert soils.

The diversity and community structure of soil nematodes were examined at three elevations along a north-facing slope in the Taylor Valley of the Transantarctic Mountain Range in Antarctica. Soils were sampled at 17 points within a 20x20m grid at each elevation, and nematodes were extracted with a sugar centrifugation technique. At higher elevations, Scottnema lindsayae (Timm, 1971) was dominant, making up over 99% of the total nematode community, while Plectus spp. and Eudorylaimus spp. made up nearly 35% of the nematode population at the lowest elevation. The higher elevation soils had a greater abundance of nematodes (>1000 nematodes/kg) but a small proportion were living (<30%) compared to the lower elevation ($P < 0.0001$). Scottnema community age structure shifted from a mostly juvenile population (55%) at the higher elevation to a predominantly adult population (63%) at lower elevations. Differences in community structure and diversity are attributed to differences in soil moisture with elevation, and to soil characteristics associated with marked changes in the pedological history of each elevation.

PRICE, PETER, W. Northern Arizona University, Flagstaff, AZ 86011-5640, USA. Preference-performance linkage and insect herbivore population dynamics: Comparing common and rare species in temperate and tropical systems.

Female ovipositional behavior may be tightly linked to larval performance or it may be largely independent of larval establishment and survival. This simple dichotomy in the evolution of life histories has repercussions on the population dynamics of many insect herbivores, and their status as common or rare species, both in temperate and tropical systems. Tight preference-performance linkage commonly results in resource limitation because of the low frequency of required high quality plant modules. Dynamics are dominated by resource availability which maintains species as uncommon or rare and patchily distributed. The contrasting dynamics of species that commonly become eruptive and damaging in ecosystems derives from absence of preference-performance linkage. Larvae evolve generalized capacity to utilize a wide range of food quality within a host plant species, resulting in high carrying capacity in a plant population. Tests of this hypothesis include temperate and tropical species.

PROVENCHER, LOUIS, SCOTT GLEESON AND DREW BARTON. The Nature Conservancy, P. O. Box 875, Niceville, FL 32588-0875, USA and University of Kentucky, Lexington, KY 40506-0225, USA.
Partial differential equation model of plant plasticity.

We modeled plasticity in one population of plants. Plants were defined in time and by the masses of the root, stem, and foliage. We used three dimensional partial differential equations (PDE) to track population density in time. The population level PDE contained a constant mortality rate, a mass-specific reproductive term, and three biomass growth rate fluxes for root, stem and foliage. Associated equations defined the rate of growth of each part as functions of nitrogen and carbon flowing in the plant between the vascular tissue, storage reserves, and growth tissue. Carbon and nitrogen were, respectively, taken up by photosynthesis and density-dependent root uptake. Each element actively diffused to the other parts. We show that plants allocated a disproportionate mass to parts (plasticity: nonlinear % change in mass to parts) as total soil nitrogen was varied by a order of magnitude. The model and results will be further discussed.

PULLIAM, WILLIAM M., DENNIS S. OJIMA, AND WILLIAM J. PARTON. Colorado State University, Fort Collins CO.
Application of the Century model across the LTER network: Parameterization and climate change simulations.

We have implemented the Century ecosystem simulation model at all of the terrestrial Long-Term Ecological Research (LTER) sites. Century is a linked production-decomposition biogeochemical model that explicitly simulates flows and storages of C, N, and (in some cases) P in terrestrial ecosystems over annual to millennial time scales. We parameterized and tested Century for at least one representative ecosystem at each LTER site based on the extensive LTER databases. We were able to capture the key ecosystem dynamics at each site within the existing structure of the model. We then drove the model with three scenarios (derived from three different global climate models) for altered climate due to greenhouse forcing from doubled atmospheric CO_2. Century predicted that in all climate scenarios most

forest systems increase total carbon storage (live plus detrital C) while grassland and crop systems generally lost total stored carbon relative to the present day climate. However, there was considerable variability between sites in the responses to simulated climate change.

PYLE, CHARLOTTE and JERRY F. FRANKLIN. University of Washington, Seattle, WA 98195. Modeling landscape connectivity in old-growth Douglas-fir forests: Effects of variation in habitat hostility.

Landscape "maps" with patterns typical of Douglas-fir forests on the west side of the Cascade Mountains of Washington and Oregon, USA, were generated through computer simulation. Using a variety of landscape pattern indices, the simulated landscapes were sorted into pattern groups. Animal movement among patches of desired habitat was modeled for a set of animals which operated at different scales within the simulated landscapes. Connectivity among the desired patches was assessed by landscape pattern group. Habitat hostility was modeled as the risk of death in the landscape areas outside the desired habitat patches. The extent to which variation in habitat hostility was important to connectivity was influenced by both the landscape pattern group aand the scale at which an animal operated in the landscape.

QUALLS, ROBERT G. and CURTIS J. RICHARDSON. Duke University, Durham, NC, 27706, USA. Effects of varying phosphate concentrations on composition of macrophyte communities of the Florida Everglades: a mesocosm approach.

The objective of this study was to determine PO_4-P concentrations and loading rates which result in significant change in the macrophyte community composition of sloughs in the marshes of the Florida Everglades. Varying loads of PO_4-P were pumped into 5 channels at each of 2 sites in the marsh to create concentration gradients. Density or % cover of all dominant species (Eleocharis cellulosa, Eleocharis vivipara, Nymphea odorata, Utricularia spp., and Chara sp.) was lower in the channel segments with the highest average phosphate-P concentrations (52 and 69 µg/L PO_4-P) than in segments with lower concentrations after 7 months of additions. The % cover of Chara sp. appeared to exhibit a maximum (97% at one site and 13% at the other) at an average concentration of 25 to 34 µg/L PO_4-P. After one year, Utricularia spp. was eliminated in all channel segments in which PO_4-P concentrations were elevated above the background of 3 to 8 µg/L PO_4-P.

QUAYE, ERIC C. University of Cape Coast, Cape Coast, GHANA. The Role of Indigenous Knowledge in Forest Management-A Case Study from Ghana.

The need to curtail the widespread destruction of forest resources in Ghana has increased over the past decade in direct response to the government's Structural Adjustment Programme (SAP). However, evolving management strategies to ensure the sustainable development of the forest resources has, so far, been elusive. I believe indigenous knowledge has a role to play in the search for alternative strategies better adapted to multiple-use, sustained yield forest management. This investigation was, therefore, undertaken to develop a knowledge-base derived from the attitudes and perceptions of the indigenous people in relation to their more or less symbiotic association with the forest. Evidently, there is the need to incorporate local conservation practices involving various systems of prohibitions with cultural and religious justifications into current management practices to ensure sustainable use of the forest resources.

QUEITZSCH, BILL E. and R.L. DEVELICE. USDA Forest Service, Chugach National Forest, Anchorage, AK, 99503, USA. Developing a Kenai Peninsula Forest Succession Model.

The current spruce bark beetle epidemic (Dendroctonus rufipennis) in white spruce-paper birch (Picea glauca-Betula papyrifera) forests of the Kenai Peninsula, Alaska is causing rapid measurable change in stand composition and structure. Nearly 100% mortality of mature white spruce has opened the forest canopy and released species which had been suppressed. An individual tree based gap model was used to simulate spruce bark beetle attack and tree succession following infestation. Based on intra-tree competition only, the model predicts a return to white spruce dominated conditions within 100 years. However, a documented lack of white spruce regeneration coupled with increases in bluejoint grass (Calamagrostis canadensis) cover suggests that herbaceous competition plays a significant role in the suppression of white spruce and should be included in future models.

RAFFA, KENNETH F. and KIER D. KLEPZIG. University of Wisconsin, Madison, WI, 53706, USA. Role of root-colonizing insect-fungal complexes in forest declines: Effects of belowground herbivory on host resistance to the stem-colonizing guild of red pine.

A basic understanding of host tree interactions with biotic and abiotic stress is required to evaluate putative agents of forest decline. We observed an association among populations of root inhabiting beetles, the incidence of decline, and mortality of red pine to the stem-colonizing bark beetle *Ips pini*. Healthy trees resist attack by *I. pini* and its associated *Ophiostoma* fungi by rapidly accumulating monoterpenes and phenolics to insecticidal and fungistatic concentrations. However introduction of *Leptographium* fungi by root beetles impedes this response, and increases host acceptance rates by *I. pini*. Abiotic stresses that reduce overall carbon pools can increase susceptibility to *Leptographium*.

RAGUSO, ROBERT A. University of Michigan, Ann Arbor, MI 48109-1048. Pollination biology of Clarkia breweri (Onagraceae) in Central California: relative efficiencies of diurnal vs. nocturnal visitors.

Few studies have documented the relative efficiencies of different classes of floral visitors as pollinators. Clarkia breweri is a self-compatible Californian annual whose pale, fragrant flowers appear to be adapted for moth pollination. During three field seasons, sphingid and noctuid moths accounted for only 2-16% of observed visits to C. breweri, while hummingbirds, long-tongued flies, solitary bees and butterflies were frequent daytime visitors. However, experiments designed to measure pollen deposition on stigmas of emasculated flowers revealed that over 80% of total outcrossed pollen was deposited by nocturnal moths. In addition, pollen labeled with fluorescent powder was transferred to stigmas more efficiently by moths (51% of visits) than by all diurnal visitors combined (5-27% of visits). These results underscore the importance of manipulative experimentation and careful observation of visitor body size and behavior in understanding plant/pollinator relationships.

RAICH, JAMES W., PETER M. VITOUSEK, ANN E. RUSSELL, HERALDO FARRINGTON, and TIM CREWS. Iowa State University, Ames, IA, 50011, USA and Stanford University, Stanford, CA, 94305, USA. Nitrogen and phosphorus stimulate plant growth in primary successional sites of Hawaii.

Ecosystem theory predicts that nitrogen limits plant productivity in young primary successional sites on N-free substrates, but that P will become more limiting through geologic time. Nitrogen alone limits forest productivity on a 200-yr-old volcanic-ash substrate in Hawaii. However, predictions from the CENTURY model indicate that P may be the most important limiting nutrient on pahoehoe-lava substrates. We tested this prediction with a complete factorial fertilization study using a randomized block design. N, P, and a combination of all other essential nutrients were added singly and in combination to Hawaiian montane forests on two ca. 140-yr-old substrates: 'a-'a lava and pahoehoe lava. After two years of fertilization tree height growth, tree basal area increment, and the height of the climbing fern Dicranopteris linearis all responded positively and significantly to added N, to added P, and to both of these nutrients in combination. N and P colimit productivity on these young substrates.

RANDA-BECK, LYNDA A[1]., JOHN A. YUNGER[1], PETER L. MESERVE[1], W. BRYAN MILSTEAD[1], SERGIO HERRERA[2], VICTOR O. LAGOS[2], SERGIO S. SILVA[3], AND FABIAN JAKSIC[3]. [1]Northern Illinois Univ., DeKalb, IL, 60115; [2]Univ. de La Serena, Chile; and [3]Univ. Catolica de Chile, Santiago, Chile. The influence of small mammal population dynamics on home range size and movements of a terrestrial vertebrate predator.

The home range and movements of a terrestrial predator may be influenced by seasonal fluctuations in resource availability. Such a response was investigated for the culpeo fox, Pseudalopex culpaeus, after an El Niño (ENSO) event in 1991 and 1992 led to a dramatic increase in small mammal prey densities at Fray Jorge National Park in north-central Chile. Monthly small mammal densities were estimated using live-trapping grids. Radiotelemetry data collected from March 1991 through August 1993 was used to estimate individual fox home range sizes and movements, which were then pooled across individuals for three month seasons. Both 95 and 50 percent contour levels were estimated for harmonic mean and mimimum convex polygon home range sizes. Regression analysis of home range size and movements on the density of foxes' preferred prey, Octodon degus, suggests a quadratic response. This may be due to a time lag of the predator response to the rise in prey density.

RANDLETT, DIANA L., DONALD R. ZAK, and KURT S. PREGITZER. University of Michigan, Ann Arbor, MI, 48109 and Michigan State University, E. Lansing, MI 48824, USA. Elevated atmospheric CO_2 and leaf litter chemistry: changes in microbial respiration and net N mineralization.

Elevated atmospheric CO_2 will likely influence rates of C and N cycling in terrestrial ecosystems by altering plant litter chemistry. Several studies suggest that leaf C:N increases in plants grown at twice-ambient CO_2. Because atmospheric CO_2 and soil N availability can influence leaf chemistry, we reasoned that leaf litter from plants grown at elevated CO_2 in N-deficient soil should slow rates of C and N cycling. To test that hypothesis, we grew Populus x euramericana cv. Eugenei with two treatments of soil N availability (low and moderate) and CO_2 (350 and 700 umol mol^{-1}) in a randomized complete block design. Kinetics of microbial respiration and net N mineralization were measured for litter-amended soils during a 32-week lab incubation. Litter C:N ratio and microbial respiration were significantly affected by soil fertility, but not by CO_2. Although the addition of leaf litter caused a net immobilization of N, rates were not significantly different for leaves grown at ambient and elevated CO_2. As such, we found no evidence for the hypothesis that leaf litter produced at elevated atmospheric CO_2 will dampen the rates of C and N cycling in soil.

RAYNAL, DUDLEY J., ANTHONY R. BRACH, TODD M. HURD, AND CHARLES S. SCHIRMER. SUNY College of Environmental Science and Forestry, Syracuse, NY, 13210, USA. Effects of nutrient additions on understory vegetation in Adirondack forests.

As a part of the Adirondack Manipulation and Modeling Project, we studied changes in cover and nutrient concentrations of understory vegetation at three sites on a west to east gradient of decreasing atmospheric S and N deposition. Five x five m plots were treated biweekly from May to

October, 1991-1993 with 14 kg N ha^{-1} in the form of HNO_3; 10 x 10 m plots were treated with single annual applications of $(NH_4)_2SO_4$ at 14 and 28 kg N ha^{-1}, 2 and 4 x ambient deposition. Additional 9 m^2 plots dominated by ferns received $(NH_4)_2SO_4$ at 50 and 250 kg N ha^{-1}, 7 and 36 x ambient deposition. N addition at 2 and 4 x ambient did not change cover; addition at 7 and 36 x ambient re duced cover. American beech and some herbs increased foliar N with low treatment levels compared to controls. Foliar Al in herbs increased at western sites with addition of $(NH_4)_2SO_4$. Only at high treatment levels, were fern N concentrations higher than controls; these were often accompanied by reduced base cation concentrations. In untreated plots at western sites, foliar N was higher than at the eastern site in herbs and ferns, but Mg was lower in wood fern and American beech. Species responses reflected their position on a habitat fertility gradient.

READER, RICHARD J. University of Guelph, Guelph, Ontario, N1G 2W1, Canada. Stress-tolerance, competitive-ability and species relative abundance in an unproductive habitat.

A field experiment tested whether differential tolerance of low soil resource availability and (or) competition from neighbours could account for differences in the abundance of ten old-field plant species in an abandoned pasture. Adding a nutrient solution to reduce nutrient and water stress increased shoot growth and flowering of uncommon species more than common species. Apparently, uncommon species were less tolerant of naturally-occurring, low soil resource availability than were common species. Removing neighbours to reduce competition increased shoot growth and flowering about equally for common and uncommon species. These results suggest that a species tolerance of low resource availability is a more important determinant of its abundance in an unproductive habitat than is its competitive ability.

REDFEARN, ANDREW and STUART L. PIMM. Oak Ridge National Laboratory, Oak Ridge, TN, 37831, USA and University of Tennessee, Knoxville, TN, 37996, USA. Population fluctuations in phytophagous insects.

We examined how community interactions affect year-to-year population variability in three groups of phytophagous insects: British aphids and moths, and Canadian moths. We first examined how the number of host plant species on which a given phytophagous insect species feeds affects its population variability. Specialist insect species showed a weak tendency to be more variable than generalist species. We then examined how the number of species of parasitoids from which a given phytophagous insect species suffers affects its population variability. Species that are host to few parasitoid species showed a weak tendency to be more variable than species with many parasitoid species. These relationships also depend on other aspects of the life histories of the phytophagous insect species.

REDFORD, KENT H. The Nature Conservancy, Arlington, VA, 22209, USA. Hunting by humans, forest composition and the definition of 'natural'.

Humans have hunted in tropical forests since they first inhabited them. Factors such as human population density, land use patterns, and geographical setting have all mediated the ways in which the hunting has affected both game animal populations, and through seed dispersal and predation, the structure and composition of the forests themselves. It may be, in some areas, that these effects have persisted long after the cessation of hunting. These questions are of tremendous importance for contemporary debates on national parks and the role of people in relation to the 'naturalness' of conservation areas.

REEVE, JOHN D., MATTHEW P. AYRES AND PETER L. LORIO, JR. Southern Forest Experiment Station, Pineville, LA, 71360, USA and Dartmouth College, Hanover, NH, 03755, USA. Population dynamics of bark beetles.

Population outbreaks are a common feature of the dynamics of many bark beetles. We review the role of host resistance, natural enemies, and competition, in the genesis of these outbreaks, with emphasis on the southern pine beetle, Dendroctonus frontalis. We examine the effects of moisture stress on resistance in southern pines, and show that under moderate stress resistance to attack by *D. frontalis* actually increases, potentially reducing the chances of an outbreak. A more likely cause of outbreaks in this system are predator-prey interactions with natural enemies, and competition for resources within the tree. Predation by the clerid beetle Thanasimus dubius can cause significant mortality of D. frontalis, and combined with its long life-cycle, may help destabilize the system and so increase the probability of an outbreak. Low levels of the bluestain fungus Ophiostoma minus, a competitor of D. frontalis within the host tree, are associated with high survivorship of D. frontalis brood and regional outbreaks.

REICE, SETH R. University of North Carolina, Chapel Hill, N.C. 27599-3280 USA. A model of nonequilibrium control of community structure: disturbance-mediated coexistence of competitors.

A spatial matrix model of community structure will be presented which includes the roles of spatial heterogeneity, disturbance and recolonization. Three modes of recolonization are included (migration,

recruitment and regrowth). Each is spatially defined. The loss of individuals due to disturbance results in random colonization from a recruitment pool. This permits the reversal of the outcome of interspecific competition and the survival of the potential losers in the system. Random colonization results in increased species diversity with increasing disturbance.

REICHARD, SARAH H. and C.W. HAMILTON. Center for Urban Horticulture, University of Washington, GF-15, Seattle, WA, 98195, USA. Predicting invasive potential of woody plants introduced to North America.

Despite the numerous documented effects invasive non-native plants have on native plants and ecosystems, it is likely that new plant species will be introduced to North America. Under current procedures, all species may be admitted unless a risk can be clearly demonstrated. Explicit means of evaluating risk of invasiveness are currently unavailable, but by discriminant analysis of several characteristics of 236 invasive and 114 non-invasive woody plants introduced to North America we have identified variables that distinguish the two groups. Analyses of different geographic scales incorporate different variables in the respective predictive models; but variables related to stress-tolerance, such as deciduous and semi-evergreen leaves, and those related to increased reproductive output are found at all scales. The highest ability to predict invasions occurs at the regional scale: the model produced for the west side of the Cascade Range correctly classified 86% of the 81 invasive and non-invasive species tested, while the model developed for all of temperate North America correctly classified 80%.

REID, CHANTAL D. and EDWIN L. FISCUS. North Carolina State University and USDA/ARES, Raleigh NC 27606, USA. Interactive effects of O_3 and CO_2 enrichment on photosynthetic acclimation. I. Biochemical limitations.

To determine how Rubisco activity affects photosynthetic acclimation to combined elevated atmospheric CO_2 and O_3, soybeans (*Glycine max*) were grown in a 2 x 2 factorial design of atmospheric CO_2 (current, +350µl/l) and O_3 (charcoal-filtered, 1.5x ambient) in open-top field chambers for one growing season. Soybeans were sampled for Rubisco activity at regular intervals throughout the season. A/C_i measurements were carried out in the laboratory on field-grown soybean. Rubisco capacity to carboxylate CO_2, determined by the slope of A/C_i curve, was reduced most in CO_2 x O_3 treatment. Biochemical determinations of Rubisco activity and total content indicate that plants grown in CO_2 x O_3 show the lowest activity (45.5 vs 63.5 µmol $CO_2.m^{-2}.s^{-1}$) although ozone-treated plants initially had the lowest activity (33.1 µmol.$m^{-2}.s^{-1}$ at 36 dap). In CO_2 x O_3-treated plants, the decline in carboxylation is due to a decline in Rubisco content and reduced activity whereas, in ozone-treated plants, only Rubisco content declined. Photosynthetic capacity at saturating C_i was lowest under elevated CO_2 x O_3, from 43 µmol $CO_2.m^{-2}.s^{-1}$ (control) to 19 µmol $CO_2.m^{-2}.s^{-1}$ (CO_2 x O_3). The combined effects of high CO_2 and O_3 on the biochemical limitation of photosynthesis are additive.

REID, ROBIN S., CATHLEEN J. WILSON, RUSSELL L. KRUSKA, and BRENT M. SWALLOW. ILRAD and ILCA, Nairobi, Kenya. Ecological consequences of controlling a livestock disease: changes in land-use and vegetative cover in Ethiopia.

More effective control of the tsetse fly will reduce the livestock disease constraint of trypanosomiasis which lowers livestock productivity and, in some areas, is thought to limit the ability of farmers to keep livestock and to cultivate land with the oxen and plow in Africa. Our objective was to determine how tsetse/trypanosomiasis control affects the expansion of agricultural land-use and how, in turn, altered land-use modifies vegetation and landscape pattern in Ghibe Valley, southwestern Ethiopia. Characteristics of the vegetation were sampled during ground surveys while measurements of current patterns and recent changes in land-use were made using satellite imagery and interviews with farmers. At the farm level, tsetse control has spurred a substantial increase in livestock numbers, changes in herd composition, expansion of cultivated areas and has encouraged human immigration. Expansion of cultivated areas has created a patchwork of fields within a matrix of lesser-used woodlands. Woody and herbaceous cover were similar on small-scale farms to that in uncultivated woodlands but trees, shrubs and grass patches were almost entirely removed on large-scale farms. Maintenance of vegetative cover thus may be related more to the scale of farming than to the presence or absence of human land-use.

RESCHKE, CAROL. New York Natural Heritage Program, Latham, NY, 12110, USA. Analysis of disturbance regimes maintaining alvar grasslands at Chaumont Barrens, Jefferson County, NY.

Alvar grasslands are seasonally inundated and seasonally droughty grasslands occurring on very shallow soils over limestone or dolomite bedrock in northwestern New York, southern Ontario, and northeastern Michigan. Three hypotheses have been proposed to explain the disturbance regime that maintains these rare grasslands and prevents invasion of woody species: 1) summer drought is the primary factor limiting woody plant growth, 2) the combined regime of seasonal inundation and summer drought maintains the grassland, and 3) the alvar grasslands, like midwestern prairies, are maintained by periodic fire. The validity of these three alternate hypotheses is explored using data collected in 1992-93 from four permanent transects established in two alvar grasslands at The Nature Conservancy's Chaumont Barrens Preserve. Data collected along the transects included inundation pattern and frequency, water depth, vegetation composition in 1 x 5 m plots, soil depths, soil characteristics, and presence of charcoal. Preliminary results suggest that vegetation patterns are correlated with inundation pattern, moisture regime, and soil organic matter, and that there is no significant correlation between vegetation pattern and presence of charcoal. Therefore the data support the second hypothesis: the combined regime of seasonal inundation and summer drought maintains the grassland. Data on surface water chemistry (pH and conductivity) sampled near the transects suggest that the inundation is primarily from groundwater.

RESETARITS, W.J., JR. University of Missouri - St. Louis, Mo. 63121, USA. Competitive asymmetry and coexistence in size-structured populations of brook trout and spring salamanders.

The idea of species coexistence is central to community ecology theory. The question is more complex when dealing with size-structured populations. I conducted a field experiment on interactions between fingerling Salvelinus fontinalis (TL 78-101 mm) and larval Gyrinophilus porphyriticus (35.7-62.4 mm SVL) in experimental streams. Salvelinus reduced survival of Gyrinophilus by 50%, growth by > 90% (mass) and 44% (SVL), and altered their habitat use. Gyrinophilus had no effect on Salvelinus. These results parallel the interactions between small adult Salvelinus and larval Gyrinophilus. Interactions between these species are characterized by strong asymmetry. Persistence of Gyrinophilus with Salvelinus is probably the result of aspects of the life history and local demography of both species, coupled with aspects of the local environment. Complex mechanisms of species coexistence are more likely with size-structured populations than simple explanations based on models of exploitative competition between competitors of fixed body sizes.

REY BENAYAS, JOSE M., JESUS PASTOR, ANA J. HERNANDEZ, and AGUSTIN SANCHEZ. Centro de Ciencias Medioambientales, Madrid, E-28006, Spain. Restoration of vegetation in set-aside agricultural lands of Mediterranean regions.

The EU is fostering the transformation of agricultural lands into forest lands. For assessment of vegetation restoration in set-aside agricultural lands, we are monitoring 800 seedlings of evergreen oak (Quercus rotundifolia) growth and survivorship rates under four treatments: artificial shadowing, irrigation in the dry season (60 l/m² twice), a combination of shadowing and irrigation, and "natural" climate conditions (control treatment). The different treatments affected seedling survivorship ($P<0.0007$). The survivorship in the control treatment averaged 61% after 8 months. We found a significant, positive effect of artificial shadowing (survivorship was 95%), irrigation (90%), and the interaction of the two formers (survivorship was 100% during the dry period). The positive effect of the irrigation is attributed to the development of a thick Amaranthus albus stratum (weed aerial biomass was 671 g/m² whereas for no irrigation treatments weed aerial biomass was 290 g/m²) that provided shadow to the seedlings.

REYNOLDS, DOUGLAS N. Eastern Kentucky University, Richmond, KY, 40475, USA. Population dynamics of ramets and genets of Saxifraga flagellaris.

The reproductive characteristics and survival of ramets and genets of four cohorts (1984, 1985, 1986, 1990) of Saxifraga flagellaris were measured through 1993 at an alpine site in Colorado. Plants grow as rosettes for a number of years before simultaneously flowering and producing stolons; the parent rosette begins to die immediately afterward. Ramet survival (16-41%) by 1993 was much lower than corresponding genet survival (78-95%) in all cohorts. Genet size (# of ramets per genet) initially declined in all cohorts as daughter ramets died but then increased as survivors reproduced vegetatively. After 10 years, average genet size for the 1984 cohort was 3.5 ramets with individual genets having from 0 to 16 ramets. Numbers of flowers and stolons and stolon lengths varied between plants and years. There was a positive correlation between numbers of flowers and stolons produced. Plants that produced more stolons and stolons of intermediate length were the most successful in terms of genet size by 1993.

REYNOLDS, HEATHER L. and F. STUART CHAPIN III. University of California, Berkeley, CA, 94720, USA. Mechanisms of coexistence in a serpentine annual grassland.

We examined the relative importance of site factors versus plant effects on soil quality in maintaining patchy structure of an annual serpentine grassland by manipulating species composition of patches over a growing season. At the end of the growing season, patches differed in both soil moisture and available soil N. Soil moisture differences among patch types were abiotic -- patches originally dominated by *Lasthenia californica* were wetter than patches originally dominated by *Plantago erecta* or *Calycadenia multiglandulosa*, and changing the species composition of patches did not change soil moisture. Nitrate accumulated on ion-exchange resins was clearly decreased in the presence of *Plantago*, even in patches previously dominated by the other species. Survival and biomass data suggest that the wetter sites favored by *Lasthenia* are poor sites for growth of *Plantago*. *Plantago* survival and reproduction were also reduced in *Calycadenia* sites, which was likely due to allelopathic effects of *Calycadenia's* highly resinous litter. These results suggest that both differential species response to site factors and site modification by species are important in maintaining patchy species composition in this grassland.

RHODES, H.L.H., S.C. NODVIN, P.A. MOORE, J.L. SMOOT, C.E. SKELTON, and D.A. EISENHOUR. National Biological Survey-Cooperative Park Studies Unit, Department of Civil & Environmental Engineering, and Department of Zoology, The University of Tennessee, Knoxville, TN, 37996. USA. Impacts of tunnel construction on stream chemistry and biology.

The Cumberland Gap (CG) (bordering KY, TN, and VA) has served as an historic migration corridor for plants, animals, and humans. Towards an expansion of vehicular use of the corridor, a massive construction project, including development of a

~1500 m long vehicular tunnel and major re-routing of nearby access highways, was initiated in the late 1980's. Impacts of construction activities on stream chemistries and biota within the CG National Historical Park were assessed through bimonthly and event sampling over a stream monitoring network. Streams draining the tunnel construction area experienced major chemical changes including increased alkalinity, pH, and suspended sediments relative to pre-construction conditions. A substantial contributor to the observed chemical changes was contamination from concrete-based construction materials. However, management techniques used by the contractor to attempt to ameliorate changes in water quality actually exacerbated the problems, facilitating rapid streamwater pH changes over the range of pH 4 to 10. Chemical changes and increased siltation likely contributed to the observed declines in invertebrate taxa richness that were observed in the most heavily impacted streams.

RIBBENS, ERIC. University of Connecticut, Storrs, CT, 06269, USA. Seed rain and seedling recruits dispersion in northern hardwood forest: the influence of hemlock canopy and hayscented fern understory.

Using maximum likelihood techniques, functions describing seed rain and seedling dispersion can be calibrated from maps of adults and transects of seed traps and recruits. Although proximity to the parent is of prime importance in predicting dispersion, fern understory and hemlock canopy cover can alter establishment or arrival probabilities. I have added estimates of hayscented fern abundance and presence of hemlock canopies to data collected for 10 canopy codominant forest tree species in a transition oak-northern hardwood forest in northwestern Connecticut. I have analyzed this data with a modified recruitment function, which incorporated parameters that assess the influence of fern cover and hemlock cover into the recruitment functions. Seed rain of some species appears to be reduced beneath hemlock canopies. Hayscented ferns have pronounced species-specific effects on recruitment, by reducing establishment probabilities. In some cases, recruitment models that incorporate microsite effects can produce significantly improved fits between observed data and predicted distributions.

RICE, DONALD. University of Southern Illinois at Carbondale, Carbondale, IL, 62901, USA. The environmental consequences of first European Contact in the neotropics.

Human populations have been present in Amazonia for more than 11,000 years, and practicing agriculture for more than half that time. Indigenous populations may have exceeded 4 million people in Amazonia with a further 5 million in Central American and Mexico immediately prior to European Contact. Within a few decades of Contact, epidemics of typhoid, measles, influenza and smallpox had reduced these populations by more than 90%. Archaeological, archaeobotanical and paleoecological data provide evidence of wholesale abandonment of agricultural land, and the regeneration of forests about 350-400 years ago. Forests that are often described as 'pristine', or 'primary' may in many cases be within one tree generation of a disturbed landscape. This paper will include a broad geographic overview of these trends and a more detailed analysis of data from selected Central American locations.

RICE, KEVIN J. and TYSON H. HOLMES. University of California, Davis, CA, 95616, USA. Patterns of adaptation (and maladaptation?) in a threatened tree species.

Blue oak (Quercus douglasii) is a California endemic that is currently a focus of conservation research because low seedling survival in many populations threatens the persistence of this tree species. To understand the potential role of genetic variation in the survival and growth of blue oak seedlings, a series of reciprocal transplant experiments were established at three sites along a latitudinal rainfall gradient. Using a nested design, acorns from different maternal families collected at each site were planted in ten blocks within a site. Measurements of seedling survival and growth indicate 1) significant site and within-site (block) variation in seedling performance, 2) significant differences among maternal families in both seedling survival and growth, and 3) indications of both local adaptation and maladaptation in seedling performance. Seedling performance was correlated with acorn quality factors such as acorn dry weight and percent allocation to embryo. Acorn maturity, as determined nondestructively by NMR analysis, was also correlated with seedling growth rate.

RICE, MICHAEL D.[1], B.G. LOCKABY[1], B.D. KEELAND[2], and J.A. STANTURF[3]. [1]Auburn University, AL, 36849, USA, [2]National Wetlands Research Center, Lafayette, LA, 70506, USA, [3]USDA Forest Service, Stoneville, MS, 38776, USA. Influence of Hurricane Andrew on Coarse Woody Debris Decomposition Processes and Organisms in the Atchafalaya River Basin.

Hurricane Andrew caused extensive damage to the forested wetlands of the Atchafalaya River Basin of southern Louisiana, resulting in the accumulation of high coarse woody debris loads. Decomposition processes of coarse woody debris are being compared in areas which were heavily disturbed by the hurricane versus areas which were lightly disturbed. Within disturbance classes, position of the woody debris in relation to the soil is also being studied. Two diameter classes of coarse woody debris, 0.5 - 2.5 cm and 7.5 - 20.0 cm, have been placed in contact with or suspended above the soil. The two diameter classes are being evaluated with respect to both degree of disturbance and position of debris. A single tree species, pumpkin ash (Fraxinus profunda), is being utilized

since it is the most common species within the plots. Samples are retrieved biannually and mass loss, C, N, and P concentrations and content will be assessed. To further investigate hurricane influence on decomposition processes, microarthropod and other decomposer organism populations are being assessed as well.

RICE, STEVEN K. and LARRY GILES. Department of Botany, Box 90339, Duke University, Durham, NC, 27708-0339, USA. Short-term carbon isotope discrimination measurements in Sphagnum.

The relative effect of water films and leaf anatomy on resistance to CO_2 uptake was investigated in Sphagnum using a short-term carbon isotope discrimination technique. In all Sphagnum species, photosynthetic cells are surrounded by water-filled hyaline cells and species differ in the relative exposure of photosynthetic cells at the leaf surface. For the two species in this study, S. affine has photosynthetic cells that are widely exposed at the surface. Whereas S. magellanicum photosynthetic cells are enclosed within the hyaline cells. This difference is expected to lead to variation in resistance to CO_2 uptake. A closed-chamber gas exchange system was designed to measure changes in both the carbon dioxide concentration and the $\partial^{13}C$ value in the cuvet during photosynthesis. A sampling interval of approximately 10 minutes permitted 6-8 sample points for each measurement of carbon isotope discrimination (Δ). Plants were measured at two water contents: greenhouse water content (wet) and blotted dry (dry). Without correcting for respiration, Δ values differed significantly between wet (overall mean: 22.66‰) and dry (29.95‰) plants. However, there was no significant difference between species means and no species x water content interaction. Corrections for respiration lowered the Δ values by approximately 8.4‰ but had no other effect on the results. Therefore, we conclude that variation in water content leads to a greater difference in resistance than variation in leaf anatomical properties. For Sphagnum in field conditions, fluctuating water regimes likely mitigate the effect that leaf anatomical differences have on total carbon gain.

RICH, PAUL M., ROBIN L. CHAZDON, and JULIE S. DENSLOW. University of Kansas, Lawrence, KS, 66045, USA, University of Connecticut, Storrs, CT, 06269, USA, and Tulane University, New Orleans, LA, 70118, USA. Spatial and temporal variation of solar radiation regimes in plant canopy gaps.

Spatial and temporal variation of solar radiation regimes within plant canopy gaps influences energy balance, microclimate, primary production, and water balance. We conducted a systematic study of the effects of canopy gap geometry on photosynthetically active radiation (PAR) using the GIS-based SOLARFLUX model. In particular, we examined the effects of gap radius, canopy height, and latitude on PAR under clear sky conditions. A series of theoretical cylindrical and irregular shaped gaps were examined across two orders of magnitude of gap radii (1-100 m) and canopy heights (also 1-100 m), and across latitudes ranging from 0° to 90°. First, gap geometry was represented by constructing a series of digital elevation models using ARC/INFO GRID. Then, SOLARFLUX was used to simulate 1) incident direct PAR at half-hour intervals through the day, 2) duration of direct radiation, 3) hemispherical viewsheds, 4) sky view factors, and 5) incident diffuse PAR. Morning shade on east sides of gaps and afternoon shade on west sides of gaps resulted in pronounced east-west spatial variation of incident PAR within each day. Seasonal shifts in solar angle resulted in pronounced north-south spatial variation of incident PAR across seasons for all latitudes. This temporal and spatial variation defines distinct gradients of microclimate, available PAR, and water stress.

RICHARDS, JAMES H., LISA A. DONOVAN, KEVIN J. FORT, ELIZABETH J. SCHABER, CATHERINE A. TOFT. University of California, Davis, CA, 95616-8627, USA. Rapid establishment of shrubs on a recently exposed desert playa, Mono Lake, CA.

Initial colonization of desert alkaline, saline playas is often delayed by high soil Na, Cl, B and SO_4 content, high soil and groundwater pH, alternating drought and flooding, abrasion by wind-blown sand, low seed input, and low seed retention. We studied these characteristics for a large disjunct population of the halophytic shrub Sarcobatus vermiculatus established on playa surfaces exposed by recent (<20 yr) decline in Mono Lake level. The broad population age and size structures (1 to ≥ 12 yr and seedlings to seed-producing, medium-sized adults, respectively) indicate that establishment is not episodic; the seed rain is adequate, where coarse textured surfaces provide retention microsites. Root excavations and mapping indicated that taproot extension was inhibited at ≈ 40 cm depth where the soil was influenced by hypersaline, anoxic groundwater (EC ≈ 37 dS/m, Eh < -250 mV, pH > 9.7). Lateral roots developed extensively (>2.2 m) and were highly branched in thin, organic-rich (0.34% total N) soil layers. Leaf Na and B contents were high (13% and 234 ppm) as was leaf N (3.6%). The unique combination of surface roughness and soil heterogeneity at the site coupled with toxic ion tolerance and root system plasticity of S. vermiculatus appear to be responsible for the unusually rapid colonization in this extremely harsh saline alkaline playa.

RICHARDSON, CURTIS J., JERRY G. QUALLS and PANCHABI VAITHIYANATHAN. Duke University, Durham, NC 27708, USA. Effects of phosphorus enrichment on slough communities of the Everglades: An experimental approach using mesocosms.

The Everglades is a phosphorus limited system that historically received most inputs of nutrients via rainfall but has more recently been impacted by over 200 metric tons of P per year from agricultural drainage. To determine a threshold level of phosphorus responsible for changes in community structure and ecosystem processes, a replicated solar-driven, in-situ mesocosm experiment was conducted during 1992-1993. Twelve channels, each 10 meters long, were dosed with 0, 30, 50, 75, and 150 µg/l of PO_4-P . Control PO_4-P concentrations averaged 5.8 µg/l ($\pm$ 3.9) while channels receiving highest concentrations (150 µg/l of P) displayed varying P levels that ranged between 50 and 100 µg/l of P depending on water depth, season and distance down the channel. A carbon-based model for P retention is presented along with mechanisms controlling P retention and cycling.

RIECHERT, SUSAN E. and KENDRA LAWRENCE. University of Tennessee, Knoxville TN, 37996-0810, USA. Comparison of single species versus species assemblage effects of generalist predators on associated prey.

Open-field cages set up in an old field in east Tennessee were used to test the model result that single spider species limit prey to the same extent that multiple spider species would. Four replicates of six treatments were es-

tablished in May of 1993: no spiders, all spider species, the prominent web builder only, the prominent wandering spider only, the largest web building spider species only, and the largest wandering spider only. Weekly removals were made from the cages to maintain the treatments. Each month for 3 sampling periods spider species numbers and compositions were censused in the cages as well as the numbers and taxonomic representations of associated insects. Marked differences were observed in insect numbers between no spider and all spider species treatments. However, differences were also observed in individual samples in the effects of single spider species on associated prey that corresponded to the stage of the life cycle the predator was at as well as its potential to encounter and capture particular prey. The assemblage of spider species, in general, was more effective in limiting prey than any single species.

RIPLEY, BONNIE J. Woods Hole Oceanographic Institution, Woods Hole, MA, 02543, USA. A comparison of bivalve life history strategies using matrix population models.

A stage-classified matrix model was used to compare life history strategies of an array of marine bivalve species. These represented tropical, temperate, and Antarctic species, including brooders and broadcast spawners, over a range of sizes from 4 mm (Gemma gemma) to 1 m (Tridacna gigas). Parameters used in the model were drawn from the literature. For the sake of comparison, the fecundity/larval survivorship parameter — the most difficult to determine accurately — was scaled so that the dominant eigenvalues of all matrices were equal. Similar sensitivity and elasticity structures resulted for all species, despite considerable variation in their life history strategies.

RITCHIE, J.C., F.R. SCHIEBE, C.M. COOPER, and J.A. HARRINGTON, JR. USDA-ARS, Beltsville, MD 20705; Durant, OK 74702; Oxford, MS 38655; and Indiana State Univ., Terra Haute, IN 47809 USA, Using broad band spectral sensors to measure chlorophyll in the presence of suspended sediments.

Broad band spectral sensors aboard satellites can be used to monitor suspended sediments. However monitoring chlorophyll using these sensors in the presence of high concentrations (>50 mg l^{-1}) of suspended sediments has been questioned. In this study, concentrations of chlorophyll-a in waters with high concentrations of suspended sediments were measured in three lakes and compared with broad band (100 nm) Landsat MSS digital data for 104 dates between December 1976 and August 1988. Concentrations of chlorophyll-a ranged from 0.3 to 211 mg m^{-3} for 452 measurements. Concentrations of suspended sediments ranged from 1 to 867 mg l^{-1} in the same samples. No significant pattern related to the concentration of chlorophyll-a and MSS data was found indicating that the estimation of chlorophyll-a with broad band data will provide limited information on chlorophyll in sediment dominated systems. Determination of chlorophyll using spectral data in sediment dominated systems will require high resolution spectral data (10 to 15 band widths) at 675 and 705 nm.

ROBERTS, DAVID W. Department of Forest Resources and Ecology Center, Utah State University, Logan, UT, 84322-5215, USA. Flexible, conservative similarity functions for quantitative vegetation ecology.

The calculation of plot-to-plot similarity generally assumes that the species abundances are known without error. Often, however, the values used are simply codes for broad ranges of abundance, or rough estimates of actual abundance. I designed an algorithm to eliminate the effect of abundance class interval on the calculation of plot-to-plot similarity, and applied the algorithm to 160 sample plots (with 169 vascular plant species) from Bryce Canyon National Park. I tested the effect of the algorithm on three abundance transformations (presence/absence, class ordinal code, and class mid-point) and three abundance weightings (all species equal, proportional to abundance, and proportional to abundance squared). In general, the effect of eliminating the errors in abundance is an increase in plot-to-plot similarity. Within a specific transformation, the improvement is relatively small for high abundance weightings, and larger for low abundance weightings. The effect varies by transformation, however, with the largest improvements shown for the presence/absence transformation, and the smallest improvement shown for weighting by abundance squared.

ROBERTS, MARK R. and FRANK S. GILLIAM. University of New Brunswick, Fredericton, N.B., E3B 6C2, CANADA and Marshall University, Huntington, WV, 25755, USA. Vegetation and soil fertility changes with forest succession in northern lower Michigan.

Our study examined changes in herb-layer composition and soil characteristics over time on two contrasting site types in successional aspen forests. Species diversity (H') and richness decreased significantly with stand age on both site types, but the decrease was greater on mesic than dry-mesic sites. On mesic sites, species composition shifted from a predominance of Pteridium aquilinum, Acer saccharum and Rubus idaeus to a variety of tree species and Maianthemum canadense over time. There was little compositional change on dry-mesic sites, with Pteridium aquilinum, Vaccinium angustifolium, Gaultheria procumbens, and Acer rubrum maintaining dominance over time. Surface soil pH, organic matter, and extractable Ca, K, and Mg decreased significantly with stand age on mesic sites, but exhibited little change on dry-mesic sites. Results suggest a relationship between soil nutrient dynamics and species change with forest succession.

ROBERTSON, KEVIN AND WILLIAM J. PLATT. Louisiana State University, Baton Rouge, LA, 70803, USA
The effects of Hurricane Andrew on the demography of epiphytic Bromeliads in Everglades National Park, Florida.

In August, 1992, the eye wall of a high-intensity hurricane passed directly over Long Pine Key in Everglades National Park, Florida. On Long Pine Key are sub-tropical hardwood "hammocks" (tree islands) in which permanent plots were established prior to the hurricane to census five species of epiphytic Bromeliads in the genus Tillandsia. In this study a 1991 (pre-hurricane) census and 1993 (post-hurricane) census are compared. Each census recorded the epiphyte species, leaf length, flowering stage, clonal reproduction, vertical distribution, position (tree, branchfall, etc.) and the species, status, and diameter at breast height of the host tree. The post-hurricane census revealed a change in the vertical distribution of epiphytes due to the damage inflicted on host trees and showed increases in flowering and/or clonal growth specific to the epiphyte species. Responses are presumably due to the increase of light from the defoliation of the hammock canopies.

ROCHE, BERNADETTE M., ROBERT S. FRITZ, and GINA L. SYLVAN. Vassar College, Poughkeepsie, NY 12601, USA. Effects of genotype and environment on susceptibility to herbivory in the silky willow, Salix sericea.

We investigated effects of genotype, environment, and genotype by environment (GxE) interaction on resistance to herbivory in the silky willow, Salix sericea. An environmental gradient of fertilizer level (low, medium, and high) was superimposed on an underlying genetic design, replicated in 2 blocks. Fertilizer effects were significant for 5 of the 7 herbivores studied (increase in susceptibility with increasing fertilizer level for 3 species; decrease in susceptibility with increasing fertilizer for 2 species). We found significant sire effects for 2 species, and a significant GxE interaction for 1 species. These results indicate that plant resistance levels depend both on herbivore species and environment, there is heritability for resistance to some herbivores, and plants exhibit different amounts of plasticity with respect to herbivore attack in varying environments.

ROCK, JANET H. USDI, NPS, Great Smoky Mountains National Park, Gatlinburg, TN, 37738. USA.
The impact of ramp (Allium tricoccum Ait.) harvesting in Great Smoky Mountains National Park.

Allium tricoccum is distributed throughout eastern North America, and the Southern Appalachians represent the southern edge of its range. Continual harvesting in the park has depleted accessible populations leaving only the most remote intact. In 1989, we implemented a study to: (1) determine the effect of harvesting at various harvest levels; (2) determine the impact of different harvest techniques; and (3) predict the number of years required to regain pre-harvest levels after a single harvest. After four years of post-harvest data, analysis indicates a clear interaction between harvest levels and population recovery appears slow.

RODEN, JOHN S. and MARILYN C. BALL. Australian National University, Canberra, ACT, 2601, Australia. The effect of elevated CO_2 on high temperature photoinhibition of two eucalypts.

A shift in species distribution associated with global climate change may be dependent on the response of seedlings to extreme stress events. Seedlings of *Eucalyptus macrorhyncha* and *E. rossii* were grown for 8 weeks in either ambient (350 ppm) or elevated (700 ppm) CO_2 concentrations and subjected to a daily, 3 h, high light (1600 μmol m^{-2} s^{-1}) and high temperature (45 °C) photoinhibitory stress period. Seedlings of *E. macrorhyncha* grown in elevated CO_2 had reduced photosynthetic efficiencies as measured by chlorophyll fluorescence (Fv/Fm) than seedlings grown in ambient CO_2. However, no significant differences in Fv/Fm were observed between CO_2 treatments for *E. rossii*. The growth enhancement in elevated CO_2 was less for *E. macrorhyncha* (41%) than for *E. rossii* (103%). A decrease in specific leaf area was the principle morphological change associated with growing in an elevated CO_2 environment. There was no discernible differences in photosynthetic acclimation to the high temperature environment for plants grown in either elevated or ambient CO_2 concentrations. In conclusion, elevated CO_2 may exacerbate high temperature photoinhibition, but the response is species specific.

RODENHOUSE, NICHOLAS L. and CHRISTINE. M. JESSUP. Wellesley College, Wellesley, MA, 02181, USA. A simulation model of annual breeding productivity and population growth of multibrooded passerine birds.

This study presents a simulation model for populations of multibrooded passerines and sensitivity analyses of the model. The model was constructed using STELLA II®, graphically based simulation software, and it uses commonly collected field data as inputs (i.e., clutch size, daily probabilities of egg and nestling mortality, frequency of renesting and second brooding). The purpose of the model was to examine the sensitivity of annual breeding productivity and population growth to demographic characteristics of bird species (granivores, insectivores, and species that are granivorous during winter but primarily insectivorous during breeding). Despite differences in diet, breeding phenology, and tendency to multiple brood, the annual breeding productivity of each species was most sensitive to changes in clutch size, less sensitive to factors influencing egg and nestling survival and least

sensitive to the proportion of females making multiple breeding attempts. Population growth was equally sensitive to breeding productivity or survival of adults or juveniles. We concluded that for a wide range of passerine species, breeding productivity was equally as important as survival in sustaining populations. To sustain breeding productivity, factors influencing clutch size (such as food abundance) should be of primary concern because nests lost to predators are often replaced.

ROLAND, JENS and PHILIP D. TAYLOR. University of Alberta, Edmonton, Alberta, CANADA. T6G 2E9. Comparison of regional herbivore-natural enemy dynamics in fragmented and continuous forests.

Regional outbreaks of the forest tent caterpillar Malacosoma disstria last longer in areas of fragmented boreal forest compared to outbreaks in continuous forest. Changes in landscape composition and configuration, as a result of habitat fragmentation, were evaluated for their effects on population processes. The impact of parasitoids and virus on forest tent caterpillar is much reduced along forest edges. Movement of tent caterpillar and of its natural enemies are differentially affected by forest clearing and fragmentation. Large-scale fragmentation of boreal forest may alter regional dynamics of this herbivore by altering the fine-scale interactions with its natural enemies.

ROMME[1], WILLIAM H., MONICA G. TURNER[2], ROBERT H. GARDNER[2], and WILLIAM W. HARGROVE[2]. [1]Fort Lewis College, Durango, CO 81301, USA, [2]Oak Ridge National Laboratory, Oak Ridge, TN 37831,USA. Does Yellowstone need large fires?

This paper synthesizes several studies initiated after the 1988 Yellowstone fires, to address the question whether the ecological effects of large fires differ qualitatively as well as quantitatively from small fires. Large burn patches had greater dominance and contagion of burn severity classes, and a higher proportion of crown fire. Burned aspen stands resprouted vigorously over an extensive area, but heavy ungulate browsing prevented establishment of new tree-sized stems. A burst of sexual reproduction occured in forest herbs that usually reproduce vegetatively, and new aspen clones became established from seed - a rare event in this region. We conclude that the effects of large fires are qualitatively different, but less dramatically so than expected.

RONSHEIM, MARGARET L. Vassar College, Poughkeepsie, NY, 12601, USA. Distance from the parental location affects the performance of asexual progeny in Allium vineale.

This field study tested for local adaptations to the parental environment of aerially produced asexual propagules (bulbils) of Allium vineale. Asexual bulbils were planted at five distances (5, 25, 50, 100 and 1000 cm) from their parent, covering the natural range of bulbil dispersal (0-100 cm, x=34 cm). There were 6 replicates at each distance around each of 24 parents, for a total of 1296 bulbils. Two bulbils were planted at each location: one from the parent plant and one from a randomly chosen "away" genotype. Total bulb weight after 2 years differed significantly among parents and with distance from parent, with bulbils 5 and 1000 cm away growing the least. Thus bulbils grew best at distances close to their average natural dispersal distance. The low total bulb weight at 5 cm may be due to competition with the parent plant. Bulbils 1000 cm from the parent also had the greatest variance in performance. The total bulb weight of "away" bulbils was either smaller or equal in size to the bulbils from the parent plant in 23 out of 24 cases, and the bulbils from the parent plant were significantly larger than the "away" bulbils at 25 cm, supporting the local adaptation hypothesis.

ROSBURG, THOMAS R., THOMAS W. JURIK, and DAVID C. GLENN-LEWIN. Iowa State University, Ames, IA, 50011, USA. Prairie communities in western Iowa's Loess Hills: Integration of community, population and ecophysiological studies.

What factors control the composition and distribution of prairie communities in the Loess Hills of western Iowa? To address this question, field research conducted between 1990 and 1993 was focused on integrating studies at various levels of ecological organization. A community study, encompassing 245 samples of prairie and woodland/edge vegetation, identified three groups of community types: mid-grass (4 types), tallgrass (4 types) and woodland/edge (5 types). Environmental measurements of each community sample indicated significant differences in slope azimuth and angle, depth of soil A horizon and total soil nitrogen among communities. Microenvironmental measurements indicated that slope azimuth affects the wind speed, air and ground temperatures, and ambient water vapor pressure that plants experience. Differences in photosynthetic rates occurred both among species within microenvironments and within species among microenvironments. Population studies showed that seed bank composition along environmental gradients encompassing all three community groups had very little correlation with community composition. Most grassland species displayed very little ability to disperse seeds beyond the boundaries of their extant populations. Most variation in prairie community composition occurs on a local scale due to topographic effects on microclimate, but this local variation is nested within variation occurring on a large scale latitudinal gradient.

ROSENBERGER, TILL and LAWTON, ROBERT O., University of Florida, Gainesville, FL, 32611, USA and University of Alabama, Huntsville, AL, 35899, USA. Risk Factors Associated with Tornado Damage.

On November 15, 1989 at 4:30 pm., a tornado touched down in Huntsville, Alabama, and then travelled Northeast through the surrounding area. Possible factors affecting an individual tree's chance of survival when exposed to high winds were investigated. Site and tree characteristics were related to amount and type of damage sustained within an old-growth mixed hardwood forest (approximately 40 ha.). Along a 200 m line transect (perpendicular to the storm track) 16 circular plots (10 m

radius) were established. Within these plots, every tree > 5 cm dbh was characterized with respect to species identity, dbh, and height. Damaged individuals were placed into one of 3 different categories: uprooted, crushed, or snapped. Initially Kolmogrov-Smirinov Chi-square tests were used to determine whether or not characteristics of individuals and/or species statistically influenced the rate of survival. Data was then analyzed using Logistic Regression Analysis to determine to what extent individual characteristics related to survival. Type of damage varied with tree size, species identity, and appeared to be partially related to the species' wood properties (modulus of elasticity and specific gravity).

ROSENZWEIG, MICHAEL L. University of Arizona, Tucson, AZ, 85721, USA. The accumulation of species in space and time.

In samples of a biotic province that comprise different areas, species diversity depends on habitat diversity and high immigration rates. But in entire biotic provinces, it depends on the rates of speciation and extinction. These are much slower. Consequently, smaller provinces have far fewer species than they would if they were merely small samples of a larger province. This result has at least two implications: (1) At large space-time scales, habitat (!) diversity is the product of speciation and extinction rates, and not of physico-chemical variation. (2) Preston's lognormally-based derivation of the slope of the species-area curve must be incomplete. Preston also conjectured that as species diversity accumulates in time, it follows the same rules as it does in space. We must now ask which rules, within-province or between-provinces? Data from one important fossil sequence suggests that the pattern follows within-province rules. But theory suggests it should follow between-province rules. The discrepancy may not be real however. It could result from variation in which community occupied the spot where the fossils were collected.

ROSS, MICHAEL S., A. R. SHARIFF, R. D. JONES, and J. J. O'BRIEN. Southeast Environmental Research Program, Florida International University, Miami, FL, 33199, USA. Nitrogen and phosphorus concentrations in ground and nearshore waters after Hurricane Andrew.

Nitrogen forms and soluble reactive phosphorus (SRP) were monitored in ground water underlying naturally vegetated portions of two Florida Keys islands, and at single nearshore locations. Sampling was monthly over a 3 year period, including 21 months prior to Hurricane Andrew and 15 months thereafter. Forests which surrounded monitoring wells on Key Largo were affected by winds of approximately 100 mph, causing extensive canopy damage and nearly complete defoliation. Lignumvitae Key was unaffected by the storm. We used a Before-After/Control-Impact model to assess post-hurricane nutrient levels in Key Largo, pairing sampling locations on that island with ones in similar vegetation and hydrologic settings on Lignumvitae Key. Unusually high concentrations of dissolved inorganic nitrogen and SRP were observed in several Key Largo wells 3 months after the storm. However, these peaks did not persist for more than a few months, and were not observed in waters adjacent to the mangrove shoreline. The resilience exhibited by these limestone island ecosystems after a sudden increase in the availability of aboveground mineralizable materials suggest that existing belowground sources, in conjunction with physical factors such as temperature, pricipation, and redox conditions, may exert control on groundwater nutrient levels.

ROSSI, ANTHONY M. and PETER STILING. University of South Florida, Tampa, FL 33613, USA. The effects of interspecific host choice on the potential fecundity of a gall maker.

Along Florida's coasts, the fly, Asphondylia borrichiae, galls the terminals of three closely related plants in the aster family: Borrichia frutescens, Iva frutescens and I. imbricata. Field and laboratory studies suggest that the fly's hierarchy in host choice varies temporally. Borrichia frutescens is the primary host for most of the year, while I. imbricata is the least preferred. Iva frutescens is the preferred host only during the winter. Gall size varies with plant choice and, as a result, crowding within the galls varies over a wide range. Galls from B. frutescens consistently produce less crowded galls and the resultant flies have a greater pupal mass and a higher egg number than do galls from the two Iva spp. These data suggest that A. borrichiae is under a selective pressure to choose B. frutescens. When novel host plants were introduced onto islands possessing only a single host, B. frutescens was consistently attacked more than the other two species by the fly. Iva frutescens may be attacked only in the winter when parasitism rates of the flies in B. frutescens are extremely high.

ROSSITER, MARYCAROL. Université Laval, Ste-Foy, Québec, G1K 7P4, CANADA. Is the Expression of Environmentally-Based Maternal Effects in Insects Related to Life History and Habitat Characteristics?

Environmentally-based maternal effects have been shown to occur in many species of insect. Previous work with *Lymantria dispar*, the gypsy moth, has shown that such effects can generate time-lagged changes in life history traits known to influence insect population dynamics. Moreover, habitat characteristics determine the strength of maternal effects expression. If maternal effects can really play a role in the initiation of insect outbreak, we need to understand the ecological characteristics of both habitats and insect species that result in the expression of maternal effects. This paper discusses the traits of species that are likely to lead it to the expression of maternal effects and the environmental circumstances under which those maternal effects are likely to influence population dynamics. A continuum is explored from the absence to the dominance of maternal effects in the expression of life history characteristics. This continuum is superimposed on a habitat template to predict the conditions under which the environmentally-based maternal effects dominate insect population ecology.

ROTH, SHERRY K. and RICHARD L. LINDROTH. University of Wisconsin, Madison, WI, 53706, USA. Elevated atmospheric carbon dioxide: effects on tritrophic interactions.

We examined how CO_2-mediated changes in tree chemistry affect performance of the gypsy moth (Lymantria dispar) and its suitability as a host for the parasitoid Cotesia melanoscelus. Four

species of deciduous trees were grown under ambient or elevated CO_2 conditions, and foliage was fed to gypsy moths in two separate bioassays. In the first, we measured performance (i.e., growth rates) of control and parasitized gypsy moth larvae for the duration of the third stadium. In the second, we assessed parasitoid performance in relation to quality of the host larvae. We found that parasitized gypsy moth larvae on all diets grew more slowly and suffered reduced food processing efficiencies relative to control larvae. The magnitude of growth suppression was greater under elevated CO_2 conditions. Parasitoid performance varied in relation to host plant species but not in relation to CO_2 environment. These results will be interpreted in relation to tree chemistry.

ROTHMAN, LORNE D. AND JUDITH H. MYERS. University of British Columbia, Vancouver, B.C., V6T 1Z4, Canada. The role of viral disease (NPV) and density in qualitative changes in lepidopteran populations.

Studies of the population dynamics of forest Lepidoptera have primarily emphasized mortality yet changes in population quality (e.g. fecundity) are commonly observed and may be important in population change. Small scale experiments provide a useful method for examining sublethal factors that may affect population quality. The potential role of NPV and density in initiating fecundity decreases in Malacosoma pluviale populations was examined in a factorial field experiment (year 1) by monitoring performance of individuals on hosts trees at high and low density in the presence and absence of NPV. In the high density treatment, larval feeding rates and development time increased and male and female pupal weights and thus potential fecundity were reduced. Male and female pupal weights were also reduced following NPV introduction. In the following season (year 2), the potential role of delayed induced resistance of host plants, disease persistence, and inheritance in delaying recovery of fecundity was examined by monitoring performance of individuals on the same experimental trees (from year 1) and by monitoring performance of offspring from year 1 parents.

ROWLAND, PAUL, McD. Northern Arizona University, Flagstaff, AZ. 86011 USA. Developing scoring rubrics for evaluation.

The use of alternative evaluation techniques is often impeded because alternative grading is frequently considered too subjective or too time consuming. Both of these issues can be readily addressed by developing and using *a priori* scoring systems referred to as scoring rubrics. Not only do scoring rubrics standardize the scoring process and increase rating reliability, but they also increase the rate of grading. More importantly, because they should be developed *a priori* and shared with students, they force the evaluator to be clear about the criteria for the evaluation task and require the evaluator to clearly and specifically identify what students are to demonstrate in the task. Example of rubrics for reports and papers will be presented and participants will be given an opportunity to wrestle with some of the knotty problems of specifying evaluated outcomes.

RUHLAND, CHRISTOPHER T. and THOMAS A. DAY. West Virginia University, Morgantown, WV 26506-6057, USA. Changes in ultraviolet-B radiation screening effectiveness with leaf age in Rhododendron maximum.

Leaves of evergreen plants such as rhododendron are exposed to large cumulative doses of ultraviolet-B radiation (UV-B; 300nm). The UV-B screening effectiveness of five leaf cohorts was assessed in shaded, naturally growing Rhododendron maximum. Epidermal transmittance and depth of UV-B penetration were measured with a fiber-optic microprobe. Epidermal transmittance (and depth of penetration) decreased with age in 1 to 4 year-old leaves, averaging 32 (62), 22 (52), 16 (45) and 13% (48μm) respectively. We assessed concentrations of UV-B-absorbing compounds and anatomical characteristics to explain differences in screening effectiveness. Concentrations of UV-B-absorbing compounds increased with age on both an area and dry-weight basis. Epidermal thickness also increased with age due to cuticle thickening. Leaf surface reflectance of UV-B was about 4% and did not vary with leaf age. Current-year leaves were more effective at screening UV-B than 1 to 4 year-old leaves. Surprisingly, they had low flavonoid concentrations. In contrast to older leaves, effective UV-B screening by current-year leaves appears related to a thick epidermal layer, and in particular a greater epidermal cell height.

RUNCK, CLAY and DEAN W. BLINN. Northern Arizona University, Flagstaff, AZ 86011, USA. Diel horizontal migration: effects on invertebrate predation and community secondary production.

Diel migrations by zooplankton effect predator-prey interactions, but few studies have considered the impact of these migrations on community secondary production. A planktonic amphipod, Hyalella montezuma, underwent diel horizontal migration in Montezuma Well, AZ. This migration occurred in the absence of vertebrate predators. Hyalella migrated from the littoral zone into the limnetic zone before sunrise and returned to the littoral zone after sunset. Phytoplankton food resources for Hyalella and physicochemical features were very similar between the two habitats. Amphipods were at greatest risk from a visual insect predator (a damselfly nymph) in the littoral zone and a non-visual, nocturnal leech predator in the limnetic zone. Field experiments suggested damselfly nymphs could drive Hyalella extinct in the Well if this endemic amphipod remained in the littoral zone during the day rather than seeking refuge in the limnetic zone. A model of trophic structure and production for Montezuma Well is presented. We propose the migratory behavior of Hyalella is an important factor contributing to high invertebrate production and pattern of energy flow in Montezuma Well.

RUNION, B.R., R.J. MITCHELL, H.ROGERS, S.PRIOR , J. AMTHOR 0and F. HENNING. School of Forestry Auburn University, AL 36849; Jones Ecological Research Center, Newton, GA 31770; ARS Soil Dynamics Laboratory, Auburn, AL36849; Lawrence Livermore National Laboratory, Livermore CA 94450. Effects of nitrogen and water stress on respiratory response of longleaf pine in elevated CO_2.

The concentration of CO_2 in the earth's atmosphere is rising which may have profound consequences on vegetation. We investigated the direct (short term) and indirect (long term) affects of CO_2 on pine respiration, and how these responses may be modified by availability of moisture and nitrogen. Concentration of CO_2 at the time of respiration measurements had only marginal affects (expressed either on a unit area or dry weight basis), with foliage measured at 720 ppm tending to exhibit slightly reduced rates compared to measurement at 360 ppm. Indirect affects of CO_2 were also small but trends were opposite with slight increases in apparent respiration rates for trees grown in elevated CO_2. However, CO_2 strongly influenced respiration rate (22% increase at elevated CO_2) when expressed on a per unit foliar N basis (CO_2 evolved/ mg N/sec). This affect was reduced when seedlings were water stressed. Both water and nutrient stress reduced respiration rate per unit leaf area and leaf weight. The direct effects of water stress and N stress on respiration were much greater than that due to enriched CO_2 levels. The influence of CO_2 on respiration rate per unit N may suggest that models that predict respiration on the basis of N content may need to account for changes in atmospheric CO_2 levels.

RUNKLE, JAMES R. Wright State University, Dayton, OH, 45435, USA. Predicting succession over a landscape: still hazy after all these years.

Englewood Reserve, in Montgomery Co., Ohio, was established in 1965. This study characterizes the successional status of each discrete section of the reserve at present and predicts the future of each section individually and of the reserve as a whole. Successional status was determined using aerial photos (1935-1993), previous studies, and new plots. From 1965-1993 the area farmed decreased (from 26% to 0%), the area in meadow increased (from 7% to 22%), the area in interspersed woods and meadow decreased (from 32% to 20%), and the area in woods increased (from 31% to 55%). The open woods-meadow stage is changing the most rapidly. Species composition within the woods also is changing, away from such species as Robinia pseudo-acacia, Maclura pomifera, and Lonicera maackii. Predicting the exact course of succession is made difficult because of the complex interplay of history and topography.

RUSSELL, ANN E., JAMES W. RAICH, and PETER M. VITOUSEK. Iowa State University, Ames, IA, 50011, USA and Stanford University, Stanford, CA, 94305, USA. Nitrogen and phosphorus dynamics in Dicranopteris linearis on windward Mauna Loa, Hawai'i.

Various aspects of nitrogen and phosphorus cycling were studied in a dominant understory fern, Dicranopteris linearis, on a matrix of sites varying in elevation (290-1660 m) and substrate age (140-3600 y-old pahoehoe lava) on windward Mauna Loa, Hawai'i. Although Dicranopteris comprises a relatively small proportion (0-11%) of the total biomass of the plant communities along the gradients, this single species accounted for up to 64% of the N and 75% of the P uptake at these sites over a 1-y period. On the young flows, this fern's contribution to P uptake (0-36% of total) was less than its impact on N uptake (up to 53% total). This fern's P-use efficiency is high on the young flows, 5400-12,000 gOM/gP, compared with 2300 to 4533 gOM/gP for the entire site. Up to 83% of P and 59% of N may be retranslocated from senescing leaves. Dicranopteris' high P-use efficiency in young volcanic soils may be one mechanism that enables this species to achieve relatively high rates of net primary productivity.

RUSSELL, CHARLES E. Pullman, WA 99163, USA. Cyclic and coastal mangals of the Guyana Coast.

The coast of Guyana is dominated by the Guiana Current and the large quantities of sediments it transports northwestward from the Amazon River. These sediments settle to form mudshoals on the continental shelf and mudflats directly inland against the shoreline. These mudshoals and their mudflats protect areas of the coastline designated as accretionary coast from wave action. As soon as a mudflat begins to emerge above high water level, a mangal establishes itself and may assist in stabilizing the mudflat. In the area of this study, two types of mangals are discernable: cyclic mangals on the mudflats of accretionary coasts, and coastal mangals on the more permanent, but generally receding coast. Because of the dynamics of mudflats, the trees of cyclic mangals are generally larger towards the eastern side of the mudflat and subject to destruction three times per century. Coastal mangals are generally larger and more complex than cyclic mangals.

RUSSELL, CLIFFORD S., Vanderbilt Institute for Public Policy Studies, Nashville, TN 37212. Regional studies as an approach to integrating ecology and economics.

Efforts to integrate economics and ecology at an abstract or conceptual level are intellectually challenging but often come off as the imposition of one discipline's paradigm and normative judgments on the other. An alternative exercise, with potential practical benefits as well as intellectual rewards, is the linking of economic and ecological system models in the context of a broader or narrower regional

problem. An early example of such an exercise was the Lower Delaware Estuary Model put together at Resources for the Future roughly 20 years ago. Some lessons may be drawn from that project for other efforts, but the problems that challenge ecologists and economists today are much tougher than the ones motivating the LDEM. The latter were acute, local, reversible on short time scales, and involved fairly gross intrusions--in the form of standard water pollutants--into the environment. Today's problems may involve chronic, low-level insults, such as small annual extensions of development into natural areas. But their implications may well be global, as when species are lost. There is often the threat of irreversible (at least on the human time scale) change. And sometimes it is even hard to be certain that a human activity is actually the cause of the identified problem. These differences combine to make the challenge facing would-be 1990s integrated modelers very tough indeed. All the more reason to get started now.

RUTHERFORD, PAMELA L. and R. H. GREEN. Univesity of Western Ontario, London, ON, CANADA. N6A 5B7. Genetic indicators of environmental stress in populations of the freshwater clam Elliptio complanata in south-central Ontario.

Many lakes in south-central Ontario have suffered shifts in water chemstry due to the effects of smelting operations to the north-west and large industrialized urban centers to the south. To identify if these environmental shifts were accompanied by genotypic shifts we collected 20 clams from each of 45 lakes. We also compiled water chemistry data (pH and conductivity), both present and historical, for each of the lakes. Allozymes were identified using protein electrophoresis of the foot tissue. We examined the data for relationships between the water chemistry of a lake and the genotypes of the clams for 2 loci (PGM-2 and PGI). As expected, lakes that are geographically closer together have more similar genotype frequencies for the 2 loci than lakes that are further apart. When this effect is taken into account there still a significant positive relationship between the frequencies of 2 genotypes (PGM-BD and PGM-CD) and pH and conductivity. Previous analyses indicated that the age of the youngest clam collected from each lake is significantly negatively correlated with pH and conductivity. Therefore, while very low pH and conductivity appears to prevent reproduction, when clams are able to reproduce, pH and conductivity may also be acting as a selective forces.

RUTTER, CAROLINE. Carleton University, Ottawa, ONTARIO, K1S 5B6, CANADA. A comparison of the pollination biology of *Solidago rugosa* in a forest understory versus an old field.

I compared the pollination biology of the insect-pollinated herb *Solidago rugosa* in forest understory versus old field habitats. I used plants drawn randomly from a common pool of seedlings to investigate differences caused by the old field and forest habitats. In addition, to validate these results, I looked at plants growing naturally in both environments. Forest plants were shorter with fewer leaves than old field plants but had larger leaf areas. In the forest, inflorescences were smaller and many fewer individuals flowered than in the field. Air and soil temperatures and light intensity were lower in the forest environment than in the field at various times of the day. Insect visitation rates were lower in the forest than in the old field, probably an effect of the limited direct sunlight in the forest habitat. The poorer growing environment, lower flower production and infrequent pollinator visits combined to dramatically reduce seed set in forest grown as compared to field grown plants.

RUZZANTE, DANIEL E, D C HAMILTON, D L KRAMER AND J W A GRANT. Dept of Biology, Dalhousie Univ, Halifax, NS B3H 4J1, Canada; Dept of Mathematics, Statistics & Computing Science, Dalhousie Univ, Halifax, NS B3H 3J5, Canada; Dept of Biology, McGill Univ, Montreal, Quebec, H3A 1B1, Canada; and Dept of Biology, Concordia Univ, Montreal, Quebec, H3G 1M8, Canada. Scaling of the variance and the quantification of resource monopolization.

Studies on feeding or mating competition often attempt to quantify resource monopolization using indices such as the variance, the coefficient of variation (CV), the coefficient of dispersion (CD), or the opportunity for selection (I). Because of the statistical association between variances and means and between variances and the number of competitors, such indices are of limited value for comparisons of studies that differ in the mean number of resources per competitor or in the number of competitors. Here we examine an alternative index of resource monopolization, Q. In this index, observed variances in resource distribution are expressed as a fraction of the difference between the variance expected under a random distribution of resources and the maximum possible variance (of discrete resource units) for a given resource abundance. On average Q is independent of mean resource abundance for overdispersed systems and Q is nearly independent of the number of competitors. We illustrate the advantages of this method with a study on feeding competition in fish.

RYAN, MICHAEL G. USDA Forest Service, Rocky Mountain Experiment Station, Fort Collins, CO 80526-2098, USA. Foliar maintenance respiration of subalpine and boreal trees and shrubs in relation to nitrogen content.

Maintenance respiration (R_m) of foliage can use a substantial portion of the carbon fixed in photosynthesis, so simple, general models to predict it are important. To test if an N-based model of R_m would apply generally for boreal and subalpine woody plants, I measured R_m (CO_2 efflux at night on fully-expanded foliage) for foliage of 7 species of trees and shrubs in the northern boreal forest (near Thompson, Manitoba, Canada) and 7 species in the subalpine montane forest (near Fraser, Colorado, USA). At 10°C, average R_m for boreal foliage ranged from 0.94 to 6.8 nmol g^{-1} s^{-1} (180-580 nmol m^{-2} s^{-1}) and for subalpine foliage from 0.99 to 7.6 nmol g^{-1} s^{-1} (280-640 nmol m^{-2} s^{-1}). CO_2 efflux at 10°C for the samples was not correlated with sample weight and only weakly correlated with leaf area (r = 0.34). However, R_m per unit foliage weight was strongly correlated with N concentration (R_m (nmol g^{-1} s^{-1}) = 0.187 * foliage N (mg g^{-1}), r = 0.83) and slopes were statistically identical between sites (p = 0.28). CO_2 efflux per unit of foliar N was about 50% greater than values published for a variety of crop species.

RYGIEWICZ[1], PAUL T., DAVID T. TINGEY[1], MARK G. JOHNSON[2], BRUCE D. McVEETY[3], DAVID M. OLSZYK[1] and RAYMOND SHIMABUKU[1]. [1]U.S. EPA, Corvallis, OR 97333 USA, [2]ManTech Environ. Technol., Inc., U.S. EPA, [3]Batelle-Pacific Northwest Labs, Richland, WA 99352 USA. Effects of CO_2 and climate change on forest trees: The TERA project

Rising atmospheric CO_2 and other greenhouse gas concentrations may lead to altered climates, which may dramatically affect forests. In 1993, Douglas fir seedlings were planted in sunlight, climate-controlled environmental chambers (Terracosms) at a new research facility (TERA). The Terracosm experiment imposes altered climate scenarios possible within approximately 50 years: two CO_2 (ambient, and ambient + 200 ppm) and two temperature (ambient, and ambient + 4°) treatments. The elevated CO_2 and temperature treatments are added continuously to current ambient levels to preserve natural climatic variability. Supporting experiments are underway in the Cascade Mountains, and in Observation and Manipulation Rhizotrons. Seven tasks describe the ecosystem responses being measured: 1) Shoot carbon and water fluxes, 2) Shoot growth and phenology, 3) System nutrients, 4) System water, 5) Litter layer, 6) Root growth and phenology, and 7) Soil biology. Data will be used in a physiological process-based tree growth model (TREGRO) to assess effects of climate change on trees. Hypotheses, objectives and an overall description of the project are presented to introduce the results shown in the following four posters.

RYKIEL, EDWARD J., JR.[1], RONALD N. KICKERT[2], and H. WU[1]. [1]Texas A&M University and [2]Battelle Pacific Northwest Labs. Ecological Phase Transitions.

In physical systems, a knowledge of phase transition properties permits predictions of system state for given environmental conditions. A variety of ecological phenomena appear to correspond to behavior known as phase transitions in other sciences. We describe phase transition concepts, and explore their applicability to ecological systems. At a phase transition, a system changes its behavior qualitatively for some particular parameter value. We examine several examples that may be considered ecological analogs of phase transitions. Melting of the arctic snowpack results in a sudden change in albedo that dramatically affects the energy balance of the tundra. Clearcutting of a pine forest on a sandy soil in east Texas resulted in a transition from a forest to a grass-shrub community. Ecotones may represent critical points where multiple phases exist simultaneously. Slight shifts in parameter values can result in major vegetation changes if the ecotone is analogous to a phase transition boundary. With further development, phase transition and critical phenomena concepts may prove to be a useful way of describing a large class of ecological phenomena.

RYPSTRA, ANN L. Miami University, Hamilton, OH, 45011, USA. The effects of prey intake and body size on the cannibalistic tendencies of spiders; a dynamic model.

Many spider species are cannibalistic. The decision to attack a conspecific is influenced by the risk of being killed. This decision was modeled as a dynamic game using the relative sizes of the spiders, and background prey intake as state variables. Successive iterations were run until the policy matrix suggested that all spiders should behave similarly in similar circumstances (ESS). The model suggests that only small and large spiders should tolerate one another. It appears that the risk of being killed is more important for small spiders and the added impact on ultimate reproductive success is more important for large spiders. Forward iterations of the model suggest that these spiders will be found in aggregations. These results are important to understanding the circumstances under which communal spiders could have evolved. Once in aggregations, spiders have higher capture efficiency and capture larger prey. These results are important to situations where it is desirable to maximize prey capture such as introductions of spiders for biological control.

SABRE, MARA, KAREN D. HOLL, and JOHN CAIRNS, JR. Virginia Polytechnic Institute and State University, Blacksburg, VA 24061, USA. Analysis of patterns of vegetation establishment on a restored landfill

The restoration of the Roanoke Regional Landfill in Vinton, Virginia, is an effort to recover some of the natural diversity of the area using a mixture of native grasses, legumes, and wildflowers. Experimental plots with varying aspects were established on slopes averaging 25%. Comparisons were made of the successful establishment of the native species mixture and the standard revegetation mixture, which was composed of nonnative grasses and legumes. Analysis of data from weekly surveys during the first year of growth indicates that aspect is significant in determining species richness on experimental plots ($p<0.0005$); however, aspect does not appear to affect the percent cover of the experimental species ($p=0.6$). The percentage of species surviving was equivalent for each seed mixture (62%). The relative frequency of planted to invading species varies, possibly due to varying seed bank sources. Data indicate that seeding wildflower mixtures will be as effective in first year establishment as standard revegetation mixtures under similar seeding ratios and regimen; consequently, the promotion of native wildflower and grasses habitats on landfill sites is a realistic alternative for post-closure landfill use.

SACCHI, CHRISTOPHER F. University of Virginia, Blandy Experimental Farm, Boyce, VA, 22620, USA. Plant life stage and genotype as determinants of resistance to herbivory in Solanum carolinense.

Plant resistance to herbivore attack is often studied on a single life stage such as seedlings or mature, reproductive individuals. The potential for selection on plants for resistance to herbivory by insects that feed on alternative plant life history stages has not been studied. I experimentally studied herbivore resistance of seedlings and reproductive individuals of horse nettle, Solanum carolinense,

to attack by the eggplant flea beetle, Epitrix fuscula. Plant life stage was the factor that most consistently affected attack by the eggplant flea beetle, with seedlings experiencing greater levels of attack than mature individuals. Seedlings and mature plants differed in morphology with seedlings producing larger leaves and no fruits while mature plants produced smaller leaves and many fruits. Despite these significant morphological differences between seedlings and mature plants, these traits were not correlated with resistance to flea beetle attack. Plant genotype also influenced herbivore attack, although not as strongly as plant life stage. I studied the correlation between resistance to herbivory in seedling and mature plants; the weak correlation suggests that horse nettle must evolve age-specific resistance to the same herbivore.

SAGERS, CYNTHIA L. University of Arkansas, Fayetteville, AR, 72701, USA. Herbivory limits productivity in light gap environments of a tropical forest.

Light gap formation and succession following gap opening are thought to explain a large part of tropical forest dynamics. Nearly all measures of the physical environment differ dramatically between gap and understory but few studies have examined how biotic interactions differ between the two habitats. In the tropical moist forest of Barro Colorado Island, Panama, I planted clones of a shade-tolerant shrub, Psychotria horizontalis, in naturally occurring light gaps and nearby understory. After 18 months, the relative growth rates in gap and understory gardens did not differ significantly. Herbivory decreased growth at the same rate in gap and understory. However, herbivory rates were significantly higher in light gaps. These results suggest that herbivory may limit the success of a shade-tolerant species in light gaps and clearly demonstrate that biotic interactions differ among light environments.

SANFORD, JR., ROBERT L., BRIAN KONOWALCHUK, and MARCIA L. ROSENBERGER. University of Denver, Denver, CO, 80208, USA. Biogeochemistry of bristlecone pine (*Pinus aristata*) at treeline.

Treeline along the front range in Colorado has shifted numerous times during the Holocene and the stems of bristlecone pine persevere in fossil stands above the present limit of tree survival. Bristlecone pine are also interesting because live foliage persist for up to 25 years. We measured foliage nutrient composition of different aged leaves, and also soil nitrogen and phosphorous fractions along an elevation transect in present day stands, and soil N and P fractions that are within fossil (800 yr BP) stands. Foliage N and P vary systematically according to elevation with nitrogen abundance increasing up-slope. Individual trees also show a marked island effect with both N and P soil content highest adjacent to stems. For stems in fossil stands, the island effect has persisted but only for some P fractions but not for nitrogen. Recent trends in foliar N and P content are discussed in terms of anthropogenic nitrogen saturation at high elevation along the front range in Colorado.

SALA, ANNA, STANLEY D. SMITH and DALE A. DEVITT. University of Nevada, Las Vegas, NV, 89154, USA. Water use by woody riparian plants in a Mojave Desert floodplain.

Water use of woody riparian plants in the lower Virgin River floodplain (Nevada) was measured using the stem heat balance method. During the 1993 growing season, comparisons of plant water use were made between one exotic species (Tamarix ramossisima) and three native species (Prosopis glandulosa, Salix exigua and Tessaria sericea). In spite of differences of individual leaf area and stomatal conductance, the four species exhibited comparable normalized sap flow (g m^{-2} leaf h^{-1}). Maximum sap flow ranged from 250 to 800 g m^{-2} leaf h^{-1}, depending on atmospheric conditions. Estimated leaf area index of dense stands of Tamarix was 3 to 5 m^2 m^{-2}. Our results suggest that water use of dense stands of Tamarix in the lower Virgin River floodplain may often exceed potential ET. Stem heat balance results of stand ET will be compared to ET estimates using the Bowen ratio technique during the 1994 growing season.

SALA, O.E., R.B. JACKSON, C.B. FIELD, & H.A. MOONEY. Stanford University and the Carnegie Institution of Washington, Stanford, CA, 94305, USA. CO_2 alters water use, carbon gain, and yield in a natural grassland.

Global atmospheric CO_2 is increasing at a rate of 1.5 to 2 ppm per year and is predicted to double by the end of the next century. Understanding how terrestrial ecosystems will respond in this changing environment is an important goal of current research. Here we present results from a field study of elevated CO_2 in a California annual grassland. Elevated CO_2 led to lower leaf-level stomatal conductance and transpiration (approximately 50%) and higher mid-day leaf water potentials (30 to 35%) in the most abundant species of the grassland, Avena barbata Brot. Higher CO_2 concentrations also resulted in greater mid-day photosynthetic rates (70% on average). The effects of CO_2 on stomatal conductance and leaf water potential decreased towards the end of the growing season, when Avena began to show signs of senescence. Water-use efficiency was doubled in elevated CO_2, as estimated by instantaneous gas-exchange measurements and seasonal carbon isotope discrimination. Increases in CO_2 and photosynthesis resulted in more seeds per plant (30%) and taller and heavier plants (27% and 41%, respectively).

SALIENDRA, NICANOR Z., JOHN S. SPERRY and JONATHAN COMSTOCK. Department of Biology, University of Utah, Salt Lake City, UT 84112, USA. Root- versus leaf-level control of stomatal conductance in *Betula occidentalis*.

Whole plant gas exchange of greenhouse-grown seedlings of *Betula occidentalis* was conducted in the laboratory under various plant hydraulic conductances (k) and soil water potentials (Ψ_S) to test the dependence of stomatal conductance (g) on leaf versus soil water status. Control plants were well-watered. Treated plants had 1) stems notched to decrease their k (notched), 2) water withheld to induce low Ψ_S (droughted), and 3) soil pressurized to increase Ψ_S (pressurized). When plants were subjected to increasing evaporative demand by decreasing the humidity of the air inside the gas exchange cuvette, the transpiration (E) and g of pressurized plants were higher, whereas E and g of notched plants were lower than those of controls. Droughted and notched plants consistently showed rapid recoveries in both E and g to control values when Ψ_S was increased by pressurizing. This indicated leaf-level control of g because soil pressurization increases turgor in shoots independent of roots. Leaf water potentials (Ψ_L) were similar whether the plant was well-watered, droughted, notched, or pressurized. This was consistent with a feedback loop between g and Ψ_L; i.e., if g had not responded to pressurization, Ψ_L would have increased. Results support leaf-level stomatal responses to k and Ψ_S in this species.

SALVEMINI, ANGIE O. and D. C. HAYES. Rutgers Pinelands Field Station, New Lisbon, NJ 08064 and Argonne National Laboratory, Argonne, IL 60439. Wetland plant community response to groundwater nitrate associated with septic systems in the New Jersey Pine Barrens.

A cedar swamp (J1) and a mixed hardwood-cedar swamp (E1) were monitored quarterly for groundwater nitrate levels prior to and four years after septic systems were installed 90 m from the wetland edge. Both sites experienced average nitrate concentrations higher than that of background levels (0.05 mg/l). J1 averaged 0.30 mg/l while E1 averaged 0.14 mg/l. A mixed hardwood-cedar swamp (H2) served as a control (no septic system) but experienced the highest average concentration of nitrate (0.47 mg/l), perhaps due to runoff from a turkey farm. Species richness of herbs and shrubs increased in all three plots over time. Mean number of herb and shrub species per quadrat did not differ for E1 or J1 but significantly increased for H2. Total Sphagnum spp. cover did not change at E1 but significantly increased at J1 and H2. Although both the migration and effect of nitrate from septic systems may be site-specific, higher nitrate is correlated with changes in the plant communities in this nutrient-poor environment.

SAMPSON, DAVID A. North Carolina State University, Raleigh, NC, 27695-8008, USA. Carbon production, storage, and partitioning of control and fertilized loblolly pine plantations examined with a new version of the simulation model BIOMASS - VERSION 13.0

I adapted and parameterized the process model BIOMASS for use in loblolly pine (Pinus taeda) stands of the southeastern United States. The model included labile carbon storage and carbon partitioning on a daily time step. Simulations were conducted on low, medium, and high productivity loblolly pine stands for control and fertilized treatments for the 1988 growth year. Simulated stemwood production ranged from 2.97 to 5.71 Mg C ha^{-1} $year^{-1}$, and was in close agreement with the empirical estimates. Fertilization increased foliage production and, therefore, stemwood production within individual stands. However, increased carbon allocated to foliage production resulted in decreased stem production efficiency (stemwood production / foliage production), regardless of treatment. Simulations suggest that labile carbon storage represented a dominant determinant of the seasonal carbon budget in loblolly pine.

SAMUELSON, LISA J., MARY A. ARTHUR, DAVID A. WEINSTEN, AND GERRY S. EDWARDS. Tennessee Valley Authority, Norris, TN 37828, USA, University of Kentucky, Lexington, KY, 40546, USA, and Boyce Thompson Institute, Ithaca, NY, 14853, USA. Simulating the growth of northern red oak seedlings and mature trees in response to ozone using TREGRO.

TREGRO, a single tree physiological model, was used to simulate the growth of northern red oak seedlings and mature trees, and their responses to ozone treatment. Growth and physiological data needed to parameterize the model were obtained from a field ozone fumigation experiment and the literature. Important differences in describing tree and seedling growth by the model were stomatal and mesophyll conductances, flushing frequency, degree of self-shading and organ growth rates. Experimentally observed reductions in stomatal and mesophyll conductances in response to ozone treatment were applied to the seedling and mature tree. Twice ambient ozone treatment resulted in small reductions in aboveground growth; however, coarse root biomass was greatly reduced. Differences in ozone responses between the seedling and mature tree were compared.

SÁNCHEZ, EDUARDO F. AND BETH MIDDLETON. Plant Biology Department, Southern Illinois University, Carbondale, IL, 62901, USA. Herbivory and seed bank dynamics in a seasonal wet/dry wetland near Palo Verde National Park, Costa Rica.

Herbivory in wetlands can increase plant diversity by removing dominant species allowing less common ones to germinate from the seed bank into the openings created. This study will examine the role of cattle grazing in creating such openings for seed germination in Mata Redonda, a seasonal wet/dry wetland in Costa Rica. These openings are thought to be preferred by overwintering waterfowl. In

the highly grazed portion of the wetland at Mata Redonda, the species richness of the seed bank was lower than in the less grazed portion (19 and 37, respectively). *Typha domingensis* Pers., a species which increased after the cessation of grazing at Palo Verde, germinated more in freely drained conditions than in flooded conditions (123.3 and 33.0 seeds m^2, respectively) while the opposite was true for *Nymphaea* sp. (27.5 and 85.3 seeds m^2, respectively).

SANDQUIST, DARREN R., JAMES R. EHLERINGER and SUSAN L. PHILLIPS. Department of Biology, University of Utah, Salt Lake City, Utah 84112 USA. Naturally-burning coal vents: a unique system for examining plant response to elevated CO_2 and the application of stable carbon isotopes

In a remote region of southern Utah a coal deposit near the surface was naturally ignited and has been burning near 40 years. The combustion below ground is releasing CO_2 and steam, with traces of methane and hydrocarbons, from surface vents. The surrounding vegetation is cold-desert shrub consisting of native C_3 and C_4 perennials with weedy C_4 species in disturbed areas adjacent to the vents. Our spot measurements of atmospheric CO_2 near the vents showed significant fluctuations, but as far as 500 m from the active vents CO_2 was consistently higher than ambient. Nearer the vents the CO_2 concentrations were 65 ppm above ambient values, and closest to the vents the CO_2 concentrations were elevated by an average of 542 ppm. Using the stable carbon isotope ratio ($\delta^{13}C$) of C_4 vegetation along the CO_2 concentration gradient we estimated the long-term integrated CO_2 concentrations at each transect location. The $\delta^{13}C$ of C_3 plants along this transect showed a decrease in the ratio of internal CO_2 to ambient CO_2 (c_i/c_a) in association with increased CO_2. This system provides a unique long-term experiment of elevated CO_2 and its influence on vegetation in a natural setting.

SARGENT, SARAH. Cornell University, Ithaca, NY, 14853, USA. Patches of fruit influence movements of frugivorous birds and seed deposition patterns; a case study with mistletoes.

I examined how fruit abundance at three spatial scales influenced patch leaving times for birds feeding on fruits of the mistletoe *Phoradendron robustissimum* in Monteverde, Costa Rica. The three scales studied were 1) individual fruiting mistletoes, 2) host trees, and 3) larger neighborhoods of 0.5 to 1.0 ha. Based on focal bird observations, none of the three bird species that fed on this fruit stayed longer in mistletoe plants with more fruit. One of the bird species stayed longer in heavily infected hosts than in lightly infected ones. Two of the three species stayed longer in heavily infected (high-density) neighborhoods than in lightly infected (low-density) ones. These results in combination with seed passage times obtained from captive individuals allow an estimation that 79-93% of seeds are carried out of low-density neighborhoods, while 50% of seeds produced in high-density neighborhoods may be deposited there. I also examined the proportion of seeds being deposited on appropriate substrates by the birds; birds feeding in high-density neighborhoods were slightly more likely to deposit seeds on host branches. Overall, the final deposition pattern of a plant's seeds is influenced by the surroundings of the plant to the extent that the surroundings influence foraging movements of dispersers.

SAUNDERS, PATRICIA A., MARK FOWLKES, and KAREN G. PORTER. Univ. of Georgia, Athens, GA, 30602, USA. Seasonal shifts in prey utilization by the invertebrate predator *Chaoborus punctipennis* in a small, southeastern, warm-monomictic lake (Lake Oglethorpe, GA)

Lake Oglethorpe, GA (A_0= 30 ha; Z_{max}= 8.7 m), has two seasonal zooplankton communities. During winter mixis (Oct-Apr), the plankton is dominated by algae and crustacean zooplankton. During summer stratification (May-Sep), the plankton is composed primarily of microbially-based consumers (flagellates, ciliates, rotifers). Our data show rapid (2-3 week) cycles of peak and decline in abundances of cladocerans in early May, which defines the transition from mixed to stratified community types. This coincides with both a decline in edible algal resources, and an increase in predator activity, particularly that of *Chaoborus punctipennis*. Gut analyses of *C. punct.* have identified cladoceran remains in early May samples. While cladocerans may be an important resource for *C. punct.* in spring, high *C. punct.* densities ($1.0-1.8*10^4$ m^{-2}) must be maintained by microbially-based microzooplankton prey throughout summer stratification.

SAVIGNANO, DOLORES A. U.S. Fish and Wildlife Service, Hadley, MA, 01035, USA. Generalized attractiveness of Lycaeides melissa samuelis larvae to ants.

I observed 19 ant species in three subfamilies tending larvae of the Karner blue butterfly, Lycaeides melissa samuelis Nabokov (Lycaenidae) in the Albany Pine Bush, New York. Overall ant attendance increases larval survival, but all ant species are not equally beneficial. I conducted field studies to determine if either food preference or ant abundance are important in determining which ant species tend Karner blue larvae. I used pitfall traps to quantify abundance of ant species and honey and mealworm baits to measure the extent of sugar specialization by the ant species. The ant species tending larvae were representative of the ground-foraging ant species present at the study site, but were not all sugar specialists. The general attractiveness of Karner blue larvae to ants may mean secretions are used to appease the wide variety of ants encountered in their natural habitats. Alternatively, all ant species may be mutualistic in varying degrees.

SCHAUS, MAYNARD H. and MICHAEL J. VANNI. Miami University, Oxford, OH, 45056, USA. Transport of nutrients from benthic to limnetic habitats by detritivorous fish

The gizzard shad, Dorosoma cepedianum is a facultative detritivore capable of transporting nutrients from benthic to limnetic habitats by ingesting benthic detritus and excreting some of these nutrients in dissolved forms which are highly available to phytoplankton. We examined the potential of this detritivore to transport nitrogen and phosphorus in Acton Lake, OH, through direct excretion measurements and bioenergetics/mass-balance modeling. Our results suggest that the amount of nutrients transported varies among age classes, with young-of-year gizzard shad having significantly higher mass-specific excretion rates. In addition, we found a significant relationship between fish size and N and P content, such that smaller fish were lower in %P and higher in %N. Differences in the rates and ratios at which fish excrete N and P can stimulate primary productivity and alter phytoplankton species composition. Model output indicates that gizzard shad provide phytoplankton with a significant source of nutrients, which at certain times during the summer exceeds the nutrient inputs of Acton Lake's highly agricultural watershed.

SCHEFFER, M., S. RINALDI and Y. KUZNETSOV. RIZA, P.O.box 17, 8200 AA Lelystad, THE NETHERLANDS, Politecnico di Milano, ITALY and Russian Academy of Sciences, Pushchino, RUSSIA. A theory on clear-water phase phenomena in lakes.

We show that the occurrence of a spring clear-water phase and other prominent features of natural plankton dynamics can be reproduced simply by seasonal forcing of a minimal zooplankton-algae model. To simulate the season, we let the impact of light, temperature and planktivorous fish vary sinusoidally. The spring clear-water phase in the model is an all-or-none phenomenon that disappears at high fish densities through a bifurcation. Specific predictions from the model are checked against field data.

SCHEINER, SAMUEL M., LEV YU. YAMPOLSKY and THOMAS J. KEHOE. Northern Illinois University, DeKalb, IL, 60115, USA. Temporal variability and the coexistance of obligate asexual and cyclic parthenogenetic clones of *Daphnia pulex*.

Populations of *D. pulex* can consist of either cyclic parthenogenetic clones, obligate asexual clones, or a mixture. Asexual clones have larger body sizes and produce larger clutches and, thus, are predicted to out compete sexual clones under constant conditions. However, variable environments are predicted to favor sexual populations. We investigated the effects of different patterns of temporal predictability on these predictions. The experiment consisted of two replicates of each of three temperature treatments: 1) constant (20°C), 2) variable and predictable and 3) variable and unpredictable. In the variable treatments the temperature varied between 17, 20 and 23°C with equal time at each of the temperatures. The populations were kept in continuous growth by culling every 6 days. Each population was initiated with same genetic composition: 18 cyclic parthenogenetic and 16 obligate asexual clones. Over the 72 days of the experiment clonal diversity decreased by ca. 70% in all populations. In all but one of the predictable replicates the proportion of the asexual clones decreased during the first 3 weeks. However, by day 72 the proportion of asexual clones differed from the initial in only two replicates: 5.8% in one unpredictable replicate and 68.2% in one constant replicate. Despite the loss of up to two-thirds of the clones during the 72 days of selection and differences in fitness-related life-history traits, cyclic pathenogenetic clones and asexual clones coexisted in the experimental conditions. There is no evidence that differences in temporal predictability effects this coexistence.

SCHIMEL, JOSHUA P. Institute of Arctic Biology, University of Alaska Fairbanks, Fairbanks, AK 99775 USA. Interactions between soil microbes and plant communities in high latitude ecosystems.

Plant communities in both tundra and taiga ecosystems are limited by nutrient availability and therefore by the activity of soil microbes. On river floodplains in the taiga, the dynamics of primary succession is strongly influenced by the interaction of plant secondary chemicals, microbial activities, and nutrient supply. While tannins from balsam poplar inhibit N mineralization and N fixation in alder nodules, simple phenolics and other soluble compounds stimulate microbial growth and N immobilization, thereby reducing N supply to alder, facilitating poplar's entry into the canopy. In upland tussock tundra, both plants and microbes are N-limited and the partitioning of different forms of N between plants and microbes is an important control on plant productivity and C cycling. While *Eriophorum vaginatum* competed extremely poorly for NH_4^+, taking up less than 5% of ^{15}N injected into tussocks, it took up glycine and aspartate 2 to 3 times faster than it took up NH_4^+. Tundra productivity is thus closely linked with the microbial turnover of amino acids and NH_4^+. Because of the importance of belowground processes in high latitude ecosystems major effects of disturbance may act primarily belowground on soil microbial processes and plant nutrient supply.

SCHINDLER WESSELLS, MEREDITH, PATRICK J. BOHLEN, DAVID A. MCCARTNEY, and CLIVE A. EDWARDS. The Ohio State University, Columbus, OH, 43210. The effect of earthworms on soil respiration in corn agroecosystems with different nutrient treatments.

We measured soil respiration in 20-m^2 field enclosures in which earthworm populations had been reduced, unaltered, or increased. The enclosures were within corn agroecosystems receiving different nutrient amendments: legume winter cover crop, manure, or inorganic fertilizer. Soil respiration was measured by the static diffusion method using a NaOH trap in a 15-cm diameter PVC pipe to determine CO_2

flux in the field. The organic nutrient treatments consistently had higher respiration rates than the inorganic treatment. During April, May, and September of 1993, when earthworms were most active, soil respiration in the legume treatment was significantly increased in enclosures with increased earthworm populations. Throughout the growing season, enclosures with reduced earthworm populations consistently had the lowest respiration rates in all nutrient treatments. Our results suggest that earthworms can play an important role in the carbon cycle of corn agroecosystems by increasing soil respiration on a seasonal basis.

SCHLESINGER, WILLIAM H., JANE A. RAIKES, ANNE E. HARTLEY, AND ANNE F. CROSS. Department of Botany, Duke University, Durham, NC 27708. Small-scale spatial heterogeneity of essential and non-essential elements in desert soils of the southwestern U.S.

"Islands of fertility" associated with shrubs characterize the distribution of soil nutrients in many desert ecosystems, including those dominated by Larrea tridentata in the southwestern US. We examined the spatial pattern of essential and non-essential elements in desert soils as an index of the importance of biotic (e.g., plant nutrient cycling) vs. abiotic (e.g., soil movements by wind and water) processes that might lead to the formation of shrub islands. In the Mojave Desert of California, N and P were highly concentrated under vegetation, suggesting that biotic processes are important to the development of soil islands. Geostatistics indicate spatial dependence in N that is associated with the mean size of L. tridentata. In contrast, most non-essential/non-limiting elements show no spatial autocorrelation that is associated with vegetation. We also found higher concentrations of N and P under shrubs in the Chihuahuan Desert of New Mexico, but spatial autocorrelations in their distribution were not associated with shrub size. L. tridentata has invaded these areas of New Mexico during the last century--perhaps too recently for biotic processes to yield well-developed islands of fertility.

SCHMALHOFER, V. R. Rutgers University, Piscataway, NJ, 08855-1059, USA. Temperature effects on foraging success in the crab spider Misumenoides formosipes (Araneae: Thomisidae): a preliminary study.

Misumenoides formosipes, a sit-and-wait predator that hunts without a web, is broadly temperature-tolerant, but prefers lower temperatures than those required for flight by some of its common insect prey. To determine if M. formosipes experiences changes in foraging success with changing temperature, I offered prey (Musca domestica, the common house fly) to M. formosipes over an ecologically realistic temperature range and measured the time required for a spider to capture a fly and the amount of time flies spent moving around the container. ANOVAs indicated that the time required to capture a fly and fly activity varied significantly with temperature. A determination of whether temperature affected M. formosipes' foraging success more strongly by direct or indirect means could not be made. Trends in field and laboratory data suggest that while M. formosipes hunts effectively over a wide temperature range, it hunts more efficiently at temperatures closer to its preferred temperature.

SCHMALZER, PAUL A. The Bionetics Corporation, NASA, Biomedical Operations and Research Office, John F. Kennedy Space Center, FL, 32899, USA. Restoring unburned shrublands: an example using cutting and burning in oak-saw palmetto scrub.

Many shrublands are fire dependent. With fire suppression shrubs can reach size and structure that make reintroduction of fire difficult. Unburned oak-saw palmetto scrub in Florida becomes unsuitable as habitat for the threatened Florida scrub jay (Aphelocoma coerulescens coerulescens) and other scrub organisms. Oak-saw palmetto scrub is dominated by sprouting species. In this paper, I examine initial recovery of two stands of scrub unburned for >25 years to mechanical cutting followed by prescribed burning. Before treatment vegetation data were recorded from the >0.5 m and <0.5 m height layers on permanent 15 m transects. Scrub oaks (*Quercus myrtifolia, Q. geminata, Q. chapmanii*), saw palmetto (*Serenoa repens*) and ericaceous shrubs (e.g., *Lyonia ferruginea*) were dominant throughout. Vegetation was dense with cover > 0.5 m exceeding 100% and little or no open space. Shrub height exceeded 2 m. One stand was cut between August 1992 and February 1993 and then burned. The second stand was cut in March 1993 and burned in November. Shrubs resprouted vigorously. Minor soil disturbance from mechanical cutting may account for increases in some herbaceous species. Rapid regrowth of vines in some areas may complicate long term recovery. However, initial results suggest that this is a viable technique for restoring unburned scrub.

SCHMOETZER, LISA A. and STANLEY H. FAETH. Arizona State University, Tempe, AZ, 85287, USA. Ecological factors maintaining genetic variation of leafminers within the host plant.

Cameraria spp. is a microlepidopteran leafmining moth specializing on the scrub oak, Quercus emoryi, in the southwestern United States and Mexico. Over 98% of a population of Cameraria in central Arizona is univoltine, but a small proportion (<2%) is bivoltine. We used an evolutionary ecology approach to determine the ecological and genetic bases for this reproductive polymorphism, and whether these morphs are the same or different species. We hypothesized that (1) allochronic race formation has occurred within the same tree species, (2) the moths are phenotypically plastic and thus capable of following a different life history dependent on resource availability, or (3) some univoltine members of this population have interbred with a multivoltine species found nearby, resulting in bivoltine hybrid offspring. These hypotheses are not mutually exclusive. Ecological factors that appear to maintain this developmental polymorphism are differential rates of mortality caused by natural enemies and frequency-dependent resource availability. The univoltine and bivoltine morphs are indistinguishable morphologically, and are completely sympatric, but appear to be reproductively isolated temporally. We have screened the 3 developmental groups for 10 enzyme loci, and can distinguish each morph allozymically. The univoltine morph does not share one allele for 3 loci with the other two morphs. This evidence suggests that the univoltine and multivoltine morphs may be hybridizing, producing bivoltine offspring.

SCHMOYER, RICHARD L., Oak Ridge National Laboratory, P.O. Box 2008, Oak Ridge, TN 37831-6367.
Nonparametric Tests for Spatial Autocorrelation in Regression.

This talk will be about tests for spatial (or serial or other) correlation in the errors in a linear regression. The tests are nonparametric in the sense that the regression errors need not come from a particular parametric distribution such as the normal. P-values are computed using permutations of the residuals. I will discuss results that show, under mild conditions, that the tests are asymptotically valid and consistent, and that the test statistics are asymptotically normal. The tests are related to the Durbin-Watson (DW) test (in the serial case). In addition to providing a spatial analog to the DW test, the tests circumvent two of the DW test's difficulties: dependency on the normality of errors and "indifference zones." I will also give examples that illustrate the general need for nonparametric statistical methods in ecological studies, and I will illustrate the spatial correlation tests with a specific example involving Great Smoky Mountain stream pH data.

SCHNURR, JACLYN L., RICHARD S. OSTFELD, and CHARLES D. CANHAM. Institute of Ecosystem Studies, Box AB, Millbrook, NY 12545, USA. Effects of small mammal community organization on tree seed predation in intact and logged forests.

In 1993 we initiated a study to determine patterns of variation in seed predation by small mammals in deciduous forests of the Northeastern U.S. We characterized microhabitat types within four 6.25 hectare live trapping grids, two with closed forest canopies, one that had been selectively logged recently and another that had been recently clearcut. We determined species composition and abundance of small mammals at each site. We measured seed predation by introducing caches of red maple (Acer rubrum) seeds at each trap station. We found a significant difference ($p<0.01$) in seed predation rates among sites; this difference was associated with a significant difference among sites in total abundance ($p<0.001$) and species composition ($p<0.001$) of small mammals. Preliminary results indicate that there was no variation in seed predation due to microhabitat types as indicated solely by canopy tree species. We suggest that spatial variation in small mammal community organization may strongly affect patterns of tree regeneration in intact and logged forests.

SCHULZ, K.E. Southern Illinois University at Edwardsville, Edwardsville, IL, 62026, USA.
Transition probability matrices as tools for analyzing understory light environments.

Forest understory light environments can range from deep shade punctuated by brief sunflecks conditions of relatively low light interrupted by sustained periods of high light. Understc species may respond to these regimes as photosynthetic opportunities or stress periods. The contrasting possibilities make it desirable to compare the dynamics of light environments ir flexible, easily standardized way. This technique reduces continuous records of light intensity to matrices depicting the probability of a significant change in intensity between observations. These matrices are easily comparable by eye and by multivariate techniques. Multidimensional scaling effectively organized the light dynamics observed in 78 daily reco separating the responses observed at different sites and on different dates within each site Multivariate analysis can be standardized by including records containing known light regim and using these as reference points in scatterplots depicting scores on composite axes.

SCHUPP, EUGENE W. and REBECCA R. SHARITZ. Utah State University, Logan, UT, 84322, USA and Savanah River Ecology Laboratory, Aiken, SC, 29802, USA. Propagule characteristics associated with potential seed dispersal by water in a South Carolina bottomland community.

Most work on the abilities of plants to persist in flooded bottomland systems has focussed on flood tolerance of seedlings and saplings. Other attributes, such as the ability of propagules to float and be dispersed by water may also be critical for allowing species to exist in such communties, however. In this study we quantified flotation time for seeds and fruits of 24 tree and shrub species from a South Carolina bottomland forest: 11 with fleshy fruits, 9 with structures for wind dispersal and 4 with no apparent adaptations. Species with structures for wind dispersal floated significantly longer than secies in other groups. Within this group, the removal of dispersal structures significantly decreased floatation time. In contrast to dispersal by wind, floatation time seems to be more closely tied to the amount of dispersal structure rather than to wingloading. Fleshy-fruited species also showed a tendency for flotation time to be reduced by pulp removal. Independent of dispersal category, the four species most typical of flooded conditions floated longer than the remaining species.

SCHWAB, PHILIP M., RUTH G. SHAW, and DONALD K. BARNES. University of Minnesota and USDA-ARS, St. Paul, MN, 55108, USA. Multivariate analysis of selection for altered cell wall composition in breeding populations of alfalfa (Medicago sativa L.)

Multivariate analysis has been used to examine the influence of natural selection on traits correlated with relative fitness, but has not been used in populations under artificial selection. Three diverse alfalfa germplasm sources, represented by 2000 equally spaced plants arranged in 20 blocks of 100 plants each, were grown in the field at Rosemount, MN in 1993. The plants were harvested, oven dried and evaluated

for dry weight, stem weight, leaf to stem ratio. Stem tissue from each plant was ground and analyzed by Near Infrared Spectroscopy for the following cell wall components: acid detergent fiber (ADF), acid detergent lignin (ADL), and acid detergent cellulose (ADC). Ten plants representing the extremes in stem lignin and cellulose content were selected from each block to form 12 breeding populations of 200 plants each. Selected plants were assigned a fitness value of 1, unselected plants a fitness value of zero. Selection gradients for each population were estimated from regressions of relative fitness on all other traits. Selection altered lignin content independently of other traits. Selection for modified cellulose content altered ADF, ADL, ADC, total dry weight and stem dry weight. Selection gradients differed between germplasm sources. Multivariate analysis can aid plant breeders in understanding correlated trait interactions in selection programs.

SCHWINNING, S. University of Arizona, Tucson, AZ, 85721, USA. **Generalizations about the effects of competitive symmetry on annual plant populations.**

Plants compete for resources in two principle ways: symmetrically and asymmetrically. Several simulation models showed that these two forms of competition have distinct effects on population size structures. For example, size variation increases with population density under asymmetric, but not under symmetric, competition. However, other simulations showed that relative size variation can both increase or decrease with density under either competition type. I show that these apparently contradictory results are explained by the different ways in which random variation interacts with competition. I distinguish three categories of size-independent random variation between competitors: 1) spatially correlated variation (e.g. in site quality) , 2) spatially uncorrelated variation of resource utilization ability (e.g. of photosynthetic capacity), and 3) spatially uncorrelated variation of resource capture ability (e.g. of height). In each category competitive symmetry has predictable, though not always distinct, effects on size structure. In contrast, effects regarding the initial size advantage of individuals remain distinct and quite robust to many forms of random variation.

SCOTT, NEAL A. and DAN BINKLEY. Rocky Mountain Experiment Station, Fort Collins, CO, 80526, USA and Colorado State University, Fort Collins, CO, 80523, USA. Litter quality effects on annual net N mineralization in forests and grasslands.

The feedback between plant litterfall and nutrient cycling processes plays a major role in the regulation of nutrient availability and net primary production in terrestrial ecosystems. Several studies have addressed the negative feedback between litter chemistry and N availability within a site with uniform climate, but few have examined this relationship across sites with different climates. We assembled data from several studies to examine the relationship between aboveground litter chemistry and annual net N mineralization across sites spanning a wide range of soils and climates. Net N mineralization declined strongly and non-linearly as litter lignin:N ratio increased (r^2=.72). Net N mineralization decreased linearly as litter lignin concentration increased, but it was only significant when data for grass litter was removed from the analysis ($p < 0.01$, r^2=0.64). Litter N concentration was not a good predictor of net N mineralization. Litterfall quantity and N content correlated poorly with net N mineralization across this range of sites (p=0.18 for litterfall). A negative relationship existed between litter lignin concentration and litter N concentration, suggesting that there is an interaction between litter lignin and N across a wide range of litter types and climatic regimes.

SEARLES, PETER S.[1], MARTYN M. CALDWELL[1], and KLAUS WINTER[2]. [1]Utah State University, Logan UT, 84322-5230, and [2]Smithsonian Tropical Research Institute, P.O. Box 2072, Balboa, Panama. Response of five tropical plant species to natural solar ultraviolet-B radiation.

The tropical latitudes currently receive high solar ultraviolet-B radiation (UV-B, 280-320 nm) even without ozone depletion. Thus, the influence of natural, present-day UV-B irradiance was examined for three native rainforest tree species and two economically important species on Barro Colorado Island, Panama (9° N). Solar UV-B radiation conditions were obtained using a UV-B excluding plastic film or a near-ambient UV-B transmitting film over potted plants in a small clearing. Significant differences were often exhibited as increased foliar UV-B absorbing compounds, increased leaf mass per area, and reduced leaf blade length for plants receiving solar UV-B radiation. Plant height was typically reduced under solar UV-B, but some variation among species in response was seen. Biomass and photosystem II function were generally unaffected. The results provide evidence that tropical vegetation responds to the present level of solar UV-B radiation. This suggests even a small increase in UV-B radiation with ozone depletion may have biological implications.

SEBASTIA, MARIA-TERESA, LAURA PUIG, and JAVIER GARCIA-PEREZ. Univ. of Lleida, ETSEAL, 25006 Lleida. Spain. Seed ecology and plant diversity in subalpine Pyrenean grasslands.

We studied seed germination, seed rain, soil seed bank, and seed morphology in relation to dispersal in Pyrenaean subalpine grasslands. Many species have the ability to germinate their seeds both before and after vernalization. This is shown by comparing soil seed bank germination under different treatments at the begining, and at the end of the growing season, and from the germination experiments with seeds collected from the plant. Soil seed bank density and seed rain fluxes are low relative to previously studied grasslands. Their composition is very similar to the surrounding vegetation. Short-distance dispersal mechanisms dominate. Although Gramineae germinated easily in the experiments, they are less represented in the soil seed bank and in the seed rain than forbs. Grasses, with high capacity for vegetative spread, are the dominant

vegetation in this system, but forbs are represented by a larger number of rare species. We suggest that many of these species are maintained by means of dispersal through time in the seed bank.

SERRANO, LYDIA, M.A. NAZIR, J.S. SURFUS, and J.A. GAMON. California State University, Los Angeles, CA 90032, USA.
Estimation of leaf area index and absorbed photosynthetically active radiation with spectral absorptance

Absorbed photosynthetically active radiation (APAR) and leaf area index (LAI) are key determinants of canopy photosynthetic carbon assimilation. While APAR and LAI may be readily estimated from remote vegetation indices, confirmation of these measurements by ground truthing is often tedious and difficult. Furthermore, most ground measurements of APAR involve broadband PAR sensors which cannot readily distinguish absorption by photosynthetic material from absorption by dead or non-photosynthetic material. In some vegetation types, this can lead to overestimation of APAR by photosynthetic material. We present an alternate way to estimate APAR and LAI from ground measurements of absorptance spectra that contain information on both green and non-green canopy components. This approach may be of particular use in ground truthing of needle-leaved canopies (e.g. conifers or chaparral) where leaf area measurements are notoriously difficult.

SHAFFER, GARY P. Southeastern Louisiana University, Hammond, LA, 70402, USA. Project CYPRESS: using wetlands ecology as a vehicle for connecting biology, chemistry, physics, and mathematics.

Project CYPRESS is a content-oriented inservice program designed to bridge the gap between scientists and teachers of grades 9-12. Project CYPRESS was inspired by a series of Ecology in Education workshops sponsored by the Ecological Society of America, the Association of Southeastern Biologists, and the National Science Foundation. The intensive five-week inservice program, with follow-up workshops and a full-time site coordinator, annually targets 16 pairs of teachers from Southeastern Louisiana. Project CYPRESS relies on ecology in general and wetlands ecology in particular to integrate the physical, earth, and life sciences. Simple experiments and scenarios are used to demonstrate the laws of thermodynamics, biological and chemical cycling, the concept of variability, techniques of estimation and prediction, the importance of replication, and some fundamentals of experimental ecology. The final section of the course focuses on the science of wetlands restoration and the processes and politics involved in Louisiana's massive wetlands restoration program.

SHARITZ, REBECCA R. Savannah River Ecology Laboratory, Aiken, SC, 29802, USA. Effects of altered hydrologic conditions on small scale environmental heterogeneity and regeneration of bottomland hardwood forests.

Species richness in southeastern bottomland forests is maintained by interactions of a heterogeneous environment with the reproduction and establishment of trees. The regeneration niche for forest species growing on the floodplains of large southeastern rivers is strongly influenced by the hydrologic regime, which especially affects dispersal, germination, and seedling survival. Models of forest dynamics and conservation plans for bottomland hardwood forests seldom incorporate hydrologic conditions, such as timing, depth and duration of flooding, and their influence on species regeneration. Altered patterns of river discharges that increase or prolong inundation may reduce small scale environmental heterogeneity that is necessary for maintaining species richness. Ongoing studies of recruitment reveal individualistic species responses that, with continued altered hydrology, will drive changes in forest composition.

SHAVER, G.R., A.E. GIBLIN, K.J. NADELHOFFER, and E.B. RASTETTER. The Ecosystems Center, Marine Biological Laboratory, Woods Hole, MA, 02543, USA. Plant functional diversity and ecosystem change in Alaskan arctic tundras.

Primary production, plant biomass, and total organic matter content vary by more than two orders of magnitude among arctic ecosystem types, and this variation is accompanied by dramatic differences in the dominant plant forms of arctic vegetation. The aim of this paper is to review existing evidence for and against the hypothesis that variation of the dominant plant forms of arctic vegetation exerts any form of short- or long-term control over the accumulation and turnover of organic matter in arctic ecosystems. The alternative hypothesis is that vegetation composition and biogeochemistry are both controlled primarily by environmental variation, with little or no interaction between them. Although individual ecosystem processes may be strongly affected by variation among plant forms in the Arctic, often differences in plant function with respect to one variable are compensated in terms of their net effect on ecosystem biogeochemistry by differences in other variables. For example, differences in leaf physiology and turnover among arctic plant forms may be compensated by opposing differences in allocation to stems. However, mainly because plant forms differ in the effects of environmental change on allocation patterns and initial rates of physiological response, vegetation composition is probably of greater importance to organic matter accumulation and turnover in disturbed or rapidly changing tundras than in relatively stable ones.

SHAW, DENICE M. and MICHAEL D. JENNINGS. U.S.Environmental Protection Agency (EPA), Research Triangle Park, NC 27711, USA, and U.S.Fish and Wildlife Service, Moscow, ID 83843, USA. An Innovative Partnership for National Environmental Assessment.

Five federal environmental monitoring programs have formed a partnership with the United States Geological Survey (USGS) EROS Data Center to facilitate development of a documented comprehen-

sive land characteristics database for the United States. The goals for the partnership include the generation of Landsat Thematic Mapper (TM) based land cover data for the conterminous United States and the development of a flexible and functional Multi-Resolution Land Characteristics database (MRLC) that meets the diverse needs of the participating programs. This presentation outlines the approach of the multi-agency, Thematic Mapper-Based Land Cover activity as well as an introduction to the MRLC concept and its utility.

SHEA, RACHEL H. and GRACE S. BRUSH. The Johns Hopkins University, Baltimore, MD, 21218, USA. Vegetation associations in the Piedmont region of Maryland: a comparison of association composition over twenty years.

Thirteen forested quadrats established in the Piedmont physiographic province in Maryland in the early 1970s were resurveyed in 1993. The diameters at breast height (dbh) of all woody species > 2 cm and presence of any woody species < 2 cm dbh were recorded. Analysis of tree and seedling species between the original and revisited plots yielded Sorenson's similarity coefficients of 71% to 96%. The source of dissimilarities was the establishment and mortality of pioneer species and the failure of several species of saplings to survive beyond a certain dbh. In general, the density of the dominant species decreased, while their total basal area increased. A similarity matrix was calculated between all plots using only species present both in the original and revisited plots. A cluster analysis of the similarity matrix was used to separate the vegetation into associations. Preliminary results indicate that the composition of the vegetation associations has remained relatively stable in the Piedmont region over a period of 20 years.

SHEELY, DEBORAH L. and THOMAS R. MEAGHER. Rutgers University, Piscataway, NJ 08855, USA. Genetic and environmental effects on seedling establishment and success in experimental populations of the tropical tree Campnosperma brevipetiolata (Anacardiaceae) on Pohnpei Island, Federated States of Micronesia.

The relative importance of genetic and environmental factors to seedling growth and survival in populations of the canopy emergent, Campnosperma brevipetiolata were investigated. Stands of Campnosperma occur in both open-canopy ("sun") and closed-canopy ("shade") habitats throughout its range in Micronesia. A reciprocal transplant experiment was peformed on Pohnpei to assess the genetic adaptation of seedlings produced by trees growing in either habitat type. Seeds were collected from 12 maternal parent trees growing in both sun and shade sources, germinated, and the seedlings planted into eight experimental plots (four sun and four shade). Survival and growth of the seedlings were censused at six months and one year. After one year, Campnosperma seedlings growing in the sun plots showed significantly higher survival rates and grew significantly more than did seedlings in shade plots. No differences in survival or growth were observed for seedlings originating from different maternal trees or from different sources. These results suggest that for Campnosperma environmental factors contribute more than genetic factors to the growth and survival of these seedlings.

SHIPLEY[1], LISA A., DONALD E. SPALINGER[1], N. THOMPSON HOBBS[2,3], AND JOHN E. GROSS[3]. [1]TAES, Texas A&M Univ., Uvalde, TX, 98801, USA [2]Colorado Division of Wildlife, Ft.Collins, CO 80526 [3]NREL, Colorado State Univ., Ft. Collins, CO 80523, USA. The scaling of foraging velocity in mammalian herbivores.

Encounter rate with foods by a forager is principally a function of food spatial distribution, but differences in the size and morphology of foragers invariably influence this relationship. We developed a simple model of foraging locomotion for mammalian herbivores which consists of 2 parameters, maximum foraging velocity (V_{max}) and acceleration and a dependent variable, distance between plants. We examined the model and the scaling of locomotion in a series of experiments with 9 mammalian herbivores ranging in mass from 0.05 to 533 kg foraging on plants spaced between 0.01 and 20 m apart. Mean foraging velocity increased asymptotically with distance between plants, but the plant spacing required for an herbivore to achieve maximum foraging velocity was strongly related to herbivore mass. V_{max} was not significantly related to herbivore mass ($M^{0.04}$), but acceleration scaled with $M^{-0.17}$. Our results show that small herbivores achieve similar maximum foraging velocities compared to large herbivores, but can accelerate faster and therefore encounter plants more rapidly when plants are spaced closely together (< 2m apart).

SHIPLEY, BILL. Université de Sherbrooke, Sherbrooke (Québec) Canada J1K 2R1. Determinants of specific leaf area in 34 species of herbaceous angiosperms.

Specific leaf area (SLA, cm^2/g) is known to correlate with a number of ecologically important plant attributes such as: relative growth rate, leaf gas exchange, leaf longevity and leaf palatability. Thus, it is important to know how various leaf attributes interact to determine specific leaf area. This study uses path analysis and allometry to describe how water content, lamina thickness, vein thickness, leaf dry weight and leaf surface area interact to determine specific leaf area. The data come from 572 leaves of 194 field-collected plants belonging to 34 species, 32 genera and 18 families of angiosperms. Variation in SLA comes mostly from variation in leaf dry weight, not from leaf surface area. Dry weight is determined mostly by leaf water content and leaf thickness. Path analysis successfully accounted for the observed patterns of covariation among these traits. There was also an interspecific (but not intraspecific) allometric trend in which dry weight increased more rapidly than surface area, resulting in larger-leafed species having a lower SLA. These results suggest an explanation for the negative interspecific correlation between net leaf photosynthetic rate and maximum relative growth rate.

SHIPPERT, M.M., WALKER, D.A., AUERBACH, N.A., and LEWIS, B.E. Joint Facility for Regional Ecosystem Analysis, Institute for Arctic and Alpine Research, University of Colorado, Boulder, Colorado 80309-0450. Regional Biomass and Leaf-Area Estimates Derived from Satellite Imagery as Inputs to Spatial Trace-Gas Flux Models for Arctic Tundra.

Reflectance spectra, leaf area index (LAI), and live biomass measurements were collected for 60 plots near Toolik Lake and Imnavait Creek, Alaska during July and August, 1993. Normalized difference vegetation indices (NDVI) were calculated from the reflectance spectra. NDVI was found to be highly correlated to both LAI and biomass. These relationships have been seen in temperate ecosystems, but have never been tested in Arctic tundra previous to this study. In addition, a clear relationship is seen between NDVI values and pH and moisture. Acidic plots have much higher NDVI values than non-acidic plots, while moist plots have high NDVI values relative to dry and wet plots. The average field NDVI measurements for major physiognomic categories were compared to average NDVI values for the same categories derived from a SPOT multispectral satellite image of the area. These values were also found to be highly correlated. However, field NDVI values were consistently about 40% higher than SPOT NDVI values. Possible explanations for this consistent trend include effects of low sun angle in the Arctic in combination with relatively high view angle of the SPOT sensor. Using the regression equations for the above relationships, biomass and LAI images were calculated from the SPOT image. The resulting images show expected trends in the LAI and biomass across the landscape. The image of biomass will be used as an input to a spatial model of methane emissions for the Alaskan Arctic. Another key input variable to the methane model will be soil moisture. Alternative image processing methods and/or radar images will be used to derive this important variable.

SICCAMA, T., T.J. BATTLES, H. WHITNEY, H.W. VOGELMANN, T. PERKINS, D. HUDNUT, A. JOHNSON, K. ROY, D. VANN AND C. WILLIAMS. Yale School of Forestry & Envir. Studies, New Haven, CT 06511, USA. Is the spruce decline over?

To assess the long-term status of the red spruce forest in the Northeastern US, we focused on 4 system factors: nutrient accumulation in wood, nutrient status of the forest floor, radial growth increments, and population status. We analyzed wood samples obtained from trees over a period of four decades to assess factors impacting nutrient accumulation patterns. Spruce wood chemistries (Ca & Mg) were determined in wood from trees cut in 1938 (Mooselauke Ravine Lodge in NH), 1953 (ASRC Lodge at Whiteface Mt. NY), and in 1993 from live trees from the forest. The forest floor of spruce/fir stands is characteristically quite thick and receives considerable nutrient inputs at high elevations from fog moisture and precipitation. We analyzed Oea material from the spruce fir forest floor at Camels Hump in VT from samples collected in 1967, 1977, 1983, 1988, and 1993 for Ca, Mg, and other major elements. To assess whether spruce radial growth rates (or basal area increments) have increased, declined, or stabilized in recent years, we determined "regional" spruce growth rates from 1989-1993 based upon measurements from a number of stands in NY, VT, MA and NH. Finally we evaluated long-term population trends in spruce on Camels Hump VT from plots which were studied in 1963-65 and revisited in 1979, 1983, and 1992.

SICKLEY, THEODORE[1], DAVID MLADENOFF[1], ROBERT HAIGHT[2], ADRIAN WYDEVEN[3], and ROBERT BRANDER[4]. [1]Natural Resources Research Institute, University of Minnesota, Duluth 55811, [2] US Forest Service, North Central Experiment Station, St. Paul, MN 55108; Adrian Wydeven,[3] Wisconsin DNR, Park Falls, WI 54552, [4] National Park Service, Bayfield, WI 54714. Regional landscape analysis of wolf recolonization in the northern Lake States.

We are using GIS to assess the landscape-scale habitat characteristics that are important to wolf establishment due to movement from Minnesota. We have analyzed available data on road density, human population, land cover, and prey density. We have used GIS to analyze these data in areas with known wolf packs based on telemetry data from radio-collared wolves. Wolves in Wisconsin currently show preference for areas with road densities of less than .23 km/km^2 for their core pack territories. Several other variables were important in the location of pack territories, including the amount of forest vs. agricultural land. Based on our results, we have identified preferred habitat in the Wisconsin-Michigan region. The results help clarify areas and landscape characteristics that are and are not important for wolves at this stage in the population recovery.

SIEMANN, EVAN, DAVID TILMAN AND JOHN HAARSTAD. University of Minnesota, St. Paul, MN 55108, USA. Diversity, abundance and body size: relationships and patterns from an insect community.

Metabolic considerations for animal species predict abundance should scale with biomass to the -0.75 power. Insect community data from Cedar Creek, MN, do not support this. We sampled 39 fields and savannahs in 1992 and collected 113,515 individuals of 1298 species. Total abundance within size classes showed abundance increased to intermediate size (10 mg) then declined with biomass. The pure metabolic model was not supported but one incorporating a higher minimum viable population size for smaller insects was. Species richness peaked at intermediate size and abundance. The species richness within a size class correlated with the total number of individuals in size classes (r=.94 n=19), suggesting that competition for resources and stochastic extinction influence diversity. Insect species richness within fields was independent of field successional age, area and plant species richness. No combination of factors predicted total species richness. When insects were classified into trophic categories (herbivore, predator, parasite, saprophage), the proportion of species in each category was independent of successional age and productivity. Species interactions appear to influence diversity. Biomass of predators within a size class was correlated with the biomass of their prey, smaller herbivores, (r=.94 n=11) suggesting predation may couple species richness between trophic groups.

SIH, ANDREW and JAMES J. KRUPA. University of Kentucky, Lexington, KY 40506, USA. Community ecology of water strider mating systems.

Community ecologists have used experimental manipulations to document complex, direct and indirect effects of predators on prey behavior and survival. No previous studies, however, have examined the "community ecology of mating systems". Our recently

published work quantified strong effects of predatory sunfish on the activity, habitat use and mating behavior (mating frequency, mating duration, mating activity, non-random mating by size, male-female interactions) of a stream water strider, Aquarius remigis (family Gerridae, hence, gerrids). Many of these effects were, at first glance, counter-intuitive, but explainable in terms of the dynamics of the male-female behavioral conflict. Here, we report on our most recent experiments that examined some complex community interactions that mediate the influence of fish on water strider mating dynamics. Our results show that fish effects depend on: 1) gerrid density; 2) fish species - minnow effects differ from sunfish effects; 3) non-additive effects of the mix of fish species; and 4) other predators, e.g., fishing spiders. Overall, our results strongly suggest that for stream water striders, mating dynamics and thus sexual selection are remarkably responsive to variation in the community in which the species is embedded.

SILMAN, MILES R. Department of Zoology, Duke University, Durham, NC, 27706, USA. Peer-pressure and Sex-switching in a Deciduous Tree.

Striped maple (*Acer pensylvanicum* L.) is a functionally dioecious deciduous tree with environmental sex determination. Individuals may undergo any of the possible transitions in breeding status from year to year. I studied a population of 1200 trees for three years to determine the relative frequencies of switches among breeding states and their proximate causes. Sex ratios were found to be highly male-biased, and transition probabilities among breeding types were found to be related to the individual's competitive environment. I develop a graphical model of competition-dependent sex-switching and test the predictions on sub-populations of *Acer pensylvanicum* L.

SIMARD, MARIE-JOSEE, BERGERON, YVES and LUC SIROIS. Université du Québec à Montréal, Montréal, Québec, H3C 3P8, Canada and Université du Québec à Rimouski, Rimouski, Québec, G5L 3A1, Canada. The impact of disturbances on the germination and early survival of three conifer species in different boreal stands.

The germination and early survival of seeds falling onto disturbed surfaces may play a key role in understanding boreal forest dynamics. Many factors influence the early establishment of forest regeneration. Our research focused on the influence of both the canopy and the type of seedbed. The germination and first month survival of Abies balsamea, Picea glauca and Thuja occidentalis were monitored on previously burned, scarified, weeded, bared and undisturbed seedbeds located in 400 m^2 openings in three stand types and in the forest surrounding these openings. Logistic regressions showed all species had significantly better germination percentages ($p<0,001$) in the openings and on the disturbed seedbeds. Better survival percentages were also noted in openings ($p<0,001$), except for fir seedlings whose survival percentages were equally as good under the canopy as in the openings. No general trends could be identified regarding the effect of different seedbeds on the survival of seedlings nor regarding germination percent differences betwen burned or scarified and bared seedbeds except that these were all significantly greater ($p<0,001$) than the control.

SIMONS, THEODORE R.[1], DAVID A. BUEHLER[2], JAIME A. COLLAZO[3], and KATHLEEN E. FRANZREB[4]. [1]National Biological Survey, at North Carolina State University, Raleigh, NC, 27695,USA; [2]University of Tennessee, Knoxville, TN, 37901, USA; [3]National Biological Survey, Raleigh, NC, 27695, USA and [4]U.S. Forest Service, Clemson, SC, 29634, USA. Avian diversity in managed and unmanaged landscapes in the Southern Appalachians.

On-going research projects being conducted by the National Biological Survey, the U.S. Forest Service, and the National Park Service in the Southern Appalachians are currently examining a number of questions related to the conservation of Neotropical migratory birds under different land management regimes. Collaboration among researchers has resulted in some standardization of methods and objectives, but it has also highlighted the need for a regional scale approach to understanding the overall importance of the Southern Appalachians to these birds, and the effect that land use practices are having on their populations. The ecological attributes of these species make them well suited to a landscape scale assessment of the risks to regional biodiversity.

SIMS, DANIEL A. and STEVEN KELLEY. Emory University, Atlanta, GA, 30322, USA. Interactive effects of viral infection, light and nutrient supply on photosynthesis and growth of *Plantago lanceolata* and *Anthoxanthum odoratum*.

Tobacco mosaic virus infection reduced growth of *Plantago lanceolata* to a greater extent when light and/or nutrients also limited growth. This suggested a competition for resources between the virus and its host. However, the mechanisms responsible for this interaction were not clear from the preliminary experiments. Viral infection had the same proportional effect on photosynthetic rates at light saturation at all resource levels and had no significant effects on respiration rates or carbon allocation patterns. Viral infection may have differential effects on the quantum yield of photosynthesis or the duration of photosynthetic activity of leaves. An increased rate of leaf turnover in infected plants would have a greater proportional effect on growth when growth rates are reduced by light or nutrient limitation. These possibilities are currently being investigated. *Anthoxanthum odoratum* infected with brome mosaic virus provided a contrasting system. Although viral infection results in clearly visible symptoms, it had no significant effect on plant growth and actually increased light saturated photosynthetic rates under high nutrient conditions. To examine the mechanism of viral effects on the photosynthetic system, the activity of PSII in leaf sections with and without symptoms will be assessed with a video chlorophyll fluorescence system.

SINSABAUGH, R.L., M.M. CARREIRO and D.L. MOORHEAD. University of Toledo, Toledo, OH, 43606, USA; Calder Center, Fordham University, Armonk, NY, 10504, USA; and Texas Tech University, Lubbock, TX, 79409, USA. An enzymic resource allocation model for nitrogen and phosphorus control of litter decomposition.

Plant litter decomposition is a critical process in the macronutrient cycles of ecosystems. Most models for this process link degradation rates to measures of climate or litter composition, rather than directly to microbial activity. We developed a mathematical model based on the premise that saprotrophic microbial communities maximize their productivity by optimizing their allocation of resources in the production of extracellular carbon, nitrogen and phosphorus-acquiring enzymes. In this model, enzyme activity indicators, e.g. cellulase, chitinase, protease and phosphatase, are used to estimate instantaneous decomposition rates and to assess relative N and P availability. These activities are easy to quantify and responsive to litter quality, edaphic and climatic conditions. Data from a 3 yr, multi-site, birch stick decomposition study conformed well to model predictions. A deciduous leaf litter decomposition study, intended to provide additional data for model evaluation, is currently in progress at the Calder Center. This approach has the potential to facilitate estimation of decomposition rates and assessment of relative nutrient limitation in the field.

SKILES, J. W. (JCWS, Mail Stop 242-4), DAVID L. PETERSON (Code SGE, MS 242-4), GARTH A. HULL (Code DXE, MS T025), and THOMAS B. CLAUSEN (Code DXE, MS T025); NASA/Ames Research Center, Moffett Field, CA, 94035-1000, USA. Instructional guides for teaching the biosphere from the top down in grades 4-6.

When a child thinks of NASA, s/he envisions space, space shuttles, space suits, and satellites. This capital NASA has with youngsters can be used for learning about our planet. In contrast to traditional elementary instruction about the biosphere that starts with the study of the organism or species and works up to the community, ecosystem, and the biosphere, we are using a "top down" approach that incorporates NASA earth science expertise. We are using three themes to introduce students to the study of the biosphere. These are 1) scale, 2) complexity, and 3) interaction. By starting with a global perspective (scale), we use images of earth taken from satellites then move to images taken by high-altitude, medium-altitude, and light aircraft asking questions about what features on the surface can be seen at each scale. We are using Bay Area teachers to help us develop and test these instructional tools. We report on the activities that have been developed and tested and on the training that was necessary for the teachers to understand and teach these activities.

SMALLWOOD, JEFFREY A. University of California, Los Angeles, CA, 90024-1606, USA. Comparison of the avian communities utilizing pine-oak-juniper woodlands in the Chiricahua Mts., AZ and the Chisos Mts., TX.

The avian communities utilizing pine-oak-juniper habitat in the Chiricahua Mountains of southeast Arizona and the Chisos Mountains of west Texas were studied during the breeding seasons between 1988 and 1991. The areal extent of the habitat in the Chiricahua's is much greater than that in the Chisos, and in concordance, bird species richness, diversity, and overall densities are much lower in the Chisos. Multiple regression analyses show that community structure on the local scale is strongly determined by certain aspects of habitat structure and productivity. Productivity variables are derived from measures of foliage density and insect density. Habitat structural characteristics play an important role in determining species richness and diversity, while habitat productivity characteristics play an important role in determining species densities, and to a lesser extent, diversities. Variations in individual species densities and species interactions are strong determinants of habitat utilization changes among years, particularly in the Chiricahua habitats where the number of species is so much greater, and possibly niches are more strongly constrained.

SMEAD, HARRY and KATHY S. WILLIAMS. San Diego State University, San Diego, CA 92182, USA. Factors that influence distribution of Cerococcus quercus scales on Quercus engelmannii.

In California, the oak wax scale, C. quercus, attacks the rare Engelmann oak, Q. engelmannii. This study examined whether oak stem morphology affects scale settlement and distribution. Pubescence of branches and cambium thickness were compared to scale settlement in nature. Scales colonized new tips of branches and scale-colonized branches had thicker cambium layers and lacked trichomes. When placed on related Q. agrifolia, scales settled more frequently on stems without trichomes. Transplant experiments showed that C. quercus performed better on trees infested by their parents than on previously uninfested trees.

SMEINS, FRED E. and MICHAEL E. MOSES. Texas A&M University, College Station, TX, 77843. Temporal analysis of Golden-cheeked Warbler habitat fragmentation using remote sensing and GIS.

This study assessed the effects of land use on habitat fragmentation of the federally endangered Golden-cheeked Warbler (Dendroica chrysoparia) in the Edwards Plateau region of Texas. The study area was selected for its essential warbler habitat and high potential for anthropogenic development. Land use and vegetation cover were determined for the time period 1951 to 1991 from aerial photographs and Landsat imagery. Using GIS, changes in habitat patch area, perimeter, and

fractal dimension were measured and correlated to land use. Urban expansions consisting of residential housing, retail centers and road networks were identified as the primary causes of habitat loss and fragmentation. By examining the probable ecological impact of different land uses, an analysis was made of the viability of remaining habitat fragments. The study demonstrates that integration of remote sensing and GIS offers an improved method for the study of land use change in fragile environments.

SMILEY, ELIZABETH A. Kellogg Biological Station, Michigan State University, Hickory Corners, MI, 49060, USA. Differences in microcrustacean community composition as a function of differential resource availability.

The microcrustacean communities in the littoral and limnetic zones of lakes differ. The distinctive communities may be responding to differences in available resources (phytoplankton) caused by light limitation or competition with macrophytes in the littoral zone. An animal transplant experiment was conducted to examine the extent to which differences in available food resources in each habitat determine the community composition. Animals from each habitat were placed in bags containing water with ambient levels of phytoplankton from littoral or limnetic zones and incubated in that respective zone. Densities of Ceriodaphnia (found in both habitats) and Simocephalus (littoral) increased in both locations. Daphnia (limnetic) declined when incubated in the littoral zone and increased in the limnetic zone. This suggests that Daphnia may be more sensitive to differences in food resources, while Simocephalus and Ceriodaphnia may be limited by other factors.

SMITH, ELIZABETH R. and NIKI STEPHANIE NICHOLAS. Tennessee Valley Authority, Norris, TN 37828, USA. SAMAB Demonstration of the National Forest Health Monitoring Program

The national Forest Health Monitoring (FHM) program is a Congressionally mandated program designed to assess the current status of the nation's forests and monitor trends in forest ecosystem health. Designed to be an "early warning system" for regional scale environmental threats such as air pollution and climate change, as well as naturally occurring pests and pathogens, the program is jointly administered by the U.S. Forest Service and EPA through the Environmental Monitoring and Assessment Program (EMAP) - Forest Resource Group. The Southern Appalachian Man and the Biosphere (SAMAB) FHM Demonstration, initiated in 1992, has the additional objectives of 1) research on candidate forest health indicators; 2) providing comprehensive baseline data for a region of significant ecological resources; 3) demonstrating the feasibility of using a suite of forest health indicators to assess changes in regional forest ecosystem function; and 4) demonstrating multi-agency cooperation. In this demonstration, 1/4 of the total number of EMAP grid points are established as permanent FHM plots in each of the first 4 years, and initial measurements are made; 1994 will be the third year of establishing plots. Data from the 1992 field season have been analyzed and provide a fairly good characterization of the current status of the region's forests including information on foliar, wood, soil, and lichen chemistry; incidence of pests and pathogens; and plant biodiversity.

SMITH, GEOFFREY R. University of Nebraska, Lincoln, NE, 68588, USA. Individual habitat use and growth rate variation in a single population of the lizard, Sceloporus virgatus.

Life history variation within a single population has rarely been considered outside of annual variation. In this study, I have examined the influence of individual habitat use on growth rates in a single population of the lizard, Sceloporus virgatus in the Chiricahua Mountains of southeastern Arizona. Using mark-recapture and observations on individual habitat use, I was able to compare growth rates of individuals occurring in different habitats. Individuals using different aspects of their environment (such as slope, habitat, and substrate) as well as different combinations of these aspects grow at different rates. The results of this study suggest that proximate mechanisms used to explain interpopulation and between year life history variation may help explain within population life history variation.

SMITH, MARIAN, CHERYL CLONINGER and STEVE RICHARDS. Southern Illinois University, Edwardsville, IL. 62026, USA. Recovery potential of a threatened floodplain species, *Boltonia decurrens*, following the Flood of 1993: soil seed bank.

In 1992, *B. decurrens* was reported from 18 sites in Illinois. The flooding Illinois and Mississippi Rivers inundated populations with silt-laden water from July to December, 1993, before plants flowered. Post-flood site surveys indicated that mature plants in 15 Illinois populations did not survive the flood, and the 3 surviving populations reduced in size by *ca.* 75%. Soil cores taken from all population sites revealed viable seeds in only two of the areas where no mature plants survived. The majority of seeds recovered were found at depths from 4-8cm from the surface, and are unlikely to germinate unless the sites are disturbed, exposing seeds to the light. Areas adjacent to former populations were explored for seeds, and surface seeds were found in 1% of these sites. It is predicted that in Fall 1994 the number of populations will be reduced by >50%; the number of plants within each population will be reduced by >90%; and a few individuals will become established in new areas.

SMITH, REBECCA B., DAVID H. ZONIES, KYMBERLI A. MUMFORD, TAMULA M. PATTERSON, and YOUNG D. CHOI. Bionetics Corp., Kennedy Space Center, FL 32899, Florida A&M Univ./SLSTP, Tallahassee FL 32307, and Purdue Univ. Calumet, Hammond, IN 46323, USA. Use of roadside ditches as a wading bird habitat at the Kennedy Space Center.

Roadside ditches may provide alternative feeding habitats for wading birds, Order Ciconiiformes, to compensate for the loss of natural wetlands in central Florida. The main

objective of this study was to classify the ditches at the Kennedy Space Center based on their physical characteristics, and then determine which type supported the most species and greatest number of birds. Our factor analysis segregated twenty 0.8 km-sections of ditches into three groups: Type II ditches were narrower (mean width 0.7m) and shallower (mean depth 0.4m) than Type I (width 1.8m, depth 1.1m, vegetation 19.9%) and III (1.5m, 1.0m, 77.8%), which were separated by the frequency of submergent and emergent vegetation. A 3-year survey revealed that the birds prefer Type I (mean 6.11 birds, 2.97 spp.) and Type III ditches (7.25, 3.08) as opposed to Type II ditches (3.44, 1.67).

SMITH, THOMAS J., III and MICHAEL B. ROBBLEE. Rookery Bay National Estuarine Research Reserve, Naples, FL 33962 USA and National Biological Survey, Miami, FL 33199 USA. Recovery of mangrove forests following catastrophic disturbance: The role of precocious reproduction.

Many mangrove species are capable of precocious reproduction, that is individuals of small height (<1.5m) produce viable propagules. Hurricane Andrew caused catastrophic disturbance in much of south Florida's mangroves. Sapling sized individuals had much higher rates of survival than did canopy sized trees. We hypothesized that precociously reproducing saplings might provide the seed source for forest regeneration. The reproductive status of canopy and sapling sized individuals was measured along a disturbance gradient (from no hurricane damage to almost total forest destruction). In areas of little or no disturbance both size classes produced viable propagules. With largescale disturbance, a much smaller percentage of canopy sized individuals of all three species produced viable propagules. However, only sapling sized individuals of Laguncularia racemosa were reproductively active in heavily disturbed areas. This differential may result in Laguncularia becoming a canopy dominant in future years.

SNEDDON, LESLEY A. AND MARK G. ANDERSON. The Nature Conservany, Boston, MA, 02110, USA.
A classification scheme for coastal plain pondshore and related vegetation from Maine to Virginia.

Pondshores or shallow basins supporting coastal plain flora are wide-ranging in North America. The dynamic hydrology of these sites results in floristically related but widely variable community structure and composition, presenting a challenging classification problem. Our objective was to develop a preliminary classification that will ensure the identification and protection of the best examples of coastal plain pondshore communities in the northeast. A subset of these ponds occurring within The Nature Conservancy's (TNC) eastern region (Maine to Virginia) was selected, and releve data within each physiognomically distinct zone was collected along a transect from upland forest to the water's edge. Field work was carried out by ecologists from each of the state heritage programs and TNC's regional office using standardized sample forms. Data was analyzed using TWINSPAN, and the resulting classification presented here provides a basis for protection planning and for subsequent sampling efforts.

SNODGRASS, JOEL W. Savannah River Ecology Laboratory, Drawer E, Aiken, SC, 29801, USA. A conceptual view of the effects of beaver ponds on North American streams.

While not directly addressing disturbances, early formulations of the "River Continuum Concept" introduced the idea that disturbances would result in a shift, either up or downstream, in the continuum. The "Serial Discontinuity Concept" applies this idea to regulated streams, viewing man-made impoundments as dimensionless entities along the stream continuum that result in an up or downstream shift in the continuum. Using these ideas as a starting point, I present a conceptualization of the effects of beaver ponds on the structure and function of streams. In contrast to the above ideas, temporal succession in the stream and riparian zone of beaver disturbed reaches is considered important, and disturbed reaches are viewed as having spatial dimensions and releasing water of varying character depending on successional stage. Response surfaces are used to depict changes in physical parameters and biological phenomena (on the y-axis) in relation to the spatial continuum (x-axis) and stage of temporal succession (z-axis) of beaver disturbed reaches.

SNYDER, WILLIAM E., DAVID W. TONKYN AND DANIEL A. KLUEPFEL. Clemson University, Clemson SC, 29634, USA. Transmission of a genetically engineered microorganism by a common crop insect.

Root colonizing bacteria have been genetically engineered for many agricultural uses, from the enhancement of plant growth to the killing of insect pests. Before engineered bacteria can be widely used, however, it is necessary to examine the risk of their spreading in the environment. Crop pests commonly occur in high densities, and often have great dispersal abilities and wide host ranges, increasing this risk. We are examining the potential for the Southern Corn Rootworm (SCRW), a major Coleopteran pest of corn, to transmit a genetically engineered rhizosphere bacterium, *Pseudomonas aureofaciens* strain 3732RNL11 (L11). We have found that in the lab SCRW is an effective vector of L11, transmitting the bacterium from inoculated to non-inoculated corn plants in very short feeding times (3 hours) and both carrying and transmitting the bacterium for

long periods of time (at least 7 days). Given the well-documented dispersal ability of SCRW, this could serve as a significant dispersal mechanism for L-11 and make the containment of this bacterium at the site of application unlikely.

SOBCZAK, WILLIAM V.[1,2], LARS O. HEDIN[1,2], and MICHAEL J. KLUG[1]. [1]Kellogg Biological Station, Michigan State University, Hickory Corners, MI 49060, USA and [2]Cornell University, Ithaca, NY 14853, USA. Bacterial productivity across a riparian soil-stream interface.

There is much interest in understanding microbial processes in riparian zones. We examined whether there is a relationship between bacterial production and variation in dissolved organic carbon (DOC) across a soil-stream interface? We hypothesized that bacterial productivity would be changed as a function of DOC supply resulting in the reduction of DOC. Bacterial productivity was determined on four sampling dates along two separate transects by estimating the rate at which [3H]thymidine was incorporated into bacterial DNA in anaerobic sediments ~0.5m in depth. On the first sampling date bacterial productivity was greatest at the region of reduced DOC as predicted. However, on subsequent dates a dramatic DOC gradient was absent, and bacterial productivity was instead related to particulate organic matter content. Our results indicate the importance of spatial heterogeneity in understanding riparian microbial communities.

SOLBRECK, CHRISTER. Swedish University of Agricultural Sciences, S-750 07 Uppsala, SWEDEN.
Seed feeders in a patchy and time-varying system: Euphranta connexa (Dipt., Tephritidae) and Lygaeus equestris (Het., Lygaeidae) on Vincetoxicum hirundinaria (Asclepiadaceae).

Insect population systems often seem to operate on extended temporal and spatial scales. Here I report on the dynamics of a natural population system consisting of a perennial and patchily distributed herb and its two insect seed predators. Seed production and insect densities have been monitored in a large number of plant patches over the last seventeen years. This system is characterized by considerable fluctuations in resources as well as in insect populations, by high patch synchrony and by strong bottom-up regulation. Enemies, mainly parasitoids, have almost no effects on the seed feeders. Fluctuations in seed predator populations are largely driven by weather conditions acting directly on the insects or indirectly via host plant seed production. This may cause long time lags in resource tracking by insect populations. Long-term and large-scale monitoring is essential for understanding the dynamics of this system and for the interpretation of experiments.

SOLIS, CORINA and LEE W. COOPER. Instituto de Físcia, Universidad Nacional Autónoma de México, A.P. 20364 México, D.F., and Oak Ridge National Laboratory, Oak Ridge, TN 37831 U.S.A. Carbon, hydrogen, and oxygen isotope compositions of organic matter and water in heliophytes of a tropical deciduous forest in México.

Differences in water use, as expressed in organic matter carbon/oxygen isotope and leaf water hydrogen/oxygen isotope contents, were explored between xerophytic trees (*Jaquinia pungens* and *Coccoloba liebmannii*) that retain leaves during the dry season and a drought deciduous tree, *Thouinia paucidentata*. Diurnal variation in the $\delta^{18}O$ and δD content of leaf water was similar for xerophytes growing in dry (ridge) versus wet (arroyo) sites, and of greater magnitude than observed during the wet season for *Thouinia paucidentata*. However, physical processes influencing heavy isotope enrichment in leaf water during both the wet and dry season appear to similar for all species studied. Slopes of the linear relationships of δD relative to $\delta^{18}O$ in *T. paucidentata* did not differ significantly from those of the xerophytes in the wet season, although in the xerophytes, stronger heavy isotope enrichment was observed in April (dry season) than in December (wet season). Carbon and oxygen isotope composition of organic material are also consistent with differences in physiology and soil moisture.

SOULIA, MARGARET E., STEPHEN D. NEWMAN, KATHERINE BOLSTER, AND JOHN D. ABER. University of New Hampshire, Durham, NH, 03824, USA. Relative accuracy of wet chemical and spectrophotometric measurement of carbon fraction content in forest foliage.

As part of NASA's Accelerated Canopy Chemistry Program we evaluated the predictive capabilities of a visible/NIR reflectance spectrophotometer on canopy carbon constituents. Fresh foliage from three deciduous species was collected for carbon fraction analysis. Samples were analyzed using a series of extractions that yielded different carbon constituents: non-polar, polar, cellulose and lignin. Results showed this to be a satisfactory method for carbon fractionation. Coefficient of variation within and between runs was less than 10%. This was further supported by an interlaboratory comparison involving two other labs and samples collected as part of NSF's LTER LIDET experiment. Variations in lab results are due in part to differences in ash correction calculations. Approximately 1000 additional samples were analyzed by wet chemical methods and used as a calibration set for Visible/IR reflectance. Results show accuracy of spectrophotometric measurements to approach that of wet chemistry techniques.

SPARLING, PATRICIA M. and V. THOMAS PARKER. San Francisco State University, San Francisco, CA 94132, USA. Temporal and spatial associations between Arctostaphylos species and Pseudotsuga menziesii seedlings.

Distinct spatial and temporal patterns of P. menziesii establishment into chaparral in Marin County, California indicate different factors are important in the success of seedling recruitment. We conducted association analysis using 1 meter radius circular plots centered on individual young trees and randomly placed quadrats. The results indicate that P. menziesii, an ectomycorrhizal species, has strong positive associations in particular with Arctostaphylos glandulosa (>.001), and also Quercus wislizenii and Vaccinium ovatum (>.005), all ectomycorrhizal species. Negative associations were found with Adenostoma fasciculatum (>.005) and other endomycorrhizal species. These strong spatial patterns may be explained by mycorrhizal associations and increased soil moisture availability under chaparral stands dominated by Arctostaphylos species. When we examined temporal patterns with particular reference to recruitment peaks in Arctostaphylos stands after a 1945 fire, we found that establishment began immediately following the fire in stands of resprouting Arctostaphylos species. However, in stands dominated by A. montana, an obligate seeder and serpentine endemic, recruitment was delayed approximately 20 years. This delay can be explained by the lack of soil moisture and mycorrhizal species under A. montana seedlings as compared to those conditions normally found beneath mature stands. These patterns suggest that Arctostaphylos mycorrhizal associations and soil moisture is crucial to establishment of P. menziesii seedlings.

SPERANSKAYA, OLGA A. ECOFOREST, MOSCOW, RUSSIA. The Russian forest as an element in stabilizing global climatic change.

Russia's forests occupy nearly 1.18 billion hectares, almost one quarter of the world's woodlands. The total stock of standing timber now comprises 74.6 billion cubic meters, with an annual growth of 844 million cubic meters. The role of such large forested areas in maintaining climatic balance is well established. Among the macro-level climatic elements that major deforestation can influence are the greenhouse effect, albedo, amount of rainfall, surface temperature, and the hydrologic cycle. As a result, deforestation has far-reaching implications to existing ecosystems. In this paper, estimates are made of the effect of forest loss from forest fires (up to 1 mill. hectares), atmospheric pollution (up to 600,000 hectares), and overlogging (1.2 mill. hectares) on major climatic elements. Interactions at the regional level and implications of the changing dynamics of these sources of deforestation are explored. The need for new protective strategies, including application of forest management principles and mapping of ecological relationships in large forested areas, are also discussed.

SPERRY, JOHN S. and NICANOR Z. SALIENDRA. Department of Biology, University of Utah, Salt Lake City, UT 84112, USA. Intra- and inter-plant variation in xylem cavitation.

A method is presented that uses positive air pressures to determine the cavitation response of a single axis. The method accurately predicted the xylem tensions inducing cavitation in Betula occidentalis. The technique was used to investigate intra- and inter-plant variation in this species. Within an individual, average cavitation tension increased from 0.66 ± 0.273 MPa in roots, to 1.17 ± 0.101 MPa in trunks, to 1.36 ± 0.037 MPa in twigs. Cavitation tension was positively correlated with the hydraulically-weighted mean of the vessel diameter, and was negatively correlated with the conductance of the xylem per xylem area. Native cavitation was within the predicted range: roots were significantly cavitated at mid-day vs. mininimal cavitation in trunks and twigs. Across individuals, average cavitation tension in the main axis varied from 0.90 MPa to 1.90 MPa and was not correlated with vessel diameter. Juveniles (2-3 years old) had narrower vessel diameters than adults but the same average cavitation tension. However, juvenile xylem retained hydraulic conductance to a much higher xylem tension (3.25 MPa) than adult xylem (2.25 MPa) which could facilitate drought survival during establishment.

SPETICH, MARTIN A. and GEORGE R. PARKER. Purdue University, West Lafayette, IN, 47907-1159, USA. Spatial and structural biomass dynamics of a midwestern old-growth forest from 1926 to 1992.

To reach a better understanding of the dynamics of a midwestern old-growth forest we analyzed both structural and spatial distribution of woody biomass over a 66 year period. The site is a 20.6 ha forest in which every tree 10 cm dbh and greater has been tagged and mapped since 1926. Five windows of time are compared - 1926, 1976, 1981, 1986 and 1992. Dry weight of biomass for the core 7.92 ha area for each year is: 1926=1,221,089 kg; 1976=1,641,882 kg; 1981=1,744,140 kg; 1986=1,707,059 kg and 1992=1,674,546 kg. We found that the balance of growth and mortality for all tree species combined occurred at a spatial scale of less than 0.49 ha during the aggredation phase of development. Results indicate that this forest is currently in the transition phase of development. Biomass of American elm (*Ulmus americana*) has remained relatively stable even though this species has structurally shifted in diameter distribution and canopy dominance. Shifts in biomass among species appear to be related to shade tolerance.

SPIER, LISA P.[1] and JAMES R. SNYDER[2]. [1,2]Big Cypress National Preserve, Ochopee, FL, 33943, USA and [1]Florida International University, Miami, FL, 33199, USA. Response of a south Florida pine forest endemic herb to wet season and dry season fires: Is there a natural fire season?

Wildland fires (both lightning-caused and human-caused) occur at all times of the year in subtropical south Florida. We studied the response of *Jacquemontia curtisii* (Convolvulaceae), an herbaceous pineland endemic, to prescribed burns in June (wet season) and January (dry season). Fires during the wet season were cooler than the dry season burns but resulted in

greater mortality of adult plants (52 vs. 27%). In spite of greater mortality, total flower and seed production were greater after wet season burns. Plants surviving wet season burns produced nearly 10X more flowers than plants burned in the dry season. However, the number of seedlings germinating after the dry season burns was 5X greater than after the wet season burns. The results suggest that there is a role for both wet season and dry season burns.

STALTER, ANNA M., MARK C. WHITMORE, and MARIANNE E. KRASNY. Cornell University, Ithaca, NY, 14853, USA. Comparison of methods for measuring and describing forest gaps in central New York.

Gap area was determined in a central New York forest over the period 1990-1993 by two methods, the line intercept method of area estimation and a plane surveying technique. In 1993, we also mapped gaps using traditional and computer-aided methods. Actual gap area, as determined using plane surveying techniques, was on average 20% smaller than the estimated area using the line intercept method. Mapping showed that gap geometry was more complex when multiple gapmakers were involved, and gaps that expanded over the period 1990-1993 showed a trend toward more complex geometry, i.e, gap polygons were many-sided and edge tree to edge tree distances more variable. Closing gaps exhibited a more simplified geometry as trees in the gap interior and at gap edges grew tall enough to effectively decrease gap area.

STAMP, NANCY E. and M. DEANE BOWERS. Binghamton University-SUNY, Binghamton, NY, 13902-6000, USA and University of Colorado, Boulder, CO, 80309-0334, USA. Host plant chemistry and performance of plantain when herbivores are attacked by predatory insects.

A field experiment was conducted comparing the effects of a specialist feeder (Junonia coenia) and a generalist (Spilosoma congrua) on plantain in the presence and absence of predatory stinkbugs and wasps. Herbivory did not induce iridoid glycosides (IGs), but this result was linked to the weather conditions. IG concentrations were lower for plants used by the generalist feeder compared to the specialist and control plants. IG levels were higher for plants with stinkbugs than those with wasps. Plant mass was greater in the presence of stinkbugs than wasps for plants that were the main target of herbivory but not for adjacent plants. Analysis led to the conclusion that a potential indirect facultative mutualism between the plant and the predators was at best transitory.

STARR, SCOTT T. and R. KELMAN WIEDER. Villanova University, Villanova, PA, 19085, USA. Quantitative determination of organic matter quality in freshwater *Sphagnum*-derived peat.

Peatland ecosystems contain approximately 1/3 of the world's soil carbon. With a goal of evaluating potential carbon balance responses of peatlands under predicted scenarios of global climate change, we refined existing methods to develop a sequential extraction procedure for the quantitative characterization of organic matter quality in peat. Freeze-dried and ground peat is first extracted with CH_2Cl_2 in a sonicating water bath, filtered and weighed (mass loss = soluble fats, oils and waxes). The residue is extracted with hot (100 °C) water, dried, weighed (mass loss = hot-water extractable fraction), and the filtrate is analyzed for proteins (digestion; hydrazine reduction assay), carbohydrates (phenol/H_2SO_4 assay), and phenolics (Folin-Denis assay). The residue is partitioned two subsamples. One is analyzed for holocellulose (delignification by $NaClO_2$/acetic acid digestion; gravimetric determination), which is then fractionated into α-cellulose (KOH digestion) and hemicellulose (ethanol precipitation from the KOH filtrate). The second subsample is analyzed for lignin (H_2SO_4 digestion, filtration, gravimetric determination) with the filtrate analyzed for carbohydrates (phenol/H_2SO_4 assay) and proteins (digestion; hydrazine reduction assay). It is critical to correct for ash concentration of the residual material after each extraction step. Analysis of 7 replicate subsamples from a peat sample indicated that each organic fraction could be estimated with precision (coefficients of variation $\leq 5\%$); also the sum of the individually determined organic fractions averaged 999 $\pm$ 30 mg g^{-1} ash-free mass.

STEIN, STEVEN J. and PETER W. PRICE. St. Lawrence University, Canton, NY, 13617, USA and Northern Arizona University, Flagstaff, AZ, 86011, USA. The relative effects of plant resistance and natural enemies by plant developmental age on sawfly preference and performance.

To better understand the relationship between oviposition preference and offspring performance we must critically evaluate the relative importance of the selective forces or causes of mortality affecting developing larvae. We documented a strong relationship between oviposition preference and larval performance for two species of galling tenthredinid sawflies, Euura sp. and Pontania sp., near P. pacifica on the arroyo willow, Salix lasiolepis. There was a correlation between attack and survival on different ramet ages for both species. Mortality due to plant resistance by ramet age primarily explained the pattern of attack of both sawflies. The effect of plant resistance was strongest on willow shoots on very young ramets. This effect decreased rapidly as ramet age increased and then increased relatively slowly as ramets aged, becoming very strong on the oldest ramets. Mortality due to plant resistance was eight times greater than mortality due to natural enemies for Euura and 3.2 times greater for Pontania. Natural enemies may play a minor role in the population dynamics of these two sawflies subsidiary to the plant-herbivore interaction. We reason that selection has resulted in ovipositing females flying primarily in the upper parts of willow clones and avoiding the highly resistant younger ramets common in the lower parts of clones. Within the upper parts of clones, the evolution of female behavior that discriminates against shorter, slower growing shoots on older ramets would be selected for by the decreasing survival of offspring on these shoots.

STEINAUER, ERNEST M. and SCOTT L. COLLINS. University of Oklahoma, Norman, OK, 73019, USA. Spatial pattern in tallgrass prairie following urine deposition.

Eight 42 m transects were located in a recently burned Kansas tallgrass prairie: four in a site grazed by bison and four in an adjacent ungrazed site. Two liters of simulated bovine urine were randomly applied at nine locations on two transects per site in late May, 1991. Canopy cover of vascular plants was recorded in 128 0.1 m^2 adjacent quadrants along the transects prior to urine application and in late July, 1991. Spatial patterns in the cover of several common species, all graminoids, and all forbs, as well as in richness and Shannon diversity varied among transects prior to and following urine treatment. Neither urine treatment nor grazing consistently altered the spatial scale of patterns in the above parameters. Urine treatment produced detectable peaks in graminoid cover on ungrazed transects but preferential grazing of urine patches produced troughs in graminoid cover on grazed transects on and near urine patches. Forb cover was not altered on urine patches on grazed or ungrazed transects. Urine patches altered spatial patterns by increasing graminoid abundance and by acting as initiation sites for bison grazing.

STEINBERG[1], D.A., R.V. POUYAT[2], R.W. PARMELEE[3], AND P.M. GROFFMAN[1]. [1]Institute of Ecosystem Studies, Millbrook, NY, 12545, USA; [2]USDA Forest Service, Syracuse, NY, 13210, USA; [3]Ohio State University, Columbus, Ohio, 43210, USA. The effects of non-native earthworms (Megascolecidae) on soil nitrogen mineralization in oak stands along an urban-rural gradient.

Earthworm dry mass per unit area was found to be significantly higher in urban (2.16 g m^{-2}) than in rural (0.05 g m^{-2}) oak forest stands along a 130 km transect in the New York City metropolitan area. Net N-mineralization rates in the A horizon were also relatively high in the urban stands, despite the input of poorer quality litter. A 2 x 2 factorial microcosm study was conducted using two A horizon soil treatments (urban and rural), and two earthworm treatments (with and without earthworms) to determine if earthworms were affecting net N-mineralization rates along the transect. Net N-mineralization rates were significantly higher in urban soil with earthworms (0.15 mg N kg^{-1} d^{-1}) than in urban soil without earthworms, which had a net immobilization of N. Rural soil with earthworms (0.57 mg kg^{-1} d^{-1}) had significantly higher rates than urban soil and rural soil without earthworms (0.28 mg kg^{-1} d^{-1}). Potential net nitrification rates were 2 to 3 times higher in urban soil with earthworms than in the other treatments. These results suggest that earthworms may explain the relatively high net N-mineralization and nitrification rates in the urban stands despite the input of poorer quality litter.

STEINHART, GEOFFREY B. and WAYNE A. WURTSBAUGH. Utah State University, Logan UT, 84322-5210, USA. Under-ice diel vertical migration of zooplankton: the importance of temperature and predation.

The diel migration of zooplankton under-ice was measured in an oligotrophic mountain lake (Stanley Lake, Idaho). Samples were collected at discrete depth intervals using a closing-type Wisconsin plankton net. Sampling took place at midnight, midday, one hour before sunrise, and one hour after sunset. In addition, light intensity, temperature, dissolved oxygen, and chlorophyll were measured. The calanoid copepod *Epischura nevadensis* showed a strong reverse migration. *E. nevadensis* display a similar reverse migration during the summer months. The other dominant zooplankton in the winter, *Bosmina longirostris,* migrated to the surface at night, and returns to the bottom in the day. During the summer, *B. longirostris* does not migrate.. The winter migration may be a result of the reduced light intensity and reversed temperature stratification in the lake. *B. longirostris* may need to come to the surface to feed, but the reduced temperatures there may inhibit digestion. Descending into deeper water may increase their rate of digestion and assimilation, and decrease predation by visual planktivores.

STERN, S. JONATHAN. Texas A&M University, Galveston; TX, 77551, USA. Baleen Whales and Spatiotemporal Scales.

Spatial and temporal distribution of baleen whales on their feeding grounds was determined from census cruises off Alaska, Washington and California. The distribution of whales feeding in wind-generated upwelling systems (WGUS) was patchy at scales on the order of 20 km and random at smaller scales. Whale distribution on feeding areas in tidally induced upwelling systems (TIUS) was patchy on a scale of less than 10 km. Temporally, feeding in WGUS lasted on the order of days to weeks, then stopped, with whales leaving the area until the next wind event. However, in a TIUS, upwelling occurred daily, with whales feeding in an area continuously over months. Upwelling events in a TIUS would be smaller in amplitude and duration, but higher in frequency than those in WGUS. In a TIUS, prey tended to be trophically higher, and occur in smaller schools than prey in WGUS. Whales in TIUS would have less energy available to them per unit time than whales in WGUS. This has implications for whales that live off stored energy for up to six months per year.

STEVENS, L. E., D. L. WEGNER, R. VALDEZ, D. W. BLINN, and D. T. PATTEN. Glen Canyon Environmental Studies, P. O. Box 22459, Flagstaff, AZ 86002. Colorado River regulation effects on downstream fluvial ecosystem structure in the Grand Canyon.

Regulation of large rivers may increase complexity, resilience and linkage of aquatic and terrestrial components. Impoundment of the Colorado River between Glen Canyon Dam and Lake Mead, Arizona reduced the magnitude and variation of flow, mean and variance

of water temperature, and light attenuation. Geomorphic characteristics of the 13 discrete reaches and the location of sediment-contributing tributaries create a stepping continuum in this eddy-dominated fluvial ecosystem, and influence reach-based trophic structure, production and diversity. Flow regulation increased aquatic and terrestrial autotroph standing crop in upper and wider reaches by more than an order of magnitude. Flow regulation and cold hypolimnial releases have elevated the importance of tributaries, which now serve as reproductive refugia for macroinvertebrates, native fish and marsh plant taxa.

STILING, PETER and ANTHONY M. ROSSI. University of South Florida, Tampa, FL 33620-5150, USA. Lack of demes in a gall making fly?

We tested the idea that populations of the gall-making fly, *Asphondylia borrichiae*, are adapted to local populations of their host plant, sea oxeye daisy, *Borrichia frutescens*. Previous studies had suggested that plants from some populations are more likely to be galled than others. In the present study, plants from four separate populations, each of which supported high gall densities, were grown in a common soil in a botanical garden and all galls were removed to create gall-free plants. Pots were replaced in the field in a reciprocal transfer design and subsequent gall densities were recorded. In addition, the final sizes of all galls and the levels of mortality caused by four species of parasitic wasps, the main agents of mortality, were noted. Results that indicated the existence of demes in the initial colonization period, changed over time.

STINNER, B. R., D. A. MCCARTNEY, JOHN BLAIR, R. W. PARMELEE, and M. ALLEN. The Ohio State University, Dept. of Entomology, Wooster, OH 44691. Effects of organic and inorganic fertilized agroecosystems and earthworm manipulations on plant biomass production, N uptake and N flux.

Results are reported from an experiment comparing the impacts of earthworm manipulations and agroecosystem treatments on crop (corn, Zea mays) and weed biomass in relation to nitrogen uptake and soil available nitrogen. The experimental design consists of inorganic (ammonium nitrate) and the organic (cover crop and manure) fertility treatments. Within each fertility treatment, earthworm treatments consist of ambient, augmented and reduced population levels. Early season crop biomass was significantly influenced by earthworm x nitrogen source interaction. In turn, this effect was related to the interaction of earthworms and nitrogen source on soil mineral-N levels. There were, however, no significant differences among treatments at peak standing biomass. Very high mineral-N levels observed in the inorganic treatment relative to plant requirements for N, indicate the potential for gaseous or solute losses. These results will be discussed in relation to nutrient uptake and elemental concentrations of N in plant biomass, and in relation to agroecosystem-level flows of N.

STINNER, D. H., B. R. STINNER, E. R. ZABORSKI, M. R. FAVRETTO and D. A. MCCARTNEY. OARDC/The Ohio State University, Dept. of Entomology, Wooster, OH 44691. Ecological Analyses of Ohio Farms Under Long-Term Sustainable Management.

For three years, we have been analyzing whole-farm ecosystems in terms of nutrient budgets and nutrient cycling processes. These farms were managed under either low chemical or organic management for up to 28 years. They represent dairy, beef, and cash grain farms. Yields of crops and animal products have been average or above for each of these farms and economic analyses show that the dairy and beef farms are significantly more profitable than comparable farms in the region. At a whole-farm level, the nitrogen input/output ratio was highest on the dairy farm, intermediate on the beef farm and least on the cash grain farm. Phosphorous and K accumulated most in the cash grain farm soils and least in the beef farm soils. In comparisons of nutrient cycling processes with adjacent conventional farms, we found the decomposition of plant residue and animal manure was more rapid in the organically managed soils. There were also significant differences in particulate organic matter amounts, earthworm abundance, elemental composition of crop and weed biomass, and mineral N levels in soil between the farms.

STIVEN, ALAN E. Department of Biology, University of North Carolina, Chapel Hill, NC 27599, USA. Genetic and ecological assessment of declining and endangered freshwater mussel fauna; two case studies in the *Elliptio* genus.

As native freshwater mussels become rare from declining water quality and invasions of exotic species, it is essential that endangered species designations be based upon reliable systematics. However, this fauna is notorious for its disputed systematics derived largely from conchological differences. Two case studies are presented. The first contrasts the endemic rare *Elliptio waccamawensis* from Lake Waccamaw, NC with several allopatric populations of *E. congaraea* from adjacent waters. The second contrasts a group of largely allopatric *Elliptio* lanceolate (*producta*?) from both South and North Carolina waters. In both studies conchological parameters appear primarily associated with substrate. Genetic analysis of the *E. waccamawensis-congaraea* group found that Nei's unbiased genetic identity (I) did not distinguish 2 of the 3 *E. congaraea* populations from the Lake Waccamaw *Elliptio* population (I-values from 0.820 and 0.953). In contrast, 6 of the 8 pairwise comparisons of the *Elliptio producta?* group exhibited I-values <0.80 (0.484 to 0.796), strongly suggestive of separate species. The remainder of the pairwise comparisons had I-values indicative of subspecies. The results from these two case studies suggest that considerable biological, ecological and genetic work should be mandatory before any endangered designation of certain freshwater mussel groups is contemplated .

STOHLGREN, THOMAS J., and RICHARD R. BACHAND. National Biological Survey, Natural Resource Ecology Laboratory, Colorado State University, Ft. Collins, CO, 80523, USA. Monitoring forest change at ecotones in the Colorado Rockies.

We are assessing the potential effect of global climate change on the Front Range of the Colorado Rockies, including Rocky Mountain National Park. One objective is quantify the abiotic and biotic controls on forest distribution and productivity as a basis for assessing potential vegetation change for a range of projected climate scenarios. A series of long-term vegetation transects are being established to relate soil characteristics (e.g., soil type, texture, moisture, nitrogen content) and microclimate (air and soil temperature) to vegetation characteristics (e.g., basal area, leaf area index, tree age structure, resource use efficiency, primary production) across lodgepole pine (Pinus contorta var. latifolia) ecotones. Results from five 200+ m ecotonal transects (68 20 m x 20 m plots; over 3,753 trees) show that basal area gradients from lodgepole pine to spruce-fir (Picea engelmannii, Abies lasiocarpa), ponderosa pine (Pinus ponderosa), and limber pine (Pinus flexilis) forests are correlated strongly (but not linearly), to soil texture and summer soil moisture. Factors controlling species-specific radial growth patterns along ecotones are more complex.

STOTTLEMYER, R., and C. A. TROENDLE. U.S.D.A Forest Service Rocky Mountain Forest and Range Expt. Sta., Ft. Collins, CO, 80526, USA. A decade of alpine and subalpine catchment chemical budgets, Fraser Experimental Forest, CO.

We have quantified chemical budgets for >10 y in seven watersheds. Precipitation chemistry is some of the cleanest in Colorado, but due to high elevations (2725 - 3975 m), loading is significant (>1.5 Kg N ha^{-1}, 3 Kg S ha^{-1}). There is a significant increase in loading of NH_4^+, NO_3^-, H^+ and SO_4^{2-} with elevation and aspect ($p < 0.001$). All watersheds appear SO_4^{2-} saturated. N species are strongly retained (>95%). NO_3^- concentrations and discharge from the alpine catchments are 2 - 4 fold that from subalpine catchments, and this release occurs throughout the year. Snowmelt contains a major fraction of annual solute inputs. There is a significant relationship between NO_3^- loss as snowmelt and trends in streamwater NO_3^- concentration. However, watershed discharge of NO_3^- is so small relative to that in snowmelt (<0.5%), it appears trends in streamwater concentration are poor indicators of the fate of contaminant N inputs.

STOWE, KIRK A., VICTORIA L. SORK, and ANDREW W. FARRELL. University of Missouri-St. Louis, St. Louis, MO, 63121, USA. Effect of water treatment on the phenotypic expression of herbivore resistance in northern red oak (Quercus rubra L.) in east central Missouri.

We examined genetic differentiation in herbivore resistance between north- and south-facing slope subpopulations of Quercus rubra and the effect of water availability on the phenotypic expression of these differences. We grew seedlings from acorns collected from the two sub-populations in a common garden under two water treatments, irrigated or natural. Percentage leaf area damaged was used as a measure of the phenotypically expressed level of resistance. Overall, north slope subpopulation seedlings and those in the irrigated treatment were most resistant. However, genetic differences between the subpopulations were only expressed in the natural treatment, with north slope subpopulation seedlings expressing greatest resistance. These findings demonstrate: (1) Q. rubra subpopulations at our study site are genetically differentiated with respect to herbivore resistance; (2) the effect of water availability on phenotypic expression of herbivore resistance depends on the subpopulation of origin.

STRANGE, ELIZABETH M., THEODORE C. FOIN, and PETER B. MOYLE. University of California, Davis, CA, 95616, USA. Modeling invader impact: the role of environmental variation in patterns of species replacement.

Biological invasions are thought to result primarily from the interaction between characteristics of the potential invader and the ability of resident species to resist the invasion. The interaction between environmental variability and the probability of successful invasion has been relatively neglected. Our studies of stream fishes, using a combination of field studies and population modeling, reveal that variation in streamflow mediates invasion success by changing the relative abundances of invading and native species such that their interactions are qualitatively changed. In particular, if a given pattern of floods at recruitment time reduces native species, favoring the invader in species interactions, an invader may enter the system successfully, with long-term persistence a potential consequence. Conversely, floods may reverse the outcome of invader-resident interactions and weaken the ability of an invader to establish or persist. Results suggest that biological interactions may be less important in determining invasion success than physical variation interacting with population size to open the habitat to invasion.

STRAUSS, SHARON Y. University of Illinois, Urbana, IL, 61801, USA. Do populations of mobile insects show fine-scale genetic structure in response to host plant variability?: theoretical and empirical considerations.

The degree to which insects exhibit fine-scale adaptation to individuals or patches of their host plant is still under debate. In a few instances, short-lived, sedentary insects appear to have fine-scale population structure at the scale of individuals, or even branches, of their long-lived host plants. In at least one instance, this differentiation has been shown to have

adaptive value for insects in their use of individual host plants. Limited gene flow is required to effect such small-scale genetic structure, since even moderate gene flow can homogenize populations in the absence of very strong selection by the plant. Since mobility is an important component of gene flow, most studies have considered sedentary insects. Here, I examine under what conditions one might find genetic differentiation in response to intraspecific variation in plant quality for mobile insect species. I describe 1) which attributes of insects and plants would increase the likelihood of the existence of fine-scale genetic structure and 2) mechanisms through which such differentiation can be effected. Finally, I will describe a study in which some of these ideas are tested.

STRAWN, SHEILA A. and LINDA L. WALLACE. University of Oklahoma, Norman, OK 73019, USA. Prairie-dogs and ungulates: competitors or mutual beneficiaries?

Because ungulates and prairie-dogs graze on the same grassland species, their interaction has been assumed to be competitive. In 1993 ungulates were shown to graze more heavily on prairie-dog colonies than on nearby non-colony areas. Vegetation on prairie-dog colonies has higher nitrogen content relative to non-colony areas and could be a causative factor for this interaction. Also in 1993, prairie-dogs were noted to have vacated burrows which were formerly grazed by ungulates, after the ungulates were removed. It is suggested that shorter vegetation like that grazed by ungulates attracts prairie-dogs by increasing the visual area for predator avoidance. This would suggest a mutualistic interaction. In this study, we fenced out ungulates and clipped vegetation in half of each of four 20 X 20 m quadrats and monitored numbers of active burrows inside for comparison between clipped and unclipped treatments. A fifth colony which was clipped and a sixth colony which was grazed without further treatment were both monitored. It was determined that decreased vegetation height is related to increased numbers of prairie-dog burrows.

STROH, JAMES C. AND STEVE ARCHER. Iowa State University, Ames, IA 50011 and Texas A&M University, College Station, TX 77843-2126 USA. Dynamics of tree-grass boundaries in a subtropical savanna parkland, 1941-1990.

Changes in woodland and savanna boundaries (5 dates, 1941 to 1990) were quantified on aerial photographs. Landscape elements elements classified included uplands (sandy loam soils with discrete clusters of woody vegetation separated by herbaceous zones) which graded (1-3% slopes) into lowlands (closed-canopy woodlands in clay loam, intermittent drainages). Woodland acreage increased 27% as woody clusters formed and coalesced on their margins. Migration of woodland margins was pronounced on some portions of the landscape, but static on others. Soil properties along lowland-upland transects spanning active and dynamic woodland margins were surveyed. Differences in surficial soil properties which might regulate boundary dynamics were not readily apparent. Depth of A horizon was comparable, though contrasts were sharper along transects spanning static boundaries. Texture of A and B horizons was comparable, and coarse-textured subsurface inclusions in lowland portions of the landscape were unexpectedly discovered. Soils associated with dynamic boundaries exhibited uniformly high electrical conductivity (15-20 mS/m over 48 m distance), whereas that of soils associated with static woodland boundaries changed markedly over a distance of 18 m (9 mS/m in drainage; 14 at woodland border; 18 in upland). Differences in geomorphic properties which might explain and contrasting dynamics of woodland boundaries await investigation.

STUBBS, CONSTANCE S. University of Maine, Orono, ME, 04469-5722, USA. Lichen dispersal: soredia acquisition by insects, mites, and molluscs.

Dispersal agents acquire, transport, and transfer diaspores. I investigated acquisition by adhesion of the lichen diaspore, soredia, by invertebrates from six animal orders: mites (Acariformes); slugs (Stylommatophora); springtails and snow fleas-(Collembola); beetles (Coleoptera), moths (Lepidoptera), and ants (Hymenoptera). Invertebrates collected from tree trunks in five unevenaged forests in Central Maine were examined for the presence of soredia adhering to their externa. Substrate range for soredia positive individuals varied from two tree species for the twice stabbed lady beetle, Chilocorus stigma, to 12 tree species for the snow flea, Hypogastrura nivicola. Percentage of individuals that acquired soredia ranged from 5.3% for the ant, Myrimca detritinodis, to 76% for the forest tent caterpillar, Malacosoma disstria. Morphology and behavior accounted for interspecific differences in acquisition. Invertebrate presence on sorediate lichens and soredia acquisition were highly correlated, which suggests that invertebrate species which "seek out" lichens, such as lichenivorous snow fleas, will be more effective at soredia acquisition than "lichen neutral" invertebrates, such as foraging ants.

SUBLER, SCOTT, ROBERT W. PARMELEE, and MICHAEL F. ALLEN. The Ohio State University, Columbus, OH, 43210, USA. Comparison of buried bag and PVC core methods for *in situ* estimation of soil N mineralization.

We compared estimates of soil N mineralization using the buried bag and PVC core methods in an ongoing investigation of the effects of earthworms and N fertilizer sources on agroecosystem N dynamics. Over a 7-month period, we paired monthly buried bag and PVC core soil incubations within research plots receiving one of three N treatments (inorganic, legume, or manure fertilizers) and with manipulated earthworm populations (reduced, ambient, or increased numbers). For both methods, CV's for net ammonification, nitrification, and N mineralization were generally below 5%. Overall, results for the two methods were significantly correlated for net ammonification (r=0.89), net nitrification (r=0.58), and net N mineralization (r=0.24). In general, the two methods yielded similar seasonal estimates of net N mineralization and nitrification. However, on one occasion in the plots with the inorganic N treatment,

buried bag estimates of net N mineralization were significantly higher than the PVC core estimates (1.5 vs. -0.4 mg $N \cdot kg^{-1}$ $soil \cdot d^{-1}$, respectively). Under some conditions, the two methods may lead to quite different interpretations of soil N mineralization processes.

SUGG, PATRICK M., ORIE L. LOUCKS and ROMAN G. KUPERMAN. Miami University, Department of Zoology, Oxford, OH 45056, USA and Argonne National Laboratory, Argonne, IL 60439, USA. An apparent effect on biodiversity of soil invertebrates along a midwest acid deposition gradient.

The long-term effect of acidic deposition on biological diversity may be tested most readily in the short-lived forest soil invertebrate communities. These are being studied at sites along an acidic deposition gradient in oak-hickory forest from southern Illinois to southern Ohio. The forest cover, soil type, aspect and climate have been to narrow range for all sites, but cumulative acidic deposition and hence soil acidification increased along the gradient toward the east. Soil invertebrates were sampled using pitfall traps and soil cores. There was a significant reduction in numbers of litter degraders (e.g., earthworms, termites) as soil acidity increased and soil litter depths increased along the gradient. Biodiversity, compared by using catch results from two beetle families, the Carabidae (ground beetles) and Staphylinidae (rove beetles) also differs significantly, and only abut 35% of the species at the reference site are found at the high dose site. Taxa for which deep litter provides an optimal habitat increase in abundance as soil acidification increases. Species diversity is exceptionally low for strictly soil dwelling taxa at the acidified sites.

SUGIHARA, NEIL G. USDA Forest Service, Stanislaus National Forest, Sonora, CA 95370, USA.
Ecology of fallen trees and treefall gaps in alluvial flat coast redwood forests.

This study was conducted to document the role of treefall gaps in the ecology of alluvial flat, coast redwood forests. These forests are structurally dominated by both living and fallen redwood trees. The primary source of large tree mortality is by falling of individual trees. The tall tree layer is pure redwood, and thus gap creation, gap phase, and gap filling are all defined by the dynamics of this single species. Estimated average occupancy time for canopy trees greater than 1 meter DBH is 1,100 years. Fallen trees are nearly permanent objects, with coarse woody material averaging 293 metric tons/ha. Direction of fall and temporal occurrence do not appear to be related to catastrophic events. Treefall gaps provide spatial diversity in terms of light, stand structure, and species composition. These gaps are extremely important in maintaining both high levels of biodiversity and structural complexity.

SUGITA, SHINYA and TIM E. PARSHALL. University of Minnesota, St. Paul, MN 55108, USA.
Pollen signals of small disturbance events in a hemlock-hardwood forest, northern Michigan.

Pollen from small forest hollows was compared with growth records in tree-ring cores from a 0.5 ha area surrounding each hollow to test whether sediment from hollows records local removal of canopy trees. Short sediment cores from ten hollows in a hemlock-hardwood forest in northern Michigan were analyzed at 1 cm intervals above the ≈100 yr old ragweed horizon. Ring-width patterns of at least fifteen increment cores from each site were analyzed to estimate dates and intensities of disturbance events. Simulations of pollen production and dispersal from vegetation suggest that ratios of birch to hemlock pollen and birch to sugar maple pollen are more suitable than pollen percentages for detecting disturbance. Events removing ≥15% of the canopy took place at least once around each of seven hollows; these correspond to significant peaks of birch:hemlock and birch:sugar maple ratios. The other three sites, which have had less intense events (<15% canopy removal), do not show significant peaks of birch pollen, suggesting that very small disturbance events cannot be detected in pollen records from hollows.

SULLIVAN, GARY. Binghamton University, Binghamton, NY, 13902, USA. Genetic variation in the tradeoff between sexual and asexual reproduction in a dioecious clonal plant.

Tradeoffs in the allocation of biomass between sexual and asexual reproduction in the submersed clonal macrophyte *Vallisneria americana* can vary a great deal among females within a population. A sib analysis was performed on female sexual offspring to determine if the variation in sexual reproductive effort (SRE), asexual reproductive effort (ARE), and the proportion of total reproductive biomass (TR: sexual plus asexual) allocated to sexual reproduction (SR/TR) is genetically determined. Variation in SR/TR can be strongly related to the number of flowers produced. SRE was negatively correlated with ARE among females from all families. Although total reproductive biomass was strongly correlated with plant size, SR/TR was unrelated to plant size, varying between 0.01 and 0.81. Significant by-family intraclass correlations were measured for SRE, ARE, SR/TR, and for the number of flowers per plant and per gram dry mass. These results indicate that a significant proportion of the variation in flower production, tuber production, and the tradeoff between them, is genetically determined. These results are discussed in the context of the evolution of life history in clonal organisms.

SULLIVAN, JOE H. and LUCIA R. DILLENBURG. University of Maryland, College Park, MD, 20742, USA and Universidade Federal do Rio Grande do Sul, 90.060-110, Porto Alegre, Rio Grande do Sul, Brazil. Temporal Responses of Loblolly Pine and Sweetgum to UV-B radiation.

Loblolly pine (Pinus taeda) and sweetgum (Liquidambar styraciflua) were grown in greenhouse and field studies at the University of Maryland. Plants received either no UV-B radiation or supplemental UV-B designed to simulate depletions of stratospheric ozone of 0, 10 or 16%. Measurements of leaf elongation and the development of photosynthetic pigments and capacity were made at regular intervals during leaf development. Primary needles of loblolly pine were particularly sensitive to UV-B radiation as needle elongation was reduced by all UV-B irradiances after 10 days of exposure. The effects were dose-specific and most likely direct effects on needle growth since photosynthetic reductions were not detected until after 3 weeks of exposure to UV-B radiation. In contrast, fascicle needles of loblolly pine exhibited few deleterious effects of exposure to UV-B radiation. This may have been due in part to the lack of UV-B penetration beyond the epidermis. The rate of leaf development was reduced by UV-B radiation in sweetgum but final leaf size was not altered by exposure to UV-B radiation. The effects of UV-B radiation on primary needles of loblolly pine could have ecological significance in terms of seedling establishment of loblolly pine in native communities.

SUNDVALL, ERIC, JACQUELINE A. CUMMINS, ARTHUR E. WEIS and D. GORDON BROWN. Northern Illinois University, DeKalb, IL 60115, USA and University of California, Irvine, CA 92717, USA. Impacts of background vegetation and generalist herbivores upon the growth and reproduction of goldenrod (*Solidago altissima*) in an Illinois old field.

Early colonists of old fields may directly inhibit invasion of later ones or they may harbor herbivorous insects that attack later colonists. We established rectangular plots containing 182 goldenrod transplants grown from 2g rhizome segments in a field abandoned from agriculture in 1989. *Ambrosia trifida* (giant ragweed) that averaged 152cm in height constituted 95.65% of the closed canopy of one plot (ragweed plot). In a second plot (open plot) ragweed was rare (7.85% of canopy cover) and the canopy was short (48cm tall) and open. Plant bugs (Lygus sp.), which were common on ragweed, attacked 82% of goldenrods in the ragweed plot. In contrast, plant bugs attacked only 3% of goldenrods in the open plot. Goldenrods in the ragweed plot were shorter, had shorter internodes, lower total biomass, retarded inflorescence development, and smaller inflorescences than those growing in the open plot. Multiple regression revealed that both plot effects, probably due to shading by ragweed, and attack by plant bugs negatively affected goldenrod performance. Both competition and herbivore-mediated apparent competition may influence plant colonization during succession.

SUTTER, ROBERT D. and PETER S. WHITE. The Nature Conservancy, Chapel Hill, NC, 27514, USA and University of North Carolina at Chapel Hill, Chapel Hill, NC, 27599, USA. Managing biodiversity in historic, human-created habitats: case history of the Southern Appalachian grassy balds.

Scattered throughout the heavily forested Southern Appalachian mountains are small meadow-like communities locally called grassy balds. Circumstantial evidence suggest that most, if not all, grassy balds were created from upper slope low stature hardwood forests as summer upland pastures in the early and mid-1800. Regardless of origin, however, grassy balds universally began undergoing succession to forest with the removal of grazing animals (the use of the areas generally ended by 1930-1940). While earlier debates over grassy balds management concerned whether these were natural communities, current interest stems from the presence of the balds of a number of local endemics and regionally rare species. Because of these rare species, interest in traditional land use practices, and aesthetics (wildflower displays and vistas), a variety of Federal, State, and private conservation groups have developed management plans to combat succession and maintain rare plan populations. We provide a regional assessment of these programs and of the chances for survival of the biological diversity these habitats contain. Grassy balds illustrate the commitment that must be made to the management and monitoring of biological diversity.

SUZAN, HUMBERTO., GARY P. NABHAN* and DUNCAN T. PATTEN. Center for Environmental Studies. Arizona State University, Tempe, AZ 85287-3211, USA and *Arizona-Sonora Desert Museum, 2021 N. Kinney Road, Tucson, AZ 85743, USA. Relative importance of ironwood (Olneya tesota) as a nurse plant in the Sonoran Desert.

The role of ironwood as a nurse plant in the Sonoran Desert was evaluated in 80 permanent plots from Bahia Kino Sonora to Organ Pipe Cactus National Monument, Arizona. Beneath the canopy of ironwood trees 125 vascular plants were detected. Spatial association analysis revealed a strong dependency of columnar cacti and vines with the tree. The cases of senita cacti (Lophocereus schottii) and the Sonoran night blooming cereus (Peniocereus striatus) were studied in more detail. Significant differences of areolar apical and basal winter temperatures were detected for plants growing beneath the shade of the tree and those exposed after the removal of the trees. The quality of the ironwood stands after exploitation expressed in the damaged basal area is significantly correlated with the abundance of columnar cacti seedlings.

SWIFT, CHERYL C., JEFFREY A. SMALLWOOD, C. HAAS, E. HENDERSON, L. OWENS, & T. BARNHART. Whittier College, Whittier, CA, 90608, USA. Evidence of temporal niche shifts in two co-occurring species of Chaetodipus (Heteromyidae) in south-central Arizona.

Small mammals were live-trapped near Organ Pipe National Monument in January and October 1993 on rocky hillsides and adjacent sandy flats. Overall, six species were identified: Peromyscus maniculatus, Dipodomys merriami, Chaetodipus

penicillatus, C. intermedius, Neotoma lepida, and Onychomys torridus. Chaetodipus penicillatus were absent from all habitats in January presumably because they were in torpor, but this species was prevalent in October in the sandy flats. Chaetodipus intermedius were present in all habitats in January while restricted to rocky slope habitats in October. The burrow requirements of C. penicillatus restrict this species to the sandy flats in all seasons, while C. intermedius is usually restricted to the rocky hillsides as a result of the aggressive behavior of C. penicillatus. However, when the latter is torpid in winter, C. intermedius extends onto sandy flats, and thus shows a temporal niche shift in habitat use.

SWIFT, SUZANNE, JAMES BRYANT, AND JANET LANZA. University of Arkansas at Little Rock, Little Rock, AR, 72204, USA. Simulated herbivory on Passiflora incarnata causes increased ant attendance.

In many plants, extrafloral nectaries attract ants that protect the plants from herbivory. When subjected to simulated herbivory, Passiflora vines produce increased amounts of extrafloral nectar, suggesting that greater numbers of ants will subsequently be attracted. This study was designed to determine if simulated beetle and caterpillar herbivory on natural populations of P. incarnata caused increased ant attendance. We used two measures of ant attendance on plants before and 24 hours after simulated beetle or caterpillar herbivory -- the time it took ants to find artificial nectaries on the plants and the time ants spent feeding at P. incarnata extrafloral nectaries. Ants discovered artificial nectaries more quickly after herbivory than before. In addition, ants fed at P. incarnata extrafloral nectaries longer after herbivory than before. These results suggest that in natural conditions P. incarnata produces more extrafloral nectar after herbivory and that the increased nectar production attracts increased ant attendance. Thus, the increased nectar production after herbivory is likely to result in additional protection from herbivores.

TANK, JENNIFER L. and MICHAEL J. WINTERBOURN. Virginia Polytechnic Inst. & State Univ., Blacksburg, VA. 24061, USA and University of Canterbury, Christchurch, NZ. Heterotrophic activity and invertebrate colonization of wood in a New Zealand forest stream.

We examined microbial and invertebrate colonization on experimental substrata in a beech forest stream (Nothofagus menziesii) after 1,2,3, and 6 months. Microbial communities on wood and leaves were dominated by filamentous forms with endocellulase activity, whereas epilithic communities were predominantly autotrophic. Microbial uptake of ^{14}C-glucose and endocellulase activity increased rapidly on beech wood between months 1 and 2; uptake peaked after 3 months and endocellulase activity continued to increase at 6 months. No significant differences occurred between surface and buried beech wood ($p>0.05$) but vertically oriented pine dowels (Pinus radiata) demonstrated significantly higher activity 10cm below the surface than 25 cm below after 6 months ($p<0.05$). Nutrient releasing substrata with wood veneer diffusion surfaces demonstrated no response by heterotrophs or autotrophs to additions of N and P (by ^{14}C uptake and chl *a*). At least 14 invertebrate species were found on experimental substrata, the dominant group on both surface and buried wood being larval Chironomidae. Invertebrate densities were about 3 times greater on surface wood and increased over time in parallel with an increase in structural complexity of the epixylic biofilms. Our results suggest that buried and surface wood may provide important sites of carbon transfer to higher trophic levels in New Zealand streams.

TARDIFF, SANDRA E. and JACK A. STANFORD. Flathead Lake Biological Station, The University of Montana, Polson, MT, 59860, USA. Plant distributions and soil nitrogen availability in subalpine meadows are influenced by grizzly bear foraging.

Grizzly bears (Ursus arctos) dig up large (ca. 100 m^2) patches of subalpine meadow while foraging for glacier lily (Erythronium grandiflorum) roots. In 1993, about 25% of the surface area in the meadows we studied was dug up during July - September. Our working hypothesis is that grizzly bears structure plant communities and influence nitrogen availability when they selectively forage (dig) for plants with low carbon:nitrogen ratios (C:N) growing in subalpine meadows in the northern Rocky Mountains. Ion exchange resin bags were buried in fresh (<1 yr), recent (<5 yr) and older (ca. 10 yr) digs and surrounding, undisturbed meadow to compare differences in relative amounts of plant available nitrogen (NH^{+4}-N and NO^{-3}-N) in soil during the growing season. Initial results showed that dug soil contained significantly more NH^{+4}-N and NO^{-3}-N than undug soil; even a 10 yr old dig had significantly higher NH^{+4}-N and NO^{-3}-N than undisturbed meadow, suggesting long-term influence of bear foraging behavior. Microlysimeter incubations are being done to determine differences in nitrogen mineralization potentials between plant litter in dug and undug sites. Glacier lilies (low C:N species) were initial dig colonizers, with individual lilies growing larger than the average; high C:N plants dominated undisturbed meadow. Hence, it appears that digging by grizzlies may influence subalpine landscapes by the physical action of foraging and by changing nitrogen bioavailability.

TARUTIS, WILLIAM J. Wilkes University, Wilkes-Barre, PA, 18766, USA. A variance-discounting approach to organic matter decomposition kinetics.

An organic matter decomposition model based on a gamma distribution of reactive types is modified to include both the distribution mean ($\bar{k}$) and variance (s_k^2). Each of these is described by two parameters describing the shape (v) and scale ($1/a$) of the particular gamma distribution. Analysis of decomposition isopleths for mean-variance combinations reveals that more reactive organic matter mixtures plot higher than less reactive ones within a $[\bar{k}, s_k^2]$ coordinate system, and the decomposition rate is constrained by a line drawn from the origin to a tangential point on its isopleth. The slope of this line is equal to the scale parameter $1/a$. As decay proceeds, the rate constant of the total mixture decreases with the slope of its tangential line, and the variance tends toward zero more rapidly than the mean. This is due to the preferential removal of the more reactive organic matter components, causing the distribution to shift to the left. A variance-discounting decomposition model may lead to more accurate estimates of the short-term decomposition rate but only for somewhat reactive organic matter mixtures.

TASHIRO, JAYSHIRO. and STEPHEN JACKSON. Northern Arizona University, Flagstaff, AZ. 86011 USA. The use of ecological research methods to study ecology education.

We will explore some of the analogies between ecological communities and academic communities, with the intent to examine the applicability of ecological research models to the study of the interactions within academic systems. It is interesting to note that within both the educational and psychological literature there are works that develop and use what they refer to as an *ecological* approach. A careful analysis of these works shows that for the most part they use the term *ecological* to denote a suite of interacting environmental factors. However, they do not fully develop either the ecological conceptual frameworks nor the powerful research models of modern ecology to probe the temporal and spatial heterogeneity within and among educational and psychological systems. Our work has focused on comparisons of academic communities using some of the research methods developed for sensing vegetational patterns from pollen data. This type of research approach will be discussed in the context of examining academic systems.

TATE[1], D. JEAN, THOMAS R. RYON[1], and DOUGLAS P. REAGAN[2]. Enserch Environmental Corporation[1], Lakewood, CO 80228 and Woodward Clyde Consultants[2], Denver, CO 80237, USA. Ecological data needs for ecological risk assessments.

Descriptive ecological data are needed for hazardous waste sites to characterize current site conditions, identify important ecosystems and potential receptors, and calculate potential risk. Such information provides the basis for determining ecological endpoints, developing a conceptual model of ecological exposure, and predicting tissue concentrations in or doses to organisms at the site. For large sites, it is appropriate to collect site-specific data on contaminant concentrations in environmental media, especially for bioaccumulative chemicals in tissue. Ecological endpoints at various levels of ecological organization (e.g., species diversity, population abundance, reproductive success) are selected, based on potential exposure pathways, receptors, and contaminant effects. For consumers, toxicological endpoints are used together with dietary fraction of prey, daily feedrate and other parameters in a probabalistic model to estimate exposure and thereby calculate potential risk. These data on risk, together with data on ecological effects are used to characterize ecological risk. Specific examples from terrestrial and aquatic ecological risk assessments are used to illustrate this approach and to identify literature data gaps and site-specific data needs.

TAUB,DANIEL R.,DEBORAH GOLDBERG and LINDA OLSVIG-WHITTAKER. Mitrani Center for Desert Ecology,Sede Boker,84993,ISRAEL. Comparison of Root Architecture and Early Growth of Winter Annual Plants From Sites Differing in Soil Resource Availability.

We compared common plant species from two stabilized sand dune localities along a rainfall gradient in Israel to test the hypotheses of Fitter(1987) that root system topology varies with soil resource levels. In addition,we investigated the relationships among root topology,RGR and Root/Shoot allocation.We grew 8 species from each site in a common greenhouse environment at two levels of soil resources (water and nutrients were varied in tandem)to test whether topology differed: a)as a plastic response to soil resource availability, and b)as a fixed characteristic of species from sites that differ in soil resource availability. We found no consistent differences in topology between species from the two sites. Although many of the species exhibited plasticity in root architecture,these differences were not in a consistent direction,and do not support Fitter's hypotheses.

TAUB, FRIEDA B. and JACK H. TAUB. University of Washington, Seattle, WA 98195, USA. Effects of zooplankton seasonal dynamics on our ability to detect stress.

In many aquatic communities, insecticide exposure reduces the abundance of medium-large grazers (> 1mm) such as Daphnia, increases the abundance of rotifers, and causes secondary effects of increased phytoplankton and decreased forage for fish. Normally, grazers such as Daphnia are usually present through most of the summer, although the species assemblages change as seasonal succession occurs. In contrast, even in the absence of insecticide exposure, many shallow aquatic communities lose their medium-large zooplankton during the warm summer period when water temperatures approach or exceed 30 C. Aquatic communities with rotifers and ostracods as dominants may be natural in these shallow ponds during extremely warm periods. These warm aquatic communities may mimic pesticide-stressed cooler communities. It is important that the regional differences in zooplankton seasonal assemblages be understood before results from one area can be extrapolated to another. Data sets from several field studies will be presented to test the hypothesis that small zooplankton dominate aquatic zooplankton during high periods; larger zooplankton dominate during cooler periods. Energetics, competition, predator-prey interactions, and lake morphology seem to play a role.

TAYLOR, KATHERINE L. and JAMES B. GRACE. Coastal Carolina University, Conway, SC, 29526, USA and National Wetlands Research Center, Lafayette, LA 70506, USA. The influence of herbivory, competition, and physical factors on the distribution of three marsh grasses.

The effects of herbivory, competition, and the interaction between herbivory and competition under natural conditions were investigated to discern their effects on the biomass of three common grass species, Panicum virgatum L., Spartina patens (Ait.) Muhl., and Spartina alterniflora Loisel. This study was conducted in three community types that represent an environmental gradient from freshwater marsh to mesohaline marsh associated with the Pearl

River, Louisiana. Herbivory, competition, and, to some extent, community type, were shown to affect biomass of the dominant species in these marshes. Significant interactions were found between competition and herbivory and between competition and community type for Spartina patents biomass. We conclude that multiple factors and the interactions between factors together determine the distribution of the dominant plant species in the marshes of the Pearl River, Louisiana.

TEESE, PAUL. State University of New York, Stony Brook, NY, 11794, USA. Photosynthetic pathway variation and differential growth in the C_3-C_4 intermediate, Flaveria linearis.

A study of phenotypic variation and the performance of variants was undertaken in a plant lineage acquiring an important evolutionary novelty. Flaveria linearis, a C_3-C_4 intermediate, was measured for CO_2 compensation point (Γ), a common diagnostic for the C_4 photosynthetic pathway. Collections from four Floridian populations were propogated and grown in a common greenhouse environment before measurement of Γ. While little differentiation between populations was found, significant within population variation was present ($p<.001$). To test the hypothesis that high temperature can act as a selective agent for the C_4 pathway, plants exhibiting a range of Γ were cloned and grown for seven weeks at 25°C and 40°C. At 25°C, there was no relationship between Γ and growth. At 40°C, more C_4-like plants exhibited superior growth ($p<.01$). I conclude that there is substantial phenotypic variation available for selection and that high temperature is a sufficient selective agent for the C_4 pathway.

TERAGUCHI, S. E. Cleveland Museum of Natural History, Cleveland, OH, USA. Long-term surveillance of deciduous forest moths during gypsy moth invasion and control.

Eight mixed hardwood forests in northeast Ohio have been monitored since 1987. Ellisco-type uV light traps are run weekly, at all sites on the same night, May-October. Seven years of quantitative data for seasonal dynamics and year-to-year fluctuations in abundance are computerized. Analysis of long-term changes in abundance is underway for the 300 most common species. The fieldwork will continue at least through 1996. The impact on nontarget moths of Bacillus thuringiensis applied for gypsy moth control was examined in 1990-91. Abundances were significantly lower at traps in treated sites as compared to untreated sites for 83 of the 205 species that were abundant enough to analyze.

THEODOSE, THERESA A. and WILLIAM D. BOWMAN. University of Colorado, Boulder, CO, USA 80309-0334. The effects of neighbor and nitrogen availability on biomass and nitrogen accumulation and allocation in two alpine graminoids.

Two alpine graminoids, Kobresia myosuroides from a low resource dry meadow and Deschampsia caespitosa from a more resource rich moist meadow were subjected to high and low N treatments in the absence and presence of inter- and intraspecific neighbors to investigate how each species responds to N and if that response is influenced by neighbor. Deschampsia accumulated significantly more biomass and N than Kobresia and increased biomass and nitrogen concentration and decreased root: shoot ratios under high N. Presence of a neighbor resulted in increased biomass and N allocated to shoots. Kobresia biomass accumulation and allocation did not respond significantly to N, but root nitrogen concentration increased in the high N treatment. When grown with Deschampsia, Kobresia increased N and biomass allocation to shoots, resulting in significant increases in tillering and biomass. Thus Deschampsia was more plastic in its response to N than Kobresia. Although Kobresia had the more conservative growth response, allocation patterns shifted so that growth was not inhibited by the presence of Deschampsia, even under high N conditions.

THIEDE, DENISE[1], SUSAN KALISZ[1], KATRI KARKKAINEN[2], AND TIM HOLTSFORD[3]. [1]Michigan State University, Hickory Corners, MI, 49060, USA, [2]University of Oulu, Oulu, 90570, FINLAND, and [3]University of Missouri, Columbia, MO, 65211, USA. Interpopulation variation in mating system and inbreeding depression in *Collinsia verna* (Scrophulariaceae).

In theory inbreeding depression is considered an important selective agent in the evolution of plant mating systems. In this study we quantified variation in mating system and inbreeding depression in three populations of *Collinsia verna*. From 1990 to 1993 24-51 maternal families from each population were scored annually for 6 allozyme loci. Ritland's multilocus outcrossing rates ranged from 0.56 ($\pm$.08, SD) to 0.93 ($\pm$.04). Within a population outcrossing rates varied little across years. A greenhouse comparison of progeny produced by selfing and outcrossing examined traits early and late in the life cycle: seed weight, emergence date, relative growth rate, final size, and fecundity. Early traits (which are largely maternal) displayed very low levels of inbreeding depression ($\delta < 0.1$), while traits expressed late in the life cycle showed higher levels of inbreeding depression ($\delta > 0.3$). These results suggest that inbreeding depression may play a role in mating system evolution even in species that maintain mixed mating systems.

THOMAS, HEATHER M. and TODD A. CROWL. Ecology Center, Utah State University, Logan, UT, 84322- 5210. Competitive interactions between exotic brook trout and native Colorado Cutthroat trout in high mountain streams.

Since being introduced, brook trout populations have expanded in range and relative density, possibly at the expense of native Colorado River cutthroat trout. One hypothesis for the gradual replacement is that brook trout outcompete the natives for food resources. While the exact mechanism is not yet known, we hypothesize that brook trout are more general in their feeding behaviors and less gape-limited that the native salmonids. During the summer of 1993, we collected diet samples of both brook and cutthroat trout from streams with cutthroat only and brook and cutthroat together. Feeding behavior of cutthroat trout and brook trout was also studied experimentally in artificial laboratory streams to examine the importance of interference and exploitative competition. Our results suggest that cutthroat trout feed less aggressively when brook trout are present, feeding only in the mid-water column. We hypothesize that the presence of brook trout may cause lower feeding efficiency in cutthroat trout by interference competition.

THOMAS, MICHAEL A. Kansas State University, Manhattan, KS 66506-4901. Variation in silica and total phenolics in four tallgrass prairie C_4 grasses.

Inter- and intraspecific variation in silica and total phenolic content was analyzed for four co-occurring tallgrass prairie grass species. These species have different growth habits and nutrient requirements and were sampled from moist lowland and dry upland sites throughout the 1993 growing season at the Konza Prairie Research Natural Area. We predicted that plants would invest in the most cost efficient resistance trait, and would switch investment emphasis reflecting resource costs during the growing season. We found that as water availability decreased, both during the growing season and from lowland to upland sites, total phenolic content increased and silica content decreased.

THOMAS, R.B., M.A. BASHKIN and D.D. RICHTER. Duke University, Durham, NC 27708, USA. Responses of a tropical N_2-fixing tree (*Gliricidia sepium* (Jacq.)Walp.) to increased atmospheric CO_2 and air temperature.

Gliricidia sepium, a tropical leguminous tree species, was grown from seed for 100 days at two CO_2 partial pressures (35 and 70 Pa) and two air temperatures (28/24 C and 32/28 C, day/night). Seedlings were grown with and without N fertilizer (0, 1 and 10 mM) to facilitate a stable isotope technique to analyze N_2-fixation. We hypothesized that elevated CO_2 would reduce stress imposed by elevated air temperature. Elevated CO_2 enhanced nitrogen fixation across all treatments by increasing nodule mass (59%) and N_2-fixation rate on a nodule mass basis (24%). Elevated CO_2 increased seedling mass (60%, 111%), nodule mass (40%, 78%) and N_2-fixation rate (17%, 33%) in the low and high temperature treatments, respectively. In 35 Pa CO_2, the 4 degree increase in air temperature reduced N_2-fixation rate by 15%, but seedling N content was unaffected because N absorption rate by roots was stimulated by 32%. In 70 Pa CO_2, small reductions in N_2-fixation rate (3%) and N absorption rate (8%) due to increased temperature were compensated by the stimulation of root mass (28%) and nodule mass (29%). Nitrogen fertilizer inhibited nodulation, but N_2-fixation rate on a nodule basis was unaffected. Negative effects of N fertilizer on N_2-fixation were ameliorated by elevated CO_2 suggesting that increased carbon availability partially negates inhibitory effects of soil N. As CO_2 increases, N contributions to tropical ecosystems by symbiotic N_2-fixing trees may increase, and the duration of N_2-fixing trees in early successional forests may be lengthened.

THOMAS, S.C., JASIENSKI, M. and F.A. BAZZAZ. Harvard University, Biological Labs, 16 Divinity Ave, Cambridge, MA, 02138, USA. The ontogeny of individual vs. stand-level responses to elevated CO_2.

Plant species appear to differ widely in terms of growth responses to elevated CO_2; however, most existing comparative data are limited to observations made early in the ontogeny on plants grown as isolated individuals. We examined growth responses to elevated CO_2 in nine species of herbaceous plants, including three erect annuals (genera included *Abutilon*, *Ambrosia*, and *Cassia*) three grasses (*Dactylis*, *Lolium*, *Panicum*), and three rosette species (*Plantago*, *Rumex*, and *Taraxacum*), each grown as isolated individuals and as dense monocultures in ambient (350 ppm) and 2X ambient (700 ppm) CO_2 atmospheres in a glasshouse over 5-6 mo. Soil texture, depth, and nutrient conditions matched those of waste areas in western Massachusetts. On the basis of non-destructive estimates of leaf area index (LAI), all species exhibited large early growth responses to CO_2, ranging up to 50-120%. However, later in stand ontogeny LAI consistently converged between CO_2 treatments, eventually becoming lower at ambient than at elevated CO_2 in most species. Final total biomass effects at the stand level were in the range of 0-10% enhancements, with no consistent differences among growth forms. Reproductive output was significantly reduced by elevated CO_2 in several species, including some with very high early growth enhancements. Our results strongly suggest that CO_2 effects on early growth of individual plants greatly overestimate longer term effects on species performance and net ecosystem carbon gain.

THOMPSON, GUY B., BERT G. DRAKE and DENNIS F. WHIGHAM. Smithsonian Environmental Research Center, Edgewater, MD, 21037, USA. Decomposition of litter from C_3 and C_4 marsh communities was reduced by long term exposure to elevated atmospheric CO_2 in open top chambers in the field.

Two hypotheses were tested: 1) do plants grown in elevated CO_2, decompose slower than those grown in ambient CO_2?, and, 2) are there direct effects of elevated CO_2 on decomposition (decomp.)? Litter from chambers (at normal ambient (NA) and elevated (NA + 340ppm) CO_2) was burried in a common decomp. site, and litter from the unchambered plots was placed in each chamber. The experiment lasted 2 years. Plants grown in elevated CO_2 had a significantly lower concentration of nitrogen ([N]) than plants grown in ambient CO_2. Decomp. was analysed by ancova with [N] covarying. In the common decomp. site C_3

litter from elevated CO_2 decomposed significantly less than plants from either the ambient CO_2 or the unchambered plots while C_4 litter decomp. was not affected by CO_2 growth treatment. The standard material in the C_3 and C_4 communities decomposed the least in the elevated CO_2 chambers.

THOMSON, DIANE L. and DONALD J. LEOPOLD, SUNY College of Environmental Science and Forestry, Syracuse, NY 13210, USA. Edge effects on the understory of mid-successional forested stands of central New York, USA.

The objective of this study is to determine the effect of edge on understory vascular species richness, and evenness in stands that have regrown from cultivated lands in central New York abandoned in the early 1900's. Herbaceous and woody vegetation less than 2 meters tall were sampled along belt transects from the edges to the interiors of 8 stands. Univariate analysis of variance indicated that, in south- and west-facing stands, woody species cover and richness are significantly higher on the edge plot (0-8 meters) than on most plots further interior, but not the most interior plot (48-56 meters). Herbaceous species cover and richness in south- and west-facing stands are significantly higher on the edge (0-1 meters) than the most interior plot (48-49 meters), and not different from the other plots. Cover and richness do not consistently decrease from edges to interiors because the canopies of these developing stands have many large gaps. Understory vegetation at edges and interiors were even less distinct in north- and east-facing stands than in south- and west-facing stands, possibly due to differences in light levels measured at the edge. Edge effect on exotic species richness and evenness will also be presented.

THRELKELD, STEPHEN T., STEVEN S. BROWN, AND GARY R. GASTON. University of Mississippi, University, MS 38677, USA. Substitution effects of omnivorous fish on planktonic and macrobenthic communities.

A three-level with center-point mixture design was used in the treatment of 16 small ponds with equal biomass mixtures of three fish species (common carp, grass carp, and gizzard shad). We tested the hypothesis that substitution in a fish community by an equivalent biomass of another species or trophic component would result in no detectable change in planktonic and benthic communities. Benthic grab and sweep net samples were collected from each pond on a monthly basis, beginning one month prior to treatment and extending four months after treatment (May-September). Water quality parameters and zooplankton were analyzed at two week intervals over the same study period. There were significant consequences of substitution in the fish community composition, and some evidence of non-linear interactions between the species, even though total fish biomass was constant. Numerous interactive effects detected in the experiment suggest the need for more experimentation on multiple controls of benthic community structure.

TILMAN, DAVID. Department of Ecology, Evolution and Behavior, University of Minnesota, St. Paul, MN, 55108, USA.
Habitat Destruction and the Extinction Debt.

Habitat destruction is the major cause of species extinctions. Dominant species often are considered free of this threat because they are abundant in habitat fragments that are undisturbed by a given bout of habitat destruction. However, a new metapopulation model that explains stable multispecies coexistence in virgin habitats predicts that moderate habitat destruction causes time-delayed, deterministic extinction of dominant competitors in the undisturbed habitat fragments. Spatially explicit "neighborhood" models make the same predictions. For a given degree of habitat destruction, this time-delayed extinction, termed the "extinction debt," is predicted to be greater for habitats with numerous co-dominant species, such as tropical rainforests, than for habitats with a single highly abundant competitor, such as many temperate forests. The loss of such species, which are thought to be the best adapted to the environmental and biotic conditions of those habitats, could have a major impact on the sustainability of these ecosystems.

TINGEY[1], DAVID T., MARK G. JOHNSON[2], PAUL T. RYGIEWICZ[1], and MARJORIE J. STORM[2]. [1]U.S. Environmental Protection Agency and [2]ManTech Environmental Technology, Inc., U.S. EPA Environmental Research Laboratory, Corvallis, OR, 97333, USA. Effects of CO_2 and climate change on forest trees: Roots and mycorrhizae.

Rising atmospheric CO_2 and climate change may have dramatic effects on forested systems. Under elevated CO_2 most forest species increase their allocation of C belowground to acquire additional resources for growth. As a part of a long-term study of elevated CO_2 and climate change on forest trees (the EPA's TERA project) minirhizotrons and root/soil coring are being used to investigate effects on root dynamics and mycorrhizal colonization. Video images of roots are collected every four weeks and root cores are collected every six months. Data, extracted from the video tapes using the ROOTS software, are used to characterize root and mycorrhizae development and life histories. Mycorrhizal colonization and morpho-type data are collected using roots taken from the soil cores. Most roots observed are fine roots (diameters < 2mm). Percent mycorrhizal colonization exceeds 90%. Methods used and results will be presented including a video presentation of minirhizotron images and data processing.

TISSUE, DAVID T., RICHARD B. THOMAS and BOYD R. STRAIN. Duke University, Durham, NC, 27708, USA. Effects of elevated CO_2 and non-limiting nutrients on growth and photosynthesis of loblolly pine.

The effect of long-term CO_2 enrichment and non-limiting nutrients on growth and photosynthesis were studied on loblolly pine (*Pinus taeda* L.) seedlings grown in three atmospheric CO_2 partial pressures (ambient, ambient + 15 Pa, and ambient + 30 Pa) for 18 months in the field. Total plant biomass increased 20% for plants grown at + 15 Pa and 50% for plants grown at + 30 Pa compared with plants grown at ambient CO_2. Relative growth rates were higher for elevated CO_2 plants in the first 10 months of treatment, then similar thereafter. Plants grown at elevated CO_2 were also taller, had greater photosynthetic leaf area, and more frequent leaf flushes. Net photosynthesis was higher for plants grown in elevated CO_2 in all seasons, but this difference was much greater in spring and summer. Rubisco content, activity and activation state were unaffected by growth at elevated CO_2 indicating no regulation of rubisco occurred at elevated CO_2. Results from this experiment and from a previous experiment (under limiting nutrient conditions) suggest that the magnitude of the growth and photosynthetic response to a future, high-CO_2 environment will largely depend on soil fertility.

TOCZYDLOWSKI, D., and R. STOTTLEMYER. Dept. Biological Sci., Michigan Technological Univ., Houghton, MI, 49931, USA, and National Biological Survey, 240 W. Prospect Rd., Ft. Collins, CO, 80526, USA. Change in snowpack, soil solution and runoff chemistry during snowmelt in a Northern Michigan watershed.

Since 1986, we have been studying precipitation, snowpack, snowmelt, and soil solution to quantify mechanisms responsible for observed differences in input/output budgets for H^+, NO_3^-, NH_4^+, and SO_4^{2-}. A decline in winter precipitation inputs (R^2=0.28, p=0.08) reduced ion loading. Up to peak water equivalent, there was a relationship between precipitation input and snowpack content for K^+ ($p<0.001$) and SO_4^{2-} ($p < 0.01$). No relationship was found for H^+, NH^{4+}, or NO_3^-. Snowmelt chemistry showed most snowpack H^+ and SO_4^{2-} made it into the soil. Significant amounts of NO_3^- and NH_4^+ are transformed or incorporated in the snowpack especially later in the snowmelt period. Nearly all snowmelt H^+, NH_4^+, and NO_3^- is retained in surface mineral soils especially late in the snowmelt period, but soil SO_4^{2-} flux increases accounting for a watershed input/output ratio <1.

TONER, MAUREEN M. and PAUL A. KEDDY. University of Ottawa, Ottawa, ON K1N 6N5. Striking a balance - predicting the lower limit of woody plants in shoreline wetlands.

There is growing concern over the changes in the composition of shoreline plant communities that follow the disruption of natural flood regimes. In particular, reduction of spring flood peaks in rivers is believed to lead to a reduction in the area of herbaceous wetland and an increase in cover by woody plants. We used logistic regression to model the position of the lower limit of wooded wetland as a function of the depth, duration and timing of flooding. The best predictor of the type of plant cover was the combination of the mean depth of flooding and the number of floods per season (X^2= 47.93, $P < .0001$, $n = 164$, accuracy = 76.8%). Not surprisingly, the fraction of the growing season during which flooding occurred was also a significant variable ($X^2 = 22.52$, $P < .0001$, $n = 164$, accuracy = 70.7%). The results describe the probability of occurrence of woody plants throughout the range of flood conditions. For example, if there are 3 floods per growing season, at a mean depth of 40 cm, then the probability of occurrence of woody plants is .47. If there are 4 floods, however, the probability drops to .09. This information is easily translated into testable decision rules for the conservation management of temperate zone rivers.

TONKYN, DAVID W. Clemson University, Clemson, SC, 29634 USA. Optimal strategies for the preservation of genetic diversity in endangered species.

Many endangered species exist only or primarily in captive populations, which may be their last refuge. These populations are threatened not only by low numbers, which can be restored, but also by low and declining levels of genetic variation, which cannot. As a result, decisions on which animals breed, and with whom, are made so as to minimize any further loss in such variation. Specifically, managers seek to restore equal founder representation in breeding colonies, and minimize inbreeding. Unfortunately, it is often difficult to know which choices best achieve these goals, or even if one's selection is near the optimum, because of the astronomical number of choices available. We present general procedures to solve such problems, based on translating the genetic optimization problems into their corresponding mathematical forms. This approach is illustrated with examples from the red wolf breeding program, though has broader applications in genetics.

TOPA, MARY. Boyce Thompson Institute, Ithaca, NY, 14853, USA. Phosphorus uptake strategies in slow- and fast-growing southern pines.

Pond pine (*Pinus serotina* Michx.) is a moderately fast-growing southern pine that may not only be better adapted to wet, P-deficient soils in the Atlantic Coastal Plain than fast-growing loblolly pine (*P. taeda* L.) populations, but possibly more responsive to P fertilization. The experiments in this study were the first in a series designed to test the hypothesis that pond pine is better adapted to P-deficient soils because of a greater ability to acquire and store P during natural periods of high nutrient availability and not necessarily because of enhanced rates

of uptake under low-P conditions. Pond pine and several edaphic seed sources of loblolly pine (two fast- and one slow-growing) were grown in continuously-flowing solution culture under high P (100 μM) conditions. Short-term ^{32}P uptake experiments were conducted to more closely examine species (seed source) differences in P uptake and allocation under aerobic and hypoxic solution conditions. Under high-P conditions, pond pine seedlings had comparable growth with the two fast-growing loblolly pine seed sources, yet accumulated more P in root and shoot tissue. Rates of unidirectional ^{32}P influx were 6-10 times those of the loblolly pine seed sources under aerobic or hypoxic solution conditions. After 24 h in labeled uptake solution, pond pine seedlings had accumulated 4-7 times more ^{32}P than the loblolly pine seed sources. Rates of ^{32}P influx and overall seedling accumulation of ^{32}P in loblolly pine seedlings were not correlated to their different growth rates.

TRACY, BENJAMIN F. and SAMUEL J. McNAUGHTON. Syracuse University, Syracuse N.Y., 13244, USA. Fire effects, net aboveground production patterns and ungulate utilization in Yellowstone National Park grasslands.

Net aboveground production (NAP) and consumption by ungulates (H) were measured from winter, transitional and summer ungulate ranges in 1992 and 1993. NAP was significantly lower in 1993 (95 ± 7 g/m^2/yr) compared to 1992 (144 ± 11 g/m^2/yr) likely due to the unseasonably cool, wet summer. NAP did not differ between winter and summer ranges and was lowest at the minimally used transitional range. Consumption by ungulates did not differ between years ($p=.36$) and was greatest at the summer range. NAP and H were positively related in both years ($p<.005$) suggesting that ungulates commonly consume more forage in highly productive patches. Effects from the 1988 fires were not detected in 1992 and 1993, but an experimental burn conducted in 1992 increased NAP by 51% and H by 30%. NAP and H data from the 1992 burn support earlier findings and suggest stimulatory fire effects persist for no more than three years post-fire in the sagebrush grasslands of Yellowstone.

TRAMMELL, PAUL W. and THOMAS A. DAY. West Virginia University, Morgantown, WV, 26505-6057, USA. Ultraviolet-B-absorbing compound and chlorophyll concentrations in Typha latifolia leaves growing along natural light gradients.

Emergent plants such as Typha latifolia (cattail) grow through a steep UV-B (ultraviolet-B; 300 nm) and visible irradiance gradient. Underwater, UV-B and visible irradiances decrease with water depth. Above water, UV-B and visible irradiances are highest just above the water surface but decline abruptly and then remain relatively constant with distance above the surface. We examined UV-B-absorbing compound and chlorophyll concentrations at 4-cm intervals along emergent and terrestrial T. latifolia "leaves" to assess whether these leaves were responsive to these irradiance gradients. Ultraviolet-B-absorbing compound and chlorophyll concentrations paralleled irradiance gradients, with ultraviolet-B-absorbing compound concentrations peaking just above the water surface. The ratio of UV-B-absorbing compound:chlorophyll decreased with increasing irradiance. In contrast to emergent environments, irradiance changes very little along terrestrial T. latifolia leaves. As expected, UV-B-absorbing compound and chlorophyll concentrations did not change with height along terrestrial leaves. The strong correlation between UV-B-absorbing compound concentrations and UV-B irradiance along T. latifolia leaves suggests that these leaves are very responsive to ambient UV-B levels.

TRIPLER, C.E., CHARLES D. CANHAM, AND RICHARD S. OSTFELD. Institute of Ecosystem Studies, Box AB, Millbrook, NY, 12545, USA. Influence of canopy tree species on understory sapling nitrogen content and herbivory by white-tailed deer (*Odocoileus virginianus*).

Soil nitrogen mineralization varies predictably as a function of canopy tree species in forests of western Connecticut. Under canopy tree species that create low light conditions and high nitrogen availability, saplings luxury consume and sequester nitrogen in their stems. Saplings collected in the winter of 1993 showed significant ($p<0.01$) effects of neighborhood tree species composition on tissue nitrogen content. Saplings under canopies of high N-mineralization species (e.g. sugar maple, *Acer saccharum*) may thus be more susceptible to browse by white-tailed deer (*Odocoileus virginianus*). Preliminary data collected from transects located in five sites of diverse overstory canopies suggest that neighborhood compositions do matter in predicting foraging patterns of white-tailed deer. Deer browsing reduces growth and increases mortality rates of saplings. Thus, our results indicate that overstory composition may effect understory performance indirectly, by influencing browsing patterns of deer.

TRISEL, DONALD E. AND DAVID L. GORCHOV. Miami University, Oxford, OH, 45056, USA. Regional distribution, ecological impact, and leaf phenology of the invasive shrub, Lonicera maackii.

Lonicera maackii (Rupr.) Maxim., native to China, Manchuria, Japan, and Korea, was originally introduced to North America ca. 1855. Analysis of herbarium specimens shows that non-cultivated shrubs of L. maackii occur in Ontario and 24 states of the eastern US. L. maackii can be found growing at densities of up to 6800 shrubs/ha in secondary forests. Because there is a reduced herb layer under dense stands of this shrub, L. maackii may be disrupting the natural succession of forests and old fields. L. maackii is photosynthetically active over a longer period than native woody deciduous species. In 1992, in Oxford, Ohio, L. maackii leaf expansion began in early March and green, photosynthetically active leaves were retained through mid November, resulting in a photosynthetic period of 254 days. The photosynthetic periods of Acer saccharum, Asimina triloba, and Lindera benzoin were 190, 183, and 180 days, respectively. End-of-season

leaf damage was lower for L. maackii than for native woody species. Leaf phenology and the relative lack of pathogens/herbivores may contribute to the success of this invasive shrub.

TROFYMOW, J. A. and B. A. BLACKWELL. Canadian Forest Service, Pacific Forestry Centre, Victoria, B.C., V8Z 1M5, CANADA. Comparison of total ecosystem carbon and nutrient distributions in chronosequences of coastal temperate forests on Vancouver Island.

To address concerns about the effects of conversion of old-growth temperate rainforests to managed forests on atmospheric C emissions, site productivity, and forest structural diversity, sampling plots were established in 1992 at four sites on the eastern leeward side of Vancouver Island in the very dry maritime Coastal Western Hemlock (CWHxm) biogeoclimatic subzone and four sites in the western very wet subzone (CWHvm). Each site contained four seral stands with age ranges of 3-8, 25-45, 65-96, and >200 years. In each plot the total amounts of C, N, P and S were determined for the standing biomass, understory vegetation, forest floor detritus, coarse and fine woody debris and mineral soil. Preliminary findings show ecosystems in the CWHxm had lower total C, N, S, higher P and a greater fraction of the C in the living biomass than in the CWHvm. Amongst the seres, total C loadings were highest in old-growth forests in the CWHxm and mature forests in the CWHvm.

TRUJILLO, WILMA, KIMBERLYN WILLIAMS, and WILLIAM D. PITMAN. University of Florida, Gainesville, FL 32611, USA. Effect of defoliation on biomass production of Desmanthus virgatus (L.) Willd.

Herbivory has occasionally been shown to increase plant productivity. This study was carried out to investigate the effects of different clipping regimes on the growth and survival of Desmanthus virgatus, a rapidly growing leguminous shrub of the American and Asian tropics. Plants growing in the field at Bartow, Florida, were clipped at different frequencies (2-, 4-, and 12-wk intervals) and heights (5, 25, and 100 cm) over a 24-wk season. Total yield increased as cutting frequency increased when plants were cut at 25- and 100-cm, while cutting at 5-cm stubble height at 2- and 4-wk intervals caused stand losses. The decreased yield with infrequent tissue removal was associated with, and may have partially resulted from, a low leaf/stem ratio. In addition to the low leaf/stem ratio, which is expected to decrease total net carbon gain, these infrequent clipped plants had also low total nonstructutal carbohydrate concentration (TNC). Such low TNC concentration may have reduced the resprout capacity of D. virgatus immediately following defoliation.

TRUMBULL, V. LYLE, ERIC S. MCCLOUD, and KEN N. PAIGE. University of Illinois, Urbana, IL 61801, USA. Reproductive, morphological, and phytochemical responses of Arabidopsis thaliana ecotypes to enhanced UV-B radiation.

Two ecotypes of Arabidopsis thaliana, collected from Libya and Norway, were grown in the greenhouse under UV-B doses of 0 and 10.5 kJ m^{-2} $UV\text{-}B_{BE}$. The high UV-B dose simulated midsummer ambient conditions over Libya and a 40% reduction in stratospheric ozone over Norway. The Libyan ecotype, which originated from latitudes where solar UV-B is high, showed no UV-B induced damage to plant growth. However the Norwegian ecotype, which originated from latitudes where solar UV-B is low, showed a significant reduction in plant height, inflorescence weight, and rosette weight in response to enhanced UV-B. Although fruit and seed number for both ecotypes were unaffected by enhanced UV-B radiation the germination success of the seeds harvested from the irradiated Norwegian plants was significantly reduced. The two ecotypes also differed with respect to their accumulation of kaempferol, a putative UV-B protective filter. The Libyan ecotype increased kaempferol concentration by 38% over the 0 kJ treatment whereas the Norwegian ecotype increased by only 15%. These data suggest that, for these ecotypes, variation in UV-B sensitivity may be explained by the differential induction of UV-absorbing leaf pigments.

TUCKFIELD, R. CARY. Westinghouse Savannah River Company, P.O. Box 616, Aiken, SC, 29802, USA. Some Statistical Methods for Estimating and Defending a Temporal Sampling Frequency in Ecological Monitoring.

Ecological and environmental monitoring are temporal sampling processes. The principal problem with monitoring has less to do with estimating an appropriate sample size and more to do with estimating an appropriate sampling frequency. However, comparing one monitoring location to another will require satisfaction of an important statistical assumption, viz., that sample measurements are independent. Each sample is a collection of temporal observations on the ecosystem or environmental metric from each monitoring location. If these observations are correlated, they are only pseudo-replicate measurements of true conditions for that location. Two statistical methods have been developed to estimate an appropriate sampling frequency, one based on the concept of serial correlation and the other on the temporal variogram from geostatistics. These methods were applied to two simulated data sets with relatively high and low first order serial correlations but generated from a normal distribution with the same mean and variance. Results showed that although the serial correlation method is conceptually simpler, the variogram method utilizes more information, provides a more accurate estimate of the original variance and therefore a more appropriate estimate of sampling frequency.

TURCHIN, PETER. Southern Forest Experiment Station, Pineville 71360, USA.
Population regulation: traditional theories and new approaches.

Population ecologists are still arguing about the prevalence of density-dependent regulation in nature. Every year, newer and better tests of density dependence are proposed and applied to time-series data. I will argue that the emphasis on testing for density dependence is misplaced. Instead, we should be primarily concerned with estimation: what kinds of qualitative and quantitative

patterns of dynamical population behaviors are common in nature? New ideas and methods from nonlinear dynamics can be very useful in answering this question. Specifically, I propose that we focus on estimating the following quantities from time-series data: amplitude of fluctuations, the strength of periodicity (if any) and the prevailing period, Lyapunov stability (chaotic vs. stable dynamics), and the relative strength of endogenous vs. exogenous factors.

TURNER, CLARENCE L., MEGAN COCKE, JOHN KNEISLER and ALAN K. KNAPP. Kansas State University, Manhattan, KS 66506, USA. Responses of long-lived perennial forbs in tallgrass prairie to nitrogen additions and light environments.

Relatively little is known about the mechanisms by which long-lived forbs (non-woody, perennial herbs), maintain themselves in the face of competition from the dominant grasses in tallgrass prairie. We investigated the roles of light and nitrogen on gas exchange responses in big bluestem (a C_4 grass) and 3 co-occurring C_3 forbs at Konza Prairie Research Natural Area. Record rainfall in 1993 minimized the water stress in these plants, particularly in shallow-soiled uplands. N fertilization resulted in leaf N concentrations that were 10-60% higher compared to unfertilized plants for all species. Biomass production on fertilized plots was 25-80% higher than on unfertilized plots. The effect of N fertilization on gas exchange characteristics (photosynthesis, stomatal conductance, transpiration) was dependent on burning regime and topographic position. Fertilization increased photosynthetic rates by as much as 75% in forbs in unburned uplands vs. 70% in grasses in burned uplands. Regardless of the canopy height of their grass competitors, forbs tended to maintain maximum leaf area at a height in the canopy where light levels were about half full sunlight.

TURNER, DAVID P. ManTech Environmental Technology, Inc., US EPA Environmental Research Laboratory, Corvallis, OR, 97333, USA. The spatial distribution of potential leaf area index for Pacific Northwest coniferous forests.

Leaf area index (LAI) is a critical variable in a variety of applications, particularly modeling of land surface processes such as photosynthesis and evapotranspiration. In this study, potential LAI was estimated over a 10 km grid based on spatially distributed meteorological data. The spatial domain included the coniferous forests in the Cascade and Coastal Ranges in Oregon and Washington. For elevations from sea level to 1300 m, a regression was developed between a water balance index, defined as the growing season (May-October) precipitation minus the growing season potential evapotranspiration, and measured LAI values from the literature. At higher elevations, a regression of observed LAI and the growing season heat sum was used. A land cover map derived from satellite imagery (1 km spatial resolution) provided the basis for the current distribution of coniferous forest. The final potential LAI surface was consistent with observed LAI gradients.

TURNER[1], MONICA G., WILLIAM H. ROMME[2], ROBERT H. GARDNER[1], and WILLIAM W. HARGROVE[1]. [1]Oak Ridge National Laboratory, Oak Ridge, TN, 37831, USA, [2]Fort Lewis College, Durango, CO 81301, USA. Influence of patch size and shape on post-fire succession on the Yellowstone plateau.

The 1988 Yellowstone fires provided a unique opportunity to examine how the geometry of fire-created patches affects plant reestablishment. We initiated studies in 1990 in small (1 ha), moderate (74-200 ha), and large (480-3698 ha) crown-fire patches in each of 3 areas. Lodgepole pine forest is reestablishing in most burned areas, but seedling density varies by two orders of magnitude. At spatial scales <100 m, lodgepole seedling density declines with distance from the patch edge. Resprouting of herbaceous vegetation led to prompt revegetation in burned patches of all sizes, suggesting within-patch survival is a dominant recovery mechanism for grasses, forbs, and shrubs. Some annuals (e.g, *Gayophytum diffusum*) achieved greater densities in large vs. small crown-fire patches and colonized large patches more rapidly. Post-fire plant reestablishment in Yellowstone appears rapid and autogenic even in large burns, and the relative importance of factors controlling early postfire succession varies with spatial scale.

TURNER, ROBERT S., VIRGINIA H. DALE, AND RICHARD J. OLSON. Oak Ridge National Laboratory, Oak Ridge, TN, 37831. Ecology and the integrated assessment process.

Integrated assessment is a process in which technical, social, environmental, and economic consequences of alternative decision scenarios are evaluated. It requires evaluation and accomodation of multiple, sometimes opposing or conflicting, points of view or models of the way things work. The goal is not the development or imposition of a single unified or integrated world model, no matter how comprehensive or sophisiticated, but rather the building of a consensus among stakeholders about the direction, magnitude, and uncertainties of the societal and ecological effects of alternative decisions. The process involves clarifying the policy options available or the range of decisions that are possible, and then using observations, understanding, and projections to compare alternative scenarios or outcomes of the policies or decisions. We have developed a conceptual framework for assessement that acknowledges the wide range of uncertainty in the ecological effects of regional and global perturbations such as acidic deposition or climate change and that accomodates the multiple independent approaches that are needed to increase confidence in conclusions drawn from either sophisticated or back-of-the-envelope projections. This presentation shows how ecological findings and uncertainties were used in integrated assessment of acidic deposition and how ecologists might contribute to integrated assessment of global change.

TURRILL, NICOLE L. and FRANK S. GILLIAM. University of Tennessee, Knoxville, TN, 37996, USA and Marshall University, Huntington, WV, 25755, USA. Successional niche change of herb layer species in a montane eastern deciduous forest.

Niches are usually assumed to be broad among plant species early in succession and to narrow with time. Using canonical discriminant analysis (CDA), we compared niche differentiation in the herb layers of two young (~20 yr) and two mature (~>70 yr) stands of the Fernow Experimental Forest, WV. Watershed (stand) means of soil and plant tissue nutrients were not significantly different among watersheds, suggesting generally similar fertility. The mature stands had a greater importance of woody species compared to the young stands, in which herbaceous species were dominant. Using CDA on individual species for soil nutrient and tissue nutrient data separately, we found that woody species were more prominent on soils lower in Mg, Ca, Zn, and Mn and had lower concentrations of N, K, Mg, and Ca compared to herbaceous species, regardless of stand age. When we compared CDA Axis 1 scores for soil nutrients to those for tissue nutrients, we found no significant correlation for young stands, but found significant ($r=0.60$, $p<0.05$) correlations for mature stands. Data support assumptions that early successional species are generalists with broad niches. Species niches become more narrow through succession in these forests as a result of competitive interactions within the herb layer and the success of specialist species.

TWERY, MARK J, RUTH D. YANAI, and SUSAN L. STOUT. USDA Forest Service, Morgantown, WV 26505 USA, Boyce Thompson Institute, Ithaca, NY 14853 USA, and USDA Forest Service, Warren, PA 16329 USA. Understory development following thinning in Allegheny hardwoods.

Thinnings are performed in forest stands based primarily on their effects on the growth of residual overstory trees, but they also may have significant effects on the understory. Twenty-one Allegheny hardwood stands in 2 blocks were subjected to thinning treatments varying from 37% to 94% residual density between 1973 and 1975. Understory stems between 30 cm tall and 2.5 cm dbh were inventoried before thinning and 1, 3, 5, 10, and 15 years after treatment. The average number of stems increased for 3 to 5 years after thinning and then leveled off or decreased by 10 or 15 years. The greatest density of understory stems is seen in the stands with low residual density, and the least response occurs in the stands with high residual density (including four stands that were not cut). Stem numbers increase over time in the thinned stands, with most of the increase occurring within 3 years after treatment. In the small (30 to 90 cm tall) size class, intolerant stems are the most important numerically and the most responsive to light. In the 3' tall to 1" dbh size class, intolerant and intermediate species are more responsive to thinning than are tolerant species, but tolerant species remain more important numerically throughout the study. High cover of fern and grass is correlated with lower numbers of woody stems.

TWOMBLY, SARAN. University of Rhode Island, Kingston, RI, 02881, USA. Phenotypic variation in age and size at metamorphosis in freshwater copepods.

Physiological metamorphosis accompanied by an ecological habitat shift is a widespread life-history phenomenon, and both size and age at metamorphosis are often variable. I used both laboratory-reared and field-caught individuals to examine age and size at metamorphosis in four species of freshwater copepods to determine (1) the scale on which these traits vary, (2) if age and size at metamorphosis are equally variable and (3) if variation in metamorphosis is related to newborn size. Laboratory and field studies were used to test two major theories for age or size at metamorphosis. Sibships of the copepod Mesocyclops edax were split and raised under three food conditions to determine if age or size at metamorphosis depended on recent larval growth history (the Wilbur-Collins model). Size-specific growth and mortality rates were estimated for a field population of M. edax to test Werner's model, which predicts that the optimal size at metamorphosis depends on the ratio of mortality to growth for both pre- and post-metamorphic stages. Results showed that (1) age at metamorphosis is far more variable than size, (2) variation in age or size at metamorphosis was not related to newborn size and (3) while copepods appear as variable as amphibians, neither of the two models tested explained the variation observed in these organisms.

TYLER, JEFFREY, A.[1], KENNETH A. ROSE[1] and R. CHRISTOPHER CHAMBERS[2]. [1]Environmental Sciences Division, ORNL, Oak Ridge, TN 37830 and [2]Huntsman Marine Science Centre, St. Andrews, NB, Canada E0G 2X0. Simulating winter flounder population dynamics using coupled individual-based YOY and Leslie matrix models[3].

Winter flounder populations support an important commercial fishery in eastern North America that has recently experienced declines in catch. We developed a model for winter flounder that combines an individual-based (IBM) simulation of the young-of-the-year (yoy) period and a Leslie matrix model of the adult period. The model is designed to depict the biotic and abiotic environment of bays off of the northeastern United States coast. Using the model we replicated the spawn and recruit relationship of winter flounder determined from 12 years of study in the Niantic River. The simulations show the importance of inter-annual variation in temperature and the spawning population as well as density-dependent growth and mortality in determining yoy recruitment. With 100 year simulations we determined the effect of variation in the environment on the recruitment of yoy winter flounder and on long term population stability. [3]Research sponsored by Electric Power Research Institute, Contract RP2932-2 (DOE No. ERD-87-672); U.S. Department of Energy, Contract DE-AC05-84OR21400 with Martin Marietta Energy Systems, Inc.

UHL, CHRISTOPHER[1], and ORIANA T. DE ALMEIDA[2]. The Pennsylvania State University[1], University Park, PA and Instituto do Homem e Meio Ambiente da Amazoina (IMAZON)[2], Belem, Para, Brazil. A multidisciplinary approach to analyzing resource use and sustainable development alternatives in the Eastern Amazon.

We compare ranching, slash-and-burn agriculture, and timber extraction using economic, social, and ecological criteria in one county, Paragominas, (24,900 km^2), located along the Belem-Brasilla Highway. We estimate that returns from these activities for the county were

114 million dollars ($45/ha) in 1992 with 81% coming from wood-related activities. But if timber extraction was to continue at current levels, the wood stocks of the County would be exhausted in 30 years and annual returns would slump to 20 million dollars. However, approaches to forestry, ranching and agriculture that appear to be both ecologically sustainable and profitable have been developed for the Eastern Amazon. We showcase several examples and provide concrete examples of how policy initiatives could catalyze a shift to responsible resource uses.

UMBANHOWAR JR., CHARLES E., St. Olaf College, Northfield, MN, 55057, USA. Recent fire history of the northern Great Plains based on charcoal inputs to sediments of five lakes.

The fire history of the northern Great Plains is largely unknown or based upon anecdotal reports from the historical record. Short cores from five lakes in North and South Dakota and eastern Montana were examined for charcoal fragments. The cores span the last 123 to 380 yrs. Samples integrating 1-5 years of deposition were taken from 2 cm sections along each core and sieved. Charcoal deposition rates varied between 0.54 and 1289.01 fragments / cm^2 / yr, and mean deposition rates were weakly correlated with longitude. Results suggest periods of increased fire activity from A.D. 1700 - 1740 and A.D. 1840-1900. These peaks were broadly synchronous across the region and ranged in duration from 20 - 40 yrs. Post-settlement patterns of charcoal deposition were highly variable. Charcoal deposition rates over the past 20 yrs were generally very low (0 - 5 fragments / cm^2 / yr.

UNDERWOOD, A.J. University of Sydney, Sydney, NSW 2006, AUSTRALIA. Indeterminism, time, space and the need for long-term ecological studies

Current research on rocky shores in New South Wales, Australia, is focussed on the need to be able to interpret long-term temporal changes and patterns that recur (or fail to recur) over large spatial scales. Three examples will be illustrated. First are the patterns of abundance of intertidal barnacles (Chamaesipho columna and C. tasmanica) over two four-year periods, ten years apart. Second is the influence of recruitment on long-term patterns of colonization of shores after disturbances. Data from 21 years of sampling mussel beds will illustrate the complete lack of determinism in these habitats. Finally, the colonization of rock pools (in a total of 528 experimental pools in 24 sites) reveals all sorts of interesting patterns in space and time. The prevailing unifying theme is an attempt to understand and predict patterns of spatial and temporal variance in abundances of animals on rocky shores. So far, this has revealed why ecologists persist in being mean-minded rather than variance virtuosos.

URBAN, DEAN L. Colorado State University, Fort Collins, CO 80523, USA. Tree life-history traits and forest system dynamics: a model-based comparison of eastern deciduous *versus* western conifer forests.

Forest systems can be modeled as a set of feedbacks coupled by correlations among tree life-history traits and by physical relationships. For example, trees' shade tolerance and drought hardiness are often correlated, and solar radiation affects shading as well as the soil water balance. I use a simulation model to explore the potential for system-level feedbacks mediated by tree life-history traits to govern forest dynamics over successional time-scales. Comparisons of Pacific Northwestern conifers and southeastern Appalachian hardwoods show that correlations among tree life-history traits (shade tolerance, drought hardiness, nitrogen response) are different for the two forests, suggesting that system-level feedbacks might develop along trajectories that vary regionally. These results imply that factors controlling α- and γ-diversity in forests vary regionally, and further, that transient responses of forests to anthropogenic global change could vary qualitatively depending on species composition and environmental feedbacks.

VALENTINE, D.W.[1], L. KLINGER[2], E.A. HOLLAND[2], and D.S. SCHIMEL[2]. [1]Colorado State University, Fort Collins, CO, USA, and [2]NCAR, Boulder, CO, USA. A field experiment of substrate limitation of methane emissions in a northern wetland.

Substrate quality and quantity have been found to limit CH_4 production in laboratory incubations of peat, and indices of substrate quality decline with depth. We examined the role of substrate availability in limiting CH_4 emissions at Bog Lake in northern MN, USA. We inverted two 8 cm diameter by 40 cm deep peat cores in each of three 0.44 m^2 static chambers to test the hypothesis that substrate limitation below the water table limits CH_4 emissions. Live vegetation was removed before and replaced after the core inversion. Cores were removed and replaced without being inverted as disturbance controls in a second set of three chambers, such that only the orientation of the replaced cores differed. Fluxes of CH_4 were monitored at weekly intervals through the summer. CH_4 emissions averaged 200 mg m^{-2} d^{-1} before treatment, and were significantly correlated with peat temperature and water table depth. The treatment and disturbance control both increased CH_4 emission rates, but from 2 weeks onward CH_4 emissions were significantly greater in the treatment chambers than in the control chambers. This evidence suggests that poor substrate quality below the water table can be an important constraint on CH_4 emissions in field settings.

VAN BUSKIRK, J., and R. S. OSTFELD. Institute of Ecosystem Studies, Millbrook, NY 12545, USA. Controlling Lyme disease by modifying the density and species composition of tick hosts.

It is hypothesized that the risk to humans of contracting Lyme disease might be decreased by reducing the availability of the vertebrate hosts of vector ticks. Adult deer ticks are specialist parasites of white-tailed deer, and juvenile ticks parasitize numerous species of mammals and birds. We used computer simulation to test the impact of host control on the population density of deer ticks and the prevalence of Lyme disease. Our model demonstrated that the density of ticks was much more sensitive to the availability of hosts for juveniles than hosts for adults, since each adult host can support a large number of adult ticks and there are far fewer host-seeking adults than juveniles. This result suggests that control of Lyme disease by reducing host densities would prove difficult, since the numerous alternative hosts for juvenile ticks are not especially amenable to control. We found that the infection rate of ticks depended critically on the reservoir competence of hosts parasitized by juveniles. We conclude that measures that alter the species composition of small mammals and birds, and hence modify the average reservoir competence of juvenile hosts, may be used to reduce the risk of Lyme disease without actually changing the density of ticks.

VANCE, SARAH A. and BARBARA L. PECKARSKY. Cornell University, Ithaca, NY, 14853, USA. Parasite-induced behavioral alterations in a one host cycle: Mermithid nematodes and their mayfly host.

This study investigates the occurrence of behavioral alterations in parasitized mayfly hosts where the parasite (a mermithid nematode) utilizes only a single host individual to complete its development. The host is castrated by the infection. As the parasite develops, the host drifting behavior (movement in the water current) is altered. These changes reduce the risk of fish predation (which will increase parasite survival) and reduce colonization rates of food resources by the host (which results in parasitized larvae being smaller than their unparasitized counterparts). Why have the parasites adopted this different behavioral strategy for the host? In unparasitized mayflies, the altered drifting behavior, while reducing predation rates, would have a negative impact on fecundity since size is positively correlated with fecundity. In parasitized larvae, however, worm size (and hence fecundity) is not correlated with host size, suggesting that altered drift behavior will reduce fish predation with no associated reduction in worm fecundity.

VAN DE WATER, PETER K.[1], STEVE W. LEAVITT[2], and JULIO L. BETANCOURT[2]. [1]University of Arizona, Tucson, AZ 85721, [2]U.S. Geological Survey, Tucson AZ, 85745. Trends in stomatal density and $^{13}C/^{12}C$ ratios of *Pinus flexilis* needles during the last Glacial-Interglacial cycle.

Measurements of stomatal density and $\delta^{13}C$ of limber pine (*Pinus flexilis*) needles preserved in packrat middens from the Great Basin reveal shifts in plant physiology and leaf morphology during the last 30,000 years. Sites were selected so as to offset Glacial and Holocene climatic differences, and thus isolate the effects of changing atmospheric CO_2 levels. Stomatal density decreased ~17% and $\delta^{13}C$ decreased ~1.5 per mil during deglaciation from 15 to 12 thousand years ago, concomitant with a 30% increase in atmospheric CO_2. The isotopic results suggest that water-use efficiency increased ~15% during deglaciation. Physiological responses to changes in past atmospheric CO_2 during deglaciation may help to explain changes in species distributions not easily attributed to climate.

VAN PELT, ROBERT. University of Washington, Seattle, WA, 98195, USA. Three-year response of understory trees to experimental gaps created in old-growth Douglas-fir forests.

Two 0.2 hectare canopy gaps were created in an old-growth Douglas-fir (*Pseudotsuga menziesii*)/western hemlock (*Tsuga heterophylla*) forest in southern Washington during the winter of 1990-1991. All trees less than 2 m in height were spared for monitoring of subsequent growth and response to the new conditions. A total of 1250 understory trees (1094 *Abies amabilis* and 156 *Tsuga heterophylla*) were mapped and detailed information was collected on the crown characteristics. After the third growing season following the creation of the gaps, the trees were remeasured. Significant gap partitioning takes place in gaps of this size. Of mortality that was not directly due to the creation of the gap, most of this was focused in the north part of the gap where temperatures and light levels were dramatically increased. However, this was also the location of areas of increased growth. The area just south of gap center had the most positive response - with formerly suppressed trees developing leaders of up to 50 cm after just three years. Areas in the south part of the gap and those under the adjacent canopy showed small positive to no noticeable response after three years. Understory trees are sensitive to changes in their environment and are thus useful for monitoring potential long term changes in forest productivity and composition.

VAVREK, MILAN C. West Virginia University, Morgantown, WV, 26506-6057, USA. Effects of Seasonality on Within-Population Genetic Diversity of Taraxacum officinale.

Differential response of genotypes to seasonal (within year) environmental change may preserve genetic diversity if genotype fitnesses are equivalent for the year. The demography of five biotypes within a natural population of Taraxacum officinale in a single field was compared among four seasons and for the year. A second study using cloned individuals representing one genotype from each of the five biotypes was used to experimentally confirm biotype responses. Clones

were planted into the field in each of the four seasons at four different size classes to control for historical effects and to estimate demography over a large portion of the life-cycle. Differential survival, growth and recruitment segregated biotypes into warm and cool season individuals. Warm season biotypes grew and reproduced most, relative to cool season individuals, during summer and early autumn, yet annual finite rates of increase were approximately equal. Response to fluctuations in the environment through time may thus represent a significant portion of the environmental effect upon genetic diversity within populations.

VIDIELLA, PATRICIA E. Cornell University, Ithaca, NY 14853, USA. Effect of disturbances caused by a native camelid on desert plant communities of Chile.

This study looks at the question of whether a large herbivore (guanaco) regulates the ecology of plant communities in the desert of Chile. Guanacos (*Lama guanicoe*) are South American wild camelids which make wallows (small craters on the ground) while grooming themselves by taking dust baths. In some areas, this activity produces patches of scattered disturbances where abandoned wallows may coincide with patches of vegetation distributed in the landscape. I evaluated the impact of the wallows on a plant community of the Chilean coastal desert by looking at the seedbank (density and species richness) and nutrients (total carbon and total nitrogen) in soil cores taken from actively used wallows, abandoned wallows, and undisturbed areas between wallows. I found that seedbank density, species richness, total carbon, and total nitrogen were remarkably higher at the abandoned wallows. These results suggest that guanacos may have an indirect control on the plant community by creating disturbances where seeds and organic matter can subsequently be trapped.

VIEGLAIS, DAVID A., W.M. DUGAS, G. THOMPSON, R. HINKLE and B.G. DRAKE NASA, MD-RES, Kennedy Space Center, FL, 32899, USA. Differential species response to elevated CO_2 in a native Florida scrub oak-palmetto community.

Native Florida scrub oak-palmetto community, with two dominant oak species (*Quercus myrtifolia* and *Q. geminata*) was exposed to twice ambient concentration of atmospheric CO_2 (c_a) for 12 months using open topped chambers at Kennedy Space Center. After complete aboveground harvest at initiation of the experiment, community biomass recovered 50% under ambient and 130% under elevated c_a. Biomass increase in high c_a was due predominantly to *Q. myrtifolia* rather than *Q. geminata*. Water use efficiency of the community was increased by approximately 34% under higher c_a. Sap flow of *Q. geminata* indicated an immediate though not fully reversible effect of c_a on whole plant transpiration; comparable data were not possible for *Q. myrtifolia*. Leaf respiration for both species was reduced 20% in higher c_a, with no apparent acclimation to CO_2 level. Current investigations are focusing on mechanisms of differential species response.

VILÀ, MONTSERRAT and JAUME TERRADAS. Universitat Autònoma de Barcelona, 08193 Bellaterra (Catalonia), Spain. Effect of nutrient addition and neighbours on Erica multiflora.

The role of nutrient supply and competition on resprouting and biomass allocation patterns of the Mediterranean shrub Erica multiflora were examined by a factorial field experiment of fertilization and removal of neighbouring plants. Nutrient addition increased growth of pre-existing sprouts and biomass allocation to stems in new sprouts, but decreased the probability of plant flowering. Removal of neighbours increased the number and biomass of new sprouts, but decreased the probability of flowering and the biomass of flowers. Fertilization slightly enhanced sprout recruitment and the probability of flowering in the absence of neighbours. The results suggest that competition for nutrients limits continual basal resprouting. Shading by neighbours may increase vertical growth of new sprouts.

VILLARD, MARC-ANDRÉ and SUSAN J. HANNON. University of Alberta, Edmonton, AB, T6G 2E9, Canada. Short-term response of American Redstarts (*Setophaga ruticilla*) to experimental fragmentation in the boreal mixedwood forest.

In 1993, an experimental study was undertaken to monitor the effects of timber harvesting on the avifauna of the boreal mixedwood forests of northern Alberta. The American Redstart was selected as a target species to study processes potentially linked to species response to the fragmentation of old stands dominated by *Populus tremuloides* and *P. balsamifera*. In our study area, the redstart is associated with older stands (>80 yrs), where it nests in the dense understory of alder and willow. We collected baseline data on territorial density and reproductive performance, to be compared with 1994 data from the same study plots after they have been isolated by logging. An extensive stand (>3500 ha) will be left unfragmented and used as a control. In 1993, 39 nests were found. One case of predation was recorded. Of 49 redstart family groups observed, only one included a cowbird nestling or fledgling. Using 1994 data, we will test whether fragmentation is accompanied by (1) an increase in territorial densities ("crowding" effect), (2) a reduction in reproductive success, (3) an increase in brood parasitism, and (4) an alteration of the age structure of the male subpopulation.

VINCENT, TANIA L. S. and TILMAN, DAVID. University of Minnesota, St. Paul, MN, 55108, USA. Intermediate Disturbance? Not Necessarily.

Species richness and cover of planted grassland species were recorded on an experimental soil disturbance gradient composed of 25 1 m x 1 m plots. These plots were created by removing surface sand, gassing existing seed bank, and then planting each plot with an identical mixture of 59 grassland species. Five control plots had no soil disturbance. The remaining plots were disturbed annually, beginning in May 1991. Each plot was divided into a grid with 25 20 cm x 20 cm squares. The plot with the lowest level of disturbance had one grid square disturbed on up to the highest disturbance with 20 grid squares disturbed. Results from the past three years of disturbance (1991-1993) are discussed. In 1992, a linear decrease in the number of species along the disturbance gradient can be explained by a loss of rare species. Neither "colonist" species nor species that do well in the control plots are restricted to particular ends of the gradient. In 1993, however, "colonist" species increase along the disturbance gradient while the numbers of control-plot dominants did not change, explaining an increase in the number of species at high disturbance.

VINTON, MARY ANN and INGRID C. BURKE. Colorado State University, Fort Collins, CO, 80523, USA. The influence of plant species and plant cover on soil C and N dynamics along a precipitation gradient in the central Great Plains.

The central grassland region of the U.S. encompasses major gradients in temperature and precipitation that determine the distribution of plant lifeforms, which in turn may influence key ecosystem processes such as nutrient cycling and soil organic matter dynamics. One such gradient is the 3x increase in precipitation from the eastern Colorado shortgrass-steppe, in the rain shadow of the Rocky Mountains, to the tallgrass prairie in eastern Kansas. We investigated the relative roles of plant species and plant cover in influencing soil C and N cycling in three sites along this gradient. The wettest sites, in eastern and central Kansas, had higher levels of total soil C and N and higher ratios of C:N than did the dry site in northeastern Colorado. The wettest sites had more continuous plant cover, resulting in less plant cover-induced variation in soil C and N, than did the dry site. Plant species at the wettest sites had higher and more variable levels of tissue C:N and potential soil C:N mineralization rates in associated soils than did plant species at the dry site. These results indicate that the relative importance of plant cover patterns and plant species to soil C and N cycling varies over this gradient of increasing precipitation, with plant cover being most important at the dry end and plant species being most important at the wet end.

VITOUSEK, PETER M., DOUGLAS R. TURNER AND PAUL SCOWCROFT. Stanford University, Stanford, CA 94305-5020, USA and Institute for Pacific Island Forestry, Honolulu, HI, 96813, USA. Foliar nutrients and litter decomposition along a 4.5 million year gradient of substrate age in Hawaiian montane rainforest.

As part of an analysis of soil development and nutrient cycling, we measured foliar nutrient concentrations in 7 sites developed in substrates ranging from 200 to 4.5 million years old. All sites were at 1200 m elevation and 2500 mm/y precipitation, in volcanic soils at similar slope positions; all were rainforests dominated by the native tree Metrosideros polymorpha. Nitrogen and phosporus concentrations in Metrosideros sun leaves increased from 0.76% and 0.052% in the youngest site to 1.42% and 0.108% in a 20,000 y old substraate, then declined to 0.86% and 0.061% in the oldest site. Nine additional species were sampled across the gradient, and most varied similarly. Nutrient concentrations in Metrosideros leaf litter also were greater in intermediate-aged sites, and litter decomposition and nutrient mineralization were more rapid there. Long-term soil developmental processes cause increased nutrient availability in intermediate-aged sites, and short-term biological feedbacks reinforce this pattern.

VOGEL, CHRISTOPH S. and PETER S. CURTIS. The Ohio State University, Columbus, OH, 43210, USA. Growth, leaf gas exchange and dinitrogen-fixation in black alder (*Alnus glutinosa*) in increased CO_2 environment.

Three month old seedlings of actinorhizal (*Frankia* nodulated) black alder were planted into open bottom root boxes in northern Lower Michigan and grown for 159 d (29 May - 4 November 1993) exposed to ambient and twice ambient (700 μbar) $p(CO_2)$ in open topped field chambers. Plants grown under elevated $p(CO_2)$ exhibited greater leaf area development, total leaf mass, stem height and stem mass at the end of the season compared to plants grown under ambient $p(CO_2)$. Leaf gas exchange measurements at growth $p(CO_2)$ over the course of the growing season showed that plants receiving elevated $p(CO_2)$ always had greater net assimilation rates than plants at ambient $p(CO_2)$. Foliar dark respiration rates were higher in ambient grown plants on a mass basis than in elevated grown plants due to increased mass per unit area in the leaves of elevated grown plants. Specific nitrogenase activity (acetylene reduction assay) was 46% greater in nodules collected from elevated grown plants compared to those of ambient grown plants.

VON FISCHER, JOSEPH C., LARS O. HEDIN and BRIAN P. KENNEDY. Cornell University, Ithaca, N.Y., 14853, USA. The soil-stream interface may be a control point for ecosystem nutrient losses.

This study assesses the ability of the soil-stream interface to act as a biogeochemical control point for nutrients leaving terrestrial landscapes. We examined concentrations and forms of nutrients in water moving through soil-stream interfaces of Augusta Creek, southwestern Michigan. The chemistry at the interface indicates an oxic-anoxic transition: an upland anoxic region characterized by high levels of DOC and NH_4^+, and a near-stream oxic zone where N and S occur in oxidized forms. These spatial patterns are

seasonally stable, and appear to be driven by microbial metabolism. To test whether microbial N transformations are limited by energy supply, we experimentally added labile DOC to a part of the oxidized zone which is normally depleted in DOC. During the DOC addition, we observed a decline in concentrations of both NO_3^- and N_2O, indicating that energy supply may affect the quantity and form of N leaving the landscape.

VOSS, P.B. and F.A. BAZZAZ. Harvard University, Cambridge, MA, 02138, USA. Design of rapid gas-sampling system for the characterization CO_2 heterogeneity.

Many studies in the fields of plant ecology and physiology make use of a gas analyzers (such as IRGAs) coupled to solenoid banks for sequential analysis of multiple airstreams. We have developed an improved method of gas sampling that maximizes measurement accuracy while reducing sampling time to less than four seconds per channel. The new design requires only one additional solenoid which momentarily stops the flow before each measurement is made. This rapid sampling design is the basis for another system we developed which uses momentary in-line sample storage to generate simultaneous measurement of CO_2 (and H_2O) for 18 points in space. This simultaneous sampling system was installed at the Harvard Forest during the summer of 1993, and measurements of CO_2 and H_2O concentrations were made along a 25-meter transect from lowland with standing water to the crest of a small hill approximately six meters in elevation. "Micro-towers" were set up at five-meter intervals along this transect, each with intake ports at 5, 20, and 40 cm above the soil. CO_2 and water vapor concentrations were measured at several times during the growing season. The design of this rapid sampling system may be of interest to researchers who need maximum performance from a limited number of expensive analyzers, and seems especially well suited for the control of glasshouses, growth chambers, open-top chambers and FACE experiments.

WADDELL, TOM and MARJORIE M. HOLLAND. Environmental Monitoring and Assessment Program, U.S. Environmental Protection Agency, Research Triangle Park, NC, 27711, USA. Mid-Atlantic Integrated Assessment (MAIA) Project.

The Environmental Protection Agency (EPA) is conducting a comprehensive ecological resource assessment as part of the Office of Research and Development's (ORD'S) integrated ecological research program. This geographic initiative, Mid-Atlantic Integrated Assessment (MAIA) project, includes the land area and near coastal waters associated with all of PA, WV, MD, DE, VA and parts of NJ, NY and NC. Primary components will be: (1) a monitoring dimension, (2) a research dimension, and (3) an assessment dimension. Research questions to be addressed relate to issues such as spatial scaling, landscape/land use patterns and resource conditions, common values across resources, and common metrics for ecological indicators. Results will provide insight into the efficacy of "ecosystem" and "watershed" management approaches to addressing resource and environmental protection concerns.

WADE, GARY L. and LOUISE M. TRITTON. Northeastern Forest Experiment Station, USDA Forest Service, Burlington, VT 05402-0968, USA. Evaluating biodiversity of landscape units with respect to scale, diversity types, and social stakes.

Preserving and enhancing biodiversity is a major objective for managing many landscape units. In order to effectively evaluate the biodiversity of landscape units, managers must choose spatial scales best suited to the types of biodiversity valued by stakeholders (individuals, communities, agencies, and action groups that value biodiversity and participate in social dialogues about it). To address this need, we have developed a checklist for systematically evaluating biodiversity in landscape units at six different scales (genetic, species, habitat or community, ecosystem, landscape, and biome) and for eight different types of diversity (functional diversity; inventory, structural, and differentiation attribute diversities; and spatial, temporal, compositional, and nested pattern diversities). We also introduce consideration of seven kinds of social stakes (inherent, utilitarian, subsistence, legacy, ecosystem integrity, aesthetic, and spiritual) held by different stakeholders with commitment to, or interest and involvement in managing landscape units for biodiversity. Our conceptual diagrams and checklist offer a means for relating scale and different types of biodiversity to one another, and for linking them to social concerns.

WAGENER, STEPHEN M.[1], J.M. ANDERSON[2], MARK W. OSWOOD[1], and JOSHUA P. SCHIMEL[1]. [1]University of Alaska Fairbanks, Fairbanks, AK 99775 USA and [2]Rothamsted Experimental Station, Harpenden, Herts AL5 2JQ, Great Britain. Litter processing in streams and soil: What's the difference?

Both soils and streams receive inputs of organic matter from leaf litter and living primary producers. Despite this functional similarity, soil and stream ecologists have dissimilar views of trophic processes. Soil ecologists usually see decomposition as a process that mineralizes carbon from plant residues and provides nutrients for plant uptake, with invertebrates playing little role in carbon dynamics. In contrast, aquatic ecologists view litter decomposition in a forest stream as a series of transformations mediated by specialized invertebrates. Soil ecologists often underestimate the role of invertebrates in litter processing because they are mostly concerned with CO_2 flux, little of which is a direct result of invertebrate respiration. In contrast, the stream ecologist's measure of carbon loss includes not only CO_2 lost to the atmosphere, but leachates and fine particulates lost downstream as well. Stream ecologists underestimate the importance of microbes because much of the carbon is transported downstream to be eventually respired by microbes. The differences in perspective of the soil and stream ecologists is likely due to the very different spatial and temperal scales in soils and streams. Soil processes occur over very small distances (cm), over long time periods (years), in the dark. In contrast, decomposition in a stream occurs over much longer distances (hundreds of km), over shorter time periods (months), and in daylight. What the stream ecologist fails to see is the entire river (analogous to a soil core) as an ecosystem. Despite great differences in the perceived importance of invertebrates in decomposition processes between streams and soils, invertebrates play very similar roles in carbon mineralization in both systems.

WALDE, SANDRA J. Dalhousie University, Halifax, NS, B3H 4J1, CANADA. Metapopulation dynamics and acarine predator-prey interactions.

Metapopulation structure, where interactions among subdivided populations affect the dynamics of the whole population, has recently received considerable attention, both for theoretical reasons (as a potential source of stability) and because of its application to conservation efforts. Despite the plausibility of such theory, recent reviews have suggested that there is little empirical evidence for such dynamics in real populations. Among the best-studied predator-prey systems that do purport to show evidence of metapopulation dynamics are phytophagous mites and their predators, where experimental manipulations have been conducted in the laboratory, in greenhouses and in the field. In reviewing this literature I first discuss the characteristics of acarine systems that may make them prone to this type of dynamics. I then look at the variation among acarine predator-prey interactions and how aspects such as degree of specialization and spatial scale of the interaction affect the likelihood of seeing a metapopulation structure. Finally I focus on the importance of spatial scale in a set of field experiments with one particular predator-prey system, Typhlodromus pyri and Panonychus ulmi.

WALKER, JOAN and DEBORAH WHITE. USFS Southeastern Forest Experiment Station, Clemson, SC USA and The Nature Preserves Commission, Frankfort, KY, USA. Morphological and flower production changes with time since burning in *Macbridea alba*.

Macbridea alba, a Threatened mint endemic to Florida, grows in fire dependent longleaf pine communities. Objectives were to (1)describe population size structure, (2)describe relationships between plant size and flower production, (3) determine effects of growing season fires on plants and populations. Thirty plants in each of 11 populations were tagged for repeated measurements of height, node #, flowers produced. Populations were burned in April 1990 and sampled through 1993. The relationships of time since burning to gross morphology and flower production are presented. Across populations in the first season, up to 80% of individuals were present only as basal rosettes. After year 1, flowering stems/plant and mean height increased and remained high. Inflorescences/plant and flowers/plant decreased from years 2-4, but flowers/inflorescence varied randomly. Though population losses were low, opportunities for increases via sexual reproduction decreased markedly with fire exclusion.

WALKER, MARILYN D., DONALD A. WALKER, and NANCY A. AUERBACH. University of Colorado, Boulder, CO, 80303, USA. Classification and gradient analysis of upland tussock tundra vegetation, Southern Arctic Foothills, Alaska.

Tussock tundra is the physiognomic descriptor of the upland tundra vegetation dominated by the tussock-forming sedge *Eriophorum vaginatum*. This vegetation type is the dominant upland type throughout most of northern Alaska and the Chukotka Peninsula. The broadly-defined vegetation type is ubiquitous in Beringia, the region of Alaska and Chukotka that was not ice-free during the Pleistocene. This paper presents a floristic classification and canonical correspondence analysis of this vegetation type for the Southern Arctic Foothills physiographic province of northern Alaska. Moisture is the primary environmental gradient controlling vegetation patterns, and secondary gradients vary according to position along the moisture gradient: snow depth and duration is of importance in the driest areas, soil nutrients are of importance in mesic areas, and a combination of nutrients hydrologic regime are of importance in wet areas. The importance of long-term (10^6 years) landscape evolution in controlling modern vegetation patterns is discussed.

WALLACE, DANIEL F., PAUL F. HENDRIX, DAVID R. RADCLIFF, LARRY T. WEST AND WILLIAM P. TOLLNER. University of Georgia, Athens, GA, 30602, USA. CAT-scan images of earthworm (Lumbricus rubellus and L. terrestris) burrows predict macroporous saturated hydraulic conductivity effects.

Earthworm macropores alter water relations and affect ammendment efficiency and transport. Predicting pore saturated hydraulic conductivity(Ksat) effects is a first step in management. Earthworms were allowed to burrow in soil columns. A subset was disturbed to simulate plowing. CAT-scan images were produced at three horizontal planes and vertically. Ksat was measured by the constant head method. Predictions of Ksat were calculated assuming burrows obeyed Pouiselle's Law for flow in cylinders. Average Ksat observed was 0.38 $cm \cdot min^{-1}$. L. terrestris cores showed significantly increased Ksat at 0.661 $cm \cdot min^{-1}$, compared to a control's 0.210 $cm \cdot min^{-1}$. Predictions of Ksat from burrow characters alone were 0.270 $cm \cdot min^{-1}$, insignificant compared to control. The CAT-scan images showed cracks around the core walls. Incorporating these into predicted Ksat measures produced values of 0.531 $cm \cdot min^{-1}$ for L. terrestris and 0.287 $cm \cdot min^{-1}$ for control, a significant difference and a predicted value not significantly different from the observed Ksat.

WALLER, DEBORAH A. Old Dominion University, Norfolk, VA, 23529, USA. Preference of the wood roach, Cryptocercus punctulatus Scudder (Cryptocercidae), for low levels of dietary nitrogen.

Cryptocercus punctulatus lives and feeds in dead wood, which typically has a low nitrogen content. I presented Cryptocercus with filter paper treated with either deionized water or different concentrations and forms of combined nitrogen in choice tests. Cryptocercus preferred paper treated with an 0.1% solution (w/v) of ammonium nitrate to water-treated paper. In

contrast, they preferred water-treated paper to paper treated with 1.0% solutions (w/v) of ammonium nitrate, urea or peptone. These results suggest that Cryptocercus' food preferences are adapted to a low-nitrogen diet.

WALTHO, NIGEL,PATTI ALLEN, RON ALLEN and JUREK KOLASA. McMaster University, Hamilton, Ontario, L8S 4K1, Canada. Interaction been the sampling window and habitat properties: implications for coral reef fish studies.

Determination of community structure (richness, abundances) and patterns of similarities in coral reef fish may be strongly influenced by the size of temporal sampling window (Waltho and Kolasa, Coral Reefs - submitted). We examine whether there is a difference between a continuous coral reef habitat compared to isolated coral reef patches. We recorded all fish present on ten isolated coral reef patches in Discovery Bay, Jamaica, using five sampling window sizes (5,10,15,20 and 30 minutes) on each patch. Unlike in the continuous habitat study, we found that the duration of the sampling window had a small or no effect on the determination of community structure. Consequently, neither the number of significant similarities among patches increased with time nor the variation (measured by Standard Errors) declined. A surprising result was the failure of total abundance to increase as a function of the sampling window duration. Such an increase should occur due to fish movement through the habitat. We interpret these results in the broader methodological context, including fish behavior on isolated patches and diver impact such as interference with fish movement.

WARDENAAR, ERIK C.P. University of Minnesota, St. Paul, MN, 55108, USA. Loss of species diversity in an experimental drought on an oldfield grassland in Cedar Creek Natural History Area (CCNHA).

An experimental drought in an old field at CCNHA was setup to mimic a 1988 natural drought in which species richness and standing crop were reduced by 37% and 47% respectively and rare species were most frequently lost. The 1993 experimental May-July drought caused increases in forb species mortality ranging 1.1 to 14.9 fold. Flowering ranged from a 3.1 fold increase to a 3.1 fold decrease. Reduction of growth rates ranged from 3% to 59%. Standing crop of grasses and forbs and the total biomass were reduced by 76%, 52% and 70% respectively. Average species richness fell 24% from 17 to 13 species. Given this variation in drought sensitivity, random thinning is not the sole process causing loss of rare species. Species performance under N-stress was compared with performance under water-stress. Most species have roots restricted to the top soil and show a positive correlation between N-stress performance and water-stress performance, explaining the frequent loss of rare species. Some rare species with deep roots indicate a possible tradeoff between water stress survival and N stress survival.

WARDLE, GLENDA M. University of Chicago, Chicago, IL, 60637, USA. Life history evolution in *Campanula americana*

Intraspecific variation can be used to understand the evolution of life histories as a suite of interacting traits shaped by natural selection. In *Campanula americana* individuals within and among populations vary in their age at first reproduction. Specifically there are two life history types - winter annuals and biennials. The aim of the research has been to understand what is maintaining this variation within local populations. I expected that variation in selection on a small spatial and temporal scale and the effect of age structuring by a seed bank would both be important. I have collected data on individual survivorship and reproduction in two populations that vary in the frequency of the types for a number of years. The data have been incorporated into a demographic matrix model that includes age structure and into a phenotypic analysis of selection. The conceptual focus of the research has been to compare these approaches directly using the data from natural populations and to combine the insights into one view of life history evolution.

WARNER, SUSAN C. Penn State, University Park, PA 16802, USA. Low pH tolerance of amphibians utilizing temporary ponds in North Florida.

Amphibians utilizing temporary ponds in North Florida are generally more tolerant to low pH than amphibians tested in other areas. Hyla femoralis in particular is extremely tolerant to low pH with 50% of the embryos hatching at a pH of 3.35. No other amphibian known is able to tolerate this low a pH. Other species tested were not as tolerant as Hyla femoralis, but in general were more tolerant than many other species tested elsewhere. The temporary ponds in North Florida that were monitored were diverse in pH as well as other chemical and physical variables. Many ponds were naturally low in pH, particularly those in pinewoods. Pond pH ranged from 3.46 to 8.69. No pond was low enough in pH to exclude Hyla femoralis, but other species could be excluded due to pH. The pH of many ponds was lower than the mean pH of rainfall, which is 4.7 for this area.

WASCHMANN[1], RONALD S., BRUCE D. MCVEETY[2], GLENN D. JARRELL[1], MARK G. JOHNSON[1], PAUL T. RYGIEWICZ[3], DAVID M. OLSZYK[3], and DAVID T. TINGEY[3]. [1]ManTech Environmental Technology, Inc., Corvallis, OR 97333, [2]Battelle-PNW Labs, Richland, WA 99352, U.S. Environmental Protection Agency, Corvallis, OR, 97333. Effects of CO_2 and Climate Change on Forest Trees: TERA, a state-of-the-science research facility.

The Terrestrial Ecophysiological Research Area (TERA) is a facility being used to examine the effects of elevated CO_2 and global climate change on Douglas fir (*Pseudotsuga menziesii* (Mirb) Franco) seedlings. TERA consists of 12 climate-controlled growth chambers (Terracosms) that are illuminated with natural sunlight. Terracosm environmental conditions continuously mimic diurnal and seasonal changes in ambient air temperature, dew point temperature, and CO_2 concentration to ± 1.5°C, ± 5°C, and ± 20 ppm, respectively. The terracosms are extensively instrumented in order to examine above- and belowground processes. All sensors, analytical instruments, and data acquisition equipment required for independent operation are located at each Terracosm. Data quality control is insured with centralized, redundant instrumentation. The TERA research facility will be described, including overall system performance and terracosm climate control.

WASHINGTON-ALLEN, ROBERT A., R. DOUGLAS RAMSEY, BRIEN E. NORTON, and NEIL E. WEST. Utah State University, Logan, UT, 84322-5230, USA. Historical analysis of land degradation on the Bolivian Altiplano.

Increased migration from agropastoral communities to cities on the Bolivian altiplano may be due to land degradation in the form of lowered vegetation productivity and accelerated soil erosion. The objective of this study was to determine if a degradation trend existed by relating satellite-generated ecological indicators, i.e., vegetation and soil stability (VI and SSI) indices, to drought and land use practices. The study was conducted from a 15-year perspective (1972-1987) provided by 3 Landsat Multispectral Scanner and 1 Thematic Mapper satellite images. Mean-variance and density slice analyses of SSI revealed a heterogenous landscape, with the more productive wetlands and pastures exhibiting more stability than sandy-textured cultivated and grazed sites subject to erosion. However, despite spatial variability, by 1986 the study site's vegetation had recovered to 1972 cover level after the severe 1984 drought. VI image differencing indicated that no significant change in vegetation productivity had occurred in the 15-year time span.

WATLING, JENNIFER R.[1,2], IAN E. WOODROW[1] and C. BARRY OSMOND[2]. 1. James Cook University, Townsville, QLD, 4810, AUSTRALIA. 2. Australian National University, Canberra, ACT, 0200, AUSTRALIA. Xanthophyll cycle pigments and sunfleck tolerance in rainforest plants.

The ability to deal with wide fluctuations in PFD in rainforest understoreys may partially account for distributions of so called shade tolerant and intolerant plants. Pigment profiles and rates of xanthophyll conversion were characterised for both a shade tolerant (*Alocasia macrorrhiza*) and a shade intolerant (*Omalanthus novoguinensis*) rainforest species grown under either high light (HL), low light (LL) or fluctuating light in a rainforest understorey (U). Differences in the proportions of carotenoids between the two species, indicate that pigment composition may play a role in conferring shade tolerance. HL plants showed a three-fold increase in their xanthophyll levels (mmol mol^{-1} chlorophyll) relative to LL and U plants, implying a greater capacity for zeaxanthin mediated photoprotection in the former. Conversion of violaxanthin (V) to antheraxanthin (A) and zeaxanthin (Z) was detected in all plants on exposure to full sun after some hours in low light. For LL and U plants of both species the increase in A + Z was exponential with 40-50 % of the VAZ pool being converted after 5 minutes exposure. The maximum level of conversion was 60 % for all *O. novoguinensis* and 40, 80 and 90 % for LL, HL and U *A. macrorrhiza* respectively. The kinetics of V conversion to A + Z in HL plants (60-70 % conversion in 5 minutes), exhibited oscillations which may have been induced by increased assimilation rates accompanying stomatal opening on exposure to high light.

WATTS, STEPHEN E., THOMAS W. BOUTTON, and STEVE ARCHER. Texas A&M University, College Station, TX, 77843, USA. Effects of increased tree/shrub abundance on belowground carbon and nitrogen storage in a subtropical savanna ecosystem.

Tree/shrub abundance has increased in recent history in grasslands and savannas worldwide, potentially altering nutrient pools and fluxes. In the Rio Grande Plains (TX), discrete clusters of woody plants organized around a central Prosopis glandulosa have developed recently on upland soils with an argillic horizon (Bt); groves organized around multiple Prosopis have developed where there are gaps in the Bt. We quantified organic C and total N storage to a depth of 1.4 m in roots and soils of remnant grasslands, shrub clusters, and groves. Root biomass (g m^{-2}) was greater in clusters (2600) and groves (1600) than grasslands (500); %N in roots was also greater in groves and clusters (1.4-2.3%) than grasslands (0.8-1.5%), while %C in roots varied little between sites. Thus, C and N storage in roots (g m^{-2}) was significantly greater in clusters (C=1400; N=40) and groves (C=800; N=20) than grasslands (C=200; N=10). In contrast, C and N pools (g m^{-2}) in soil were greater in grasslands (C=9700; N=900) and clusters (C=9300; N=1000) than groves (C=8200; N=800). As a result, total (root+soil) belowground mass (g m^{-2}) of C and N was higher in clusters (C=10700; N=1100) and grasslands (C=10000; N=900) than groves (C=9000; N=900), suggesting that differences in soil texture were more important than vegetation type in determining belowground storage. Greater storage of C and N where Bt is present (grasslands, clusters) may reflect the role of clay-organic matter complexation in reducing organic matter turnover. Greater root mass in clusters and groves suggests their soil C and N pools will increase in the future relative to grasslands.

WAYNE, LISA B. and V. THOMAS PARKER. San Francisco State University, San Francisco, CA, 94132, USA. Regeneration ecology of a peripheral zone halophyte, Grindelia stricta var. angustifolia, in a San Francisco Bay tidal salt marsh.

Grindelia stricta var. angustifolia is a rare shrub endemic to San Francisco Bay salt marshes where it occupies a narrow habitat zone located within a few meters of the tidal channel banks and the land-marsh interface. These areas, termed peripheral halophyte zones, are characterized

by moderate soil salinity. In order to determine the degree to which salinity levels over the growing season affect the regeneration of Grindelia, we measured germination rates, seedling survival and growth rates, and soil salinity along transects established across the land and channel peripheral halophyte zones. Our field experiments revealed that seedling survival and growth rates were negatively correlated with distance from the interface and average seasonal salinity levels in both the land ($r2 = 0.818$ and $r2 = 0.770$) and channel ($r2 = 0.847$ and $r2 = 0.966$) zones. Germination rates also declined with increasing salinity in the land and channel zones ($r2 = 0.801$ and $r2 = 0.168$). The correlation between salinity and field germination did not differ from laboratory controls suggesting that salinity is the primary constraint on germination. Although salinity levels in the land and channel zones did not differ, seed germination and seedling survival and growth displayed significantly different patterns in these two zones. The channel zone had significantly higher, yet more rapid declines in, survival and growth than the land zone. Soil salinity is clearly the major constraint on Grindelia regeneration, but the differential success of seeds and seedlings in the land interface versus channel zones suggests that other environmental factors such as the degree of tidal inundation and soil type also strongly influence regeneration.

WAYNE, P.W. and F.A. BAZZAZ. Harvard University, Biological Labs, 16 Divinity Ave, Cambridge, MA, 02138, USA. Size inequality in regenerating yellow birch stands is reduced by elevated CO_2 atmospheres.

Dense stands of yellow birch (*Betula alleghaniensis*) seedlings comprised of equal numbers of three maternal families were established in forest soil profiles in low (350 $\mu l\ l^{-1}$) and high (700 $\mu l\ l^{-1}$) CO_2 atmospheres in a glasshouse. In both CO_2 treatments, seedling size inequality (% CV) within stands increased through time with total stand biomass. However, while stands in high CO_2 maintained greater final above and below ground biomass than stands at low CO_2, inequalities in total seedling mass, shoot height, and leaf area were significantly lower in high CO_2 throughout the growing season. This effect of elevated CO_2 on stand development differs from the effects of other resource additions (e.g. light, nutrients) which generally increase inter-individual size inequality. Lower size inequalities in high CO_2 may have occurred because sub-canopy plants in low light exhibited greater proportional responsiveness to elevated CO_2 than did canopy plants in high light. Other studies with yellow birch suggest CO_2-induced photosynthetic and growth enhancements are proportionally greater at low vs. high light. Hypotheses which may explain greater CO_2 enhancements at low light are presented. Strong correlations were found between individuals' final positions in stand size hierarchies and seedlings' initial sizes and abilities to preempt light and soil nutrients. The three maternal lines differed in their responsiveness to elevated CO_2, and thus contributed differently to total stand biomass in the two CO_2 treatments.

WEATHERS, KATHLEEN C., GARY M. LOVETT and GENE E. LIKENS. Institute of Ecosystem Studies, Millbrook, NY, 12545, USA. Patterns of atmospheric deposition to a mountain landscape in southeastern New York.

We postulate that in the Catskill Mts. of southeastern NY, patterns of atmospheric deposition across the landscape are regulated primarily by four landscape features: 1) edges and gaps; 2) elevation; 3) slope aspect; and 4) vegetation type. We measured relative rates of deposition associated with these features using Pb in the forest floor as an indicator of total deposition. Deposition enhancement factors generated by these measurements were used in a geographic information system to model deposition to the landscape of Hunter Mt. Average deposition in the area above 1000m elevation was estimated to be 13% greater than to nearby low-elevation sites. Combinations of the landscape features can create "hotspots" of deposition, for instance, high-elevation coniferous forest edges, where deposition can be 300% greater than to a low-elevation forest. These results illustrate the importance of considering landscape-level variation when modeling atmospheric deposition or extrapolating deposition measurements.

WEAVER, MELISSA J. and JOHN J. MAGNUSON. Center for Limnology, Madison, WI, 53706, USA. Spatial heterogeneity of littoral fish assemblages: Response to macrophyte structural complexity in Lake Mendota.

We tested whether the spatial heterogeneity of littoral fishes was related to the structural complexity of submerged macrophytes in Lake Mendota using multivariate techniques. Fish assemblages in the shallow (nearshore) littoral zone were larger and richer than assemblages in the deeper (farther offshore) littoral zone. Abundances of age-0 fishes, especially bluegills Lepomis macrochirus and black crappies Pomoxis nigromaculatus, corresponded with the hierarchical clusters of littoral sites and defined the Bray-Curtis ordination gradients along which the littoral sites separated. We sampled the submerged macrophytes along transects perpendicular to shore with a double-headed rake for species composition and abundance and with a recording echosounder for structural heterogeneity and patchiness. Nearshore, plant communities which had the highest species richness supported the richest fish assemblages and the highest abundances of age-0 fishes. In the deeper littoral zone, patchy beds of Eurasian water milfoil Myriophyllum spicatum supported the highest abundances of age-0 bluegills and adult piscivores. The abundance and species richness of littoral fish assemblages, especially for age-0 fishes, were closely related to the presence and complexity of submerged macrophytes in Lake Mendota.

WEBER, EVERETT P. and FRANK P. DAY. Old Dominion University, Norfolk, Virginia, 23529, USA. Root Length density, fine root phenology and vertical distribution in fertilized plots in a barrier island dune ecosystem.

Minirhizotrons were used to track individual roots through an entire growing season in small plots on a 36 year old dune on Hog Island, a barrier island in the Virginia Coast reserve Long Term Ecological Research Site. Experimental plots were fertilized with nitrogen. Minirhizotron tubes were installed in each fertilized and control plot. Each tube was sampled monthly for nine months, March through November of 1992. Direct measures were made of turnover, root growth, and root senescence. Root Length Density (RLD) was expected to increase from March through September with a decrease in October and November.Preliminary results, March through June, show an increase has occurred with fertilized roots showing greater density (440 mm mm^{-2} (fertilized) vs. 190 mm mm^{-2} (unfertilized)). New roots

contributed most to each month's total RLD. The rate of root loss from May to June was higher for fertilized than for unfertilized roots (25% for unfertilized, 37% for fertilized). Fertilized roots had a greater RLD throughout the profile with a peak in RLD between 16.5-22.1 cm. This analysis suggests that nutrient limitation has significant effects not only on root length density but also on root phenology.

WEBER, LOUISE M. and SUSAN M. HAIG. Clemson University, Clemson, SC, 29634. Community structure associated with shorebirds in South Carolina coastal soft-sediments.

We propose and test a model predicting factors critical in structuring soft-sediment communities associated with spring migrating shorebirds in brackish impoundments and intertidal areas on South Island, South Carolina. We hypothesize that at water depths tolerated by shorebirds, shorebird abundance is related to invertebrate prey characteristics (density, biomass, and size) in a feedback loop. In other words, shorebird abundance is greatest in rich prey patches, but heavy predation does, in turn, negatively impact the prey population. We found that shorebirds rarely occurred at depths greater than 10 cm and most occurred at depths less than 2.5 cm. At less than 10 cm both water depth and invertebrate density were important in determining shorebird abundance. However, prey density was more important than water depth. In shorebird exclosure experiments there was significantly higher ($P < 0.05$) invertebrate biomass in exclosures compared to controls open to shorebirds in 1992 (exclosure:x = 0.028g, n = 8, control:x = 0.016g, n = 11, LSD test critical value = 0.010) and 1993 (exclosure:x = 0.033g, n = 12, control:x = 0.013g, n = 13, Welch's t-test SE = 0.014). We found no evidence of indirect interactions among prey due to shorebird predation. Results support the proposed model. At tolerable water depths shorebirds aggregate in rich prey patches, yet negatively impact the prey population.

WEGNER, DAVID L. and MICHAEL J. PUCHERELLI. Glen Canyon Environmental Studies, Flagstaff, AZ 86001 and Bureau of Reclamation, Denver, CO 80225. Ecosystem monitoring in the Grand Canyon utilizing a geomorphic based geographic information system.

The Colorado River through Grand Canyon, AZ is a distrubed ecosystem in the Southwestern United States which is defined and controlled by dam releases. In order to assess and quantify the long-term impacts of the operations of Glen Canyon Dam on the downstream resources, a geomorphic and ecosystem based geographic information system is being developed. The development of the geographic information system is defined by the linkage of the physical environment, defined by the dam releases and geomorphology, with the riparian, aquatic, vegetation, avifauna, and primary productivity of the impacted environment. Critical concerns center around endangered and threatened species and the long-term impact of short-term natural and man-induced events.

Effective long-term monitoring studies require the development of useable data base which can link the various elements of the ecosystem together. Further, the long-term monitoring data base must be able to integrate new research as it is completed. The future of resource management requires integration of resource needs.

WEIHER, EVAN R. and PAUL A. KEDDY. University of Ottawa, Ottawa, Ontario, K1N 6N5, CANADA. Patterns, null models, and community assembly rules for aquatic plants.

The detection of pattern in communities has been facilitated by the use of null models. Our goal is to establish quantitative trait-environment linkages that predict community assembly. As one step in establishing such linkages we have been investigating the patterns of incidence of 69 species of aquatic plants found in 75 lakes in northern New York and southeastern Quebec. Species incidence on habitat islands is one way of looking for pattern in nature, and is an early step for building predictive models for species and their traits. Incidence functions can often be modelled using logistic or second order regressions. We found that species belonging to the functional group of "isoetid" plants (e.g. Eriocaulon septangulare, Lobelia dortmanna) have a consistently different pattern of incidence than species belonging to other functional groups. These patterns suggest that 1) non-random factors control community assembly, at least for isoetid versus non-isoetid forms, 2) the distribution of traits associated with isoetid plants (e.g. rosette-form) is fundamentally different from traits (e.g. dissected leaves) associated with other species and 3) aquatic plant communities do not exhibit the pattern seen in animal communities by Fox and Brown, where each functional group has an equal number of species in each community.

WEISHAMPEL, JOHN F. and HERMAN H. SHUGART. NASA/Goddard Space Flight Center, Greenbelt, MD, 20771, USA and University of Virginia, Charlottesville, VA, 22903, USA. **Spatial dynamics of primary forest succession along the Glacier Bay chronosequence.**

Within-sere spatial patterns representing three stages of post-glacial primary succession of an Alaskan coastal forest were analyzed. Cartesian coordinates of each stem >1 cm dbh were recorded from a 2.56 ha ≈80 yr, Sitka alder/willow spp./black cottonwood plot, a 4.0 ha ≈220 yr Sitka spruce/western hemlock plot, and four, 1.0 ha >500 yr hemlock/spruce plots. The resulting stem maps were examined in terms of intra- and inter-group (e.g., species, size-class, mortality status) spatial relationships measured respectively with standard univariate and bivariate point pattern analysis techniques. Canopy dominant stems for all seral stages were the only group to exhibit random or uniform distributions across a range of scales (i.e., 1-20 m). Interspecific correlations among primary species were positive for the ≈80 and ≈220 yr seres at the majority of observed scales implying periods of facilitation and coalescence. But, interspecific correlation between the primary species for the >500 yr plots was significantly negative at 3 m suggesting spruce exclusion as hemlock patches coalesce. Negative correlations between recently invading/living understory and established species/canopy dominant stems as well as a positive correlation between canopy dominant and dead understory stems at scales of overstory crown widths (<7 m) correspond to gap-dynamic theory.

WELKER, M., J.BARON, G. BOWSER, B. NEWKIRK, and M.A. WOTAWA. Natural Resource Ecology Laboratory, Colorado State Univ., Ft. Collins, CO 80523. Nitrogen deposition and cycling processes in Loch Vale Watershed, CO

Nitrogen concentrations in high elevation streams of the Colorado Front Range average 16 ueq L^{-1}, whereas median NO_3 concentrations for the Western Lake Survey are 0.4 ueq L^{-1}. N deposition is higher in the Front Range than the rest of the Intermountain West. We employed grass and forest versions of the CENTURY model under a range of N deposition values (0.02-1.60 g N m^{-2} y^{-1}) to explore the possibility that high observed stream N was due to terrestrial N saturation of alpine tundra and subalpine forest. N appears to be limiting to subalpine forest productivity; but excess leachate from alpine tundra is sufficient to account for the current observed stream N. Diatom species counts from surface sediments of 21 lakes were matched to controlling chemical parameters using canonical correspondence analysis. This paleolimnological data will be used to address possible historic trends of nitrogen deposition.

WELLER, DONALD E., DAVID L. CORRELL, THOMAS E. JORDAN, AND J. MICHELLE COFFEE. Smithsonian Environmental Research Center, Edgewater, MD, 21037, USA. Effects of spatial resolution on estimates of riparian forest distribution.

Riparian forests can control landscape discharges by intercepting materials released from disturbed uphill areas, but often occur in narrow streamside bands that are hard to identify from aerial photographs or satellite images. Inability to quantify the extent of forested stream bank may limit models relating landscape structure to nutrient discharge. We compared four land use/land cover data bases of differing resolutions, all describing the Rhode River watershed near Annapolis MD. Estimates of forested area dropped from 62% to 50% between the highest and coarsest resolution data, and the estimated amount of forested stream bank dropped even more. The coarsest resolution data were most unsatisfactory in identifying forests along primary streams, where most materials first enter the stream network. Estimates derived from coarse resolution geographic data would not adequately account for the effects of riparian forests on nutrient discharges.

WELLER, ROBERT R. AND JIMMY D. WINTER. Texas Tech University, Lubbock, TX, 79409, USA. Habitat preference of flathead catfish in a West Texas reservoir.

We used ultrasonic telemetry to determine the habitat selection by flathead catfish, Pylodictus olivaris, in a 93-hectare reservoir in West Texas. We implanted temperature-sensing transmitters in 10 catfish ranging in size from 1.4 to 9.1 kg, during June and July of 1993. These fish were monitored from July 1993 until July 1994 along with an additional 10 fish tagged in early 1994. The following habitat variables were recorded at each fish location: depth, substrate, water temperature, fish temperature, dissolved oxygen, distance from shore, and the presence or absence of vegetation and woody debris. Catfish preferred substrates consisting of rocks and large boulders, and woody cover such as standing timber and human-made structures. Catfish were found at shallower depths during summer and early fall. In late fall and winter, catfish were often located in deeper, offshore water. Habitat variables such as substrate and cover were the most important parameters in habitat selection.

WERNTZ, DAVID AND JERRY F. FRANKLIN. University of Washington, Seattle, WA, 98195, USA. Monitoring Forest Structural Development and Old-growth Species Responses in Late-Successional Forest Reserves.

Monitoring programs are necessary to assess progress toward attainment of management objectives and are useful in testing the assumptions and predictions of management plans. The recently proposed Forest Ecosystem Management Plan for national forests in the Pacific Northwest established Late-Successional Reserves to protect and enhance biodiversity and forest habitat associated with late-successional forest ecosystems. It is expected that as mature forest and silviculturally-adjusted plantations within the Reserves develop old-growth structural features, the number of plants and animals associated with old-growth forest will increase. The objective of our project is to develop a procedure for monitoring forest habitat changes and species responses within a Late-Successional Reserve in the southern Washington Cascades. Parameters for monitoring the development of forest habitat are selected from structural features associated with young, mature, and old-growth forest stands. Minimum thresholds of mean size, mean abundance, and distribution of each parameter are established for all forest age-classes. The response of species to structural development is determined by monitoring population trends. Factors such as dispersal, generation time, ease of data collection, and availability of data on population variability guide the selection of species to be monitored. Estimates of cost per unit effort for collection and analysis of monitoring data, and a process for analyzing and evaluating the data are included.

WENDELN, MARCIA C. Wright State University, Dayton, OH, 45435, USA. Nutritional analysis of neotropical figs (Ficus) as related to food selection by bats.

Figs are a critical resource for frugivores. Neotropical fruit bats display a marked preference for selected species of figs. Although the nutritional significance of figs is unknown, many studies refer to them as a low quality fruit. I analyzed 14 species of figs (Ficus) from Barro Colorado Island, Panama. Fig samples were assayed for protein, cxCHO, lipids, fiber, cell wall, lignin, tannins, amino acids and minerals. Seed fraction was analyzed separately from fruit pulp. Results indicate that bat selection is positively correlated with nutrient composition of figs. The most preferred bat fig (F.insipida) had

the highest composition of essential amino acids and minerals, and lowest lignin and tannin values. Calculated metabolizable energy for all 14 species, is high (3.3 kcal/g) compared to Ugandan figs (2.4 kcal/g). Results suggest there is considerable chemical and nutritional variation among fig species influencing frugivore feeding behavior.

WERNZ, JAMES and ANDREW R. MOLDENKE. Dept of Entomology, Oregon State University, Corvallis, OR 97331 USA.
Effects of forest management practices on arthropod abundance and diversity: implications for vertebrate populations.

Arthropod abundance was monitored as resources for 1) ground-feeding, 2) foliage-gleaning and 3) flycatching vertebrates in mature Douglas-fir forests (MF), clearcuts (CC) and harvest units with retention of remnant living trees (GTR). Mature forest (MF) supported nearly 10x the micro-/meso-arthropod biomass within the litter layer than CC or GTR; population density was significantly higher in MF than GTR and GTR more than CC; species richness was equivalent. Severely slash-burned clearcut microsites had significantly lower species richness but the highest population densities recorded throughout. The epigeic macroarthropod fauna was significantly higher (density, biomass, species richness) under CC than GTR or MF conditions. Biomass is predominantly diurnal (bird resource) in CC and GTR, but nocturnal in MF (mammalian resource). Foliage-gleaning resource did not differ significantly, and arthropods large enough for good vertebrate prey are relatively uncommon throughout. Extreme decline in prey availability at end of nesting season in MF may force birds to forage in CC for rest of year. Flycatcher resource is twice as great (abundance, biomass, and species richness) in the GTR (CC=MF). Diurnal prey predominates in CC and GTR, nocturnal in MF. Forest edge, rather than retained green trees, may be causal.

WEST, JORDAN M. Cornell University, Ithaca, NY, 14853, USA. Plasticity in the sclerites of a Caribbean gorgonian: exposure, damage and light level cues.

In the soft coral Briareum asbestinum, sclerite morphology and density vary among populations from different sites. A pilot study indicated that there is a significant component of plasticity to this variation. Since sclerites function as both support and defense structures, potential cues for changes in sclerite composition are wave exposure and predator damage. Light level may also cue changes through effects on colony growth rate. To distinguish between the three factors, transplants were performed in which exposure and light levels were artificially manipulated and colonies were subjected to simulated predator damage. There was little response to reduced exposure or reduced light; however, damage significantly affected sclerite length and sclerite weight fraction within the tissue. Colonies gouged with a cutting tool (to simulate scarring by snail predators) responded by producing larger sclerites. This induction represents a significant defensive response since, for at least one major snail predator, foods with large sclerites have been shown to be less palatable than foods with small sclerites.

WETZEL, PAUL R. and ARNOLD G. VAN DER VALK. Iowa State University, Ames, IA, 50011, USA. Vesicular-arbuscular mycorrhizal fungi in fresh and saline prairie pothole wetlands.

Freshwater prairie wetlands are hydrologically dynamic systems that experience prolonged drawdowns caused by periodic droughts. In the saline prairie wetlands, salinity also increases during drought periods. Plants may cope with these changing environmental parameters through vesicular-arbuscular mycorrhizal (VAM) fungal colonization of their roots. VAM fungal colonization was measured on the roots of common plant species growing in the wet meadow and shallow emergent vegetation zones of three saline wetlands in North Dakota and three freshwater prairie wetlands in Iowa. VAM colonization ranged between 19-78% on various species from the wet meadow zones and 12-14% on plants from the shallow emergent zone. Grasses generally had a higher percent VAM fungal colonization than species from the Cyperaceae. For plants found in both saline and freshwater wetlands, such as Spartina pectinata, VAM colonization was much higher ($p > 0.001$) in saline wetlands ($n=28$, $\bar{x}=67\%$, SEM=2.8) than freshwater wetlands ($n=41$, $\bar{x}=42\%$, SEM=1.9). VAM colonization of plants sampled in early summer and late summer was not statistically different ($p > 0.54$) for both freshwater and saline wetlands. The lack of seasonal difference may have been caused by the very wet summer (1993) that prevented normal seasonal wetland drawdowns. The results of this study indicate that VAM fungi may increase a plant species' habitat range along the regional salinity gradient found in the northern prairie zone.

WESTOVER, KRISTI M., STEVEN E. KELLEY, and ANN C. KENNEDY. Washington State University, Pullman, WA 99164. The Consequences of Free-living Bacteria and Fungi for Plant Competitive Outcomes.

Plant competitive interactions occur in the context of abundant and diverse soil microbial populations. Our research has shown that rhizosphere populations of bacteria and fungi associated with co-occurring perennial plants collected in a mown field (Durham, NC) differed from each other with respect to substrate utilization, osmotic sensitivity, and antibiotic resistance. To measure the consequences of different rhizosphere microbial populations on plant competitive outcome, a field experiment was initiated in which two biotypes of both Anthoxanthum odoratum and Plantago lanceolata were planted in all possible pairwise combinations. The biotypes of Anthoxanthum and Plantago were ramets sampled from next to (1) Anthoxanthum, (2) Plantago. All were grown with each rhizosphere soil type (corresponding to the biotype pair combinations) treated in one of three ways; non-treated, steam-treated, or steam-treated with the addition of a non-treated inoculum. When planted in competition Anthoxanthum fitness (estimated using seed counts) was affected by a significant three way interaction between Anthoxanthum biotype, soil rhizosphere type, and soil treatment, suggesting that the soil rhizosphere type may be affecting plant fitness. Fitness was also significantly affected by an interaction between the competitor biotype and the soil rhizosphere type. The outcome of competition in nature is likely to be the result of complex interactions between the genetic composition of plant populations and the species and genetic composition of the soil rhizosphere bacteria and fungal communities.

WHITBECK, JULIE L. Pennsylvania State University, University Park, PA, 16802, USA. Vesicular-arbuscular mycorrhiza response to crossed carbon and phosphorus resource gradients.

Employing the annual herb *Hemizonia luzulaefolia*, native to nutrient limited grassland ecosystems in California, and a community of indigenous vesicular-arbuscular mycorrhizal (VAM) fungi, this study examined mycorrhizal response to interacting plant- and fungus-acquired resources. Plant carbon supply was manipulated through atmospheric carbon dioxide (CO_2) concentration, and substrate phosphorus (P) supply was varied in the nutrient solution. *H. luzulaefolia* responded strongly to VAM association, showing increased root and shoot biomass, greater leaf area, higher shoot P content and lower specific root length relative to non-mycorrhizal plants. Elevated (700 ppm) CO_2 plants had lower root mass, lower root:shoot ratios and slightly greater specific root length than ambient pCO_2-grown plants. VAM colonization of roots was stimulated by elevated CO_2 early in the experiment. Low P plants showed greater leaf mass per area and lower shoot P concentration than plus-P plants. P effects on measures of VAM changed over time.

While ambient pCO_2-grown plants responded to added P with increased biomass, plants grown at elevated CO_2 showed equivalent or lower biomass in plus-P treatments than in those with no added P. At the same time, ambient pCO_2-grown plants developed greater VAM colonization of roots in low P treatments, while at 700 ppm CO_2 VAM colonization was higher in plus-P treatments. It appears that atmospheric pCO_2 affects patterns of belowground allocation in *H. luzulaefolia* : ambient pCO_2 plants direct carbon resources to VAM when P is low and to roots when P is available, while elevated CO_2 plants maintain VAM colonization regardless of P environment and allocate to roots when P is low.

WHITE, DAVID A. Loyola University, New Orleans, LA, 70118, USA. Woody vegetation of tropical lowland deciduous forests and Mayan ruins on the north-central Yucatan Peninsula, Mexico.

Five forest and two Mayan ruin sites (50 - 100+ years old) within the dry tropics of the northern central Yucatan Peninsula, Mexico were sampled. Of the 155 species found 81 had a DBH $\geq$ 3.0 cm. Their distribution across the peninsula correlates with precipitation patterns. Analysis by ordination clearly distinguishes the forest from the ruin sites. The average woody basal area for the sites is 20.2 m^2/ha for forest and 28.2 m^2/ha on ruins. The average density is 3344 stems/ha in forests and only 1432 stems/ha on ruins. The Shannon-Weaver diversity index ranges from 1.76 to 2.25 in forests to 0.94 to 1.25 on ruins. Important ubiquitous forest species are Bursera simarouba, Thouinia paucidentata, Piscidia piscipula, Gymnopodium floribundum, and Caesalpinia gaumeri. Leguminous species are more common in the drier western forests and are rare on the ruins. The Mayan ruin sites are uniquely dominated by Brosimum alicastrum in the overstory and Croton lundelii in the understory.

WHITE, PETER S. University of North Carolina, Chapel Hill, NC, 27599, USA. Will the real species-area relation please stand up: revisiting scale dependence and the species-area relation in conservation biology and the southern Appalachians.

The relation between species richness and area has been used in a variety of conservation applications, particularly in conservation planning and preserve design. The species-area relation is, however, one case of a more general problem: scale dependence in ecological systems. Recently, analysis suggests that scale can be treated more precisely by addressing the two components of scale: grain and extent. The 'area' of the species-area relation has often confounded the influences of species-grain and species-extent relations. Because of the frequent spatial autocorrelation in environment and historic influences, the species-extent relation will often produce a 'distance decay' of similarity: the farther apart two observations or preserves are, the less likely they are to share species. The tendency for distance itself to explain one component of the distribution of biological diversity suggests the importance of extensive networks of conservation sites to capture the initial species distributions and the range of site conditions needed to maintain biological diversity in the future. Spatial extent also is important to such important processes as dispersal, migration, and disturbance spread.

WHITEMAN, HOWARD H. Purdue University, West Lafayette, IN, 47907, USA and the Rocky Mountain Biological Laboratory, Crested Butte, CO, 81224, USA. Larval growth and facultative paedomorphosis in the tiger salamander, Ambystoma tigrinum nebulosum.

Facultative paedomorphosis in salamanders occurs when larvae respond to varying environmental conditions by either metamorphosing or retaining their larval morphology to become sexually mature paedomorphs. Several selection mechanisms have been hypothesized for the maintenance of this dimorphism. I tested these hypotheses by following larval growth and life history in a montane population of the tiger salamander, Ambystoma tigrinum nebulosum. In some ponds, larvae which became paedomorphic were significantly smaller than those which metamorphosed. Across all ponds, a higher proportion of larvae became paedomorphic in ponds with smaller mean body sizes, and larval density explained most of the variation in larval body size. These data support the "best of a bad lot" hypothesis, which predicts that larger larvae metamorphose to escape unfavorable aquatic growth conditions, while smaller larvae become paedomorphic as a best of a bad lot. These results contrast with those for other salamander species, and suggest that geographic variation has maintained facultative paedomorphosis through different selection mechanisms in different species.

WHITHAM, THOMAS G. and NANCY A. MORAN. Dept. of Bio. Sciences, Northern Arizona Univ., Flagstaff, AZ 86011; Dept. of Ecol. & Evol. Bio., Univ. of Arizona, Tucson, AZ 85721. Hybridization in cottonwoods may affect the evolution of simple and complex life cycles in the gall aphid, Pemphigus betae.

Because plant hybridization and its effects on resistance to herbivores can affect the distribution of diverse taxa, future studies need to consider how insect evolution might be affected. In areas where hybrid trees between Populus fremontii x P. angustifolia predominate, the gall aphid, Pemphigus betae, has a complex life cycle involving alternation between two hosts. It spends its sexual and overwintering phase on cottonwoods

and its summer, asexual phase on the roots of herbaceous hosts Rumex sp. and Chenopodium album. In contrast, in the zone where pure P. angustifolia predominate, the aphids often eliminate cottonwoods and the sexual phase from their life cycles. Experiments show that where aphids have eliminated cottonwoods from their life cycle, the trees are nearly twice as resistant as in the hybrid zone. Furthermore, this variation in aphid life cycle traits has a genetic component. These results suggest that the effects of hybridization on plant resistance influence the evolution of life cycle traits.

WHITMORE, MARK C., MARIANNE E. KRASNY, ALISON OFFERMAN, AND ANNA STALTER, Cornell University, Ithaca, NY, 14853, USA. Changes in forest tree gaps formed by American beech (*Fagus grandifolia*) and oak (*Quercus spp.*) over a four year period in central NY.

Forest gaps formed by trees with greater than 50% canopy deterioration (declining), standing dead trees, and fallen trees were studied from 1990 through 1993 in three central New York State forests. In 1990, 76% of the gaps in the study were caused primarily by American beech trees subject to beech bark disease (BBD, 45%) or oak trees killed by gypsy moth defoliation (GMD, 31%). BBD gaps were larger than GMD gaps in both 1990 (mean size of 264 m^2 and 166 m^2 for BBD and GMD respectively) and 1993 (mean size of 284 m^2 and 182 m^2 for BBD and GMD respectively), and BBD gaps grew at a faster rate (mean rate of 9.2%/yr and 3.2%/yr for BBD and GMD respectively). In 1990, 73% of the BBD and 91% of the GMD gap makers were declining or standing dead. By 1993, 29% of the 1990 BBD decline and standing dead gap makers had fallen over, whereas only 5% of the 1990 GMD decline and standing dead gap makers had fallen. These differences can be explained by the biology of the trees and the organisms causing decline or defoliation, and illustrate the importance of considering these factors when developing models of gap dynamics.

WIEDER, R. KELMAN and SCOTT T. STARR. Villanova University, Villanova, PA, 19085, USA. Organic matter quality depth profiles in northern (Ontario, Minnesota) and southern (Pennsylvania, West Virginia) *Sphagnum* peat deposits.

Southern peat deposits, such as those along the Appalachian Mountains, generally are fewer, smaller, older, and shallower than their boreal counterparts. Southern peatlands have developed under historically warmer climatic conditions than northern peatlands. Hence, comparisons between northern and southern peatlands may provide insights into potential functional changes in boreal peatlands under predicted scenarios of global climate change. Depth profiles in organic matter quality were compared in peat cores collected from the Experimental Lakes Area, Ontario, the Marcell Experimental Forest, MN, Tamarack Swamp, PA, and Big Run Bog, WV; these sites span a present-day mean annual temperature range of 5.8 °C. At all sites, lignin concentrations (ash-free basis) increased with depth, while holocellulose, α-cellulose, and acid-soluble carbohydrate concentrations decreased with depth; depth patterns for hemicellulose and for soluble carbohydrates, phenolics and proteins were not consistent across all sites. Canonical discriminant analysis indicated that the peatland sites were distinguishable. Compared to northern site peat, southern site peat tended to have lower concentrations of holocellulose, α-cellulose, water-soluble and acid-soluble carbohydrates, but also higher total N and lower C/N and lignin/N ratios. Northern peat may be more susceptible to enhanced decomposition under predicted warmer temperatures than southern peat, but temperature effects may be confounded by regionally high atmospheric N deposition which also could enhance peat decomposition.

WIELINGA, PETER, GUY B. THOMPSON and BERT G. DRAKE. Smithsonian Environmental Research Center, Edgewater, MD 21037, USA. Dark respiration of CO_2 and C_4 high marsh perennials is modified by atmospheric CO_2 concentration during growth in open top chambers.

Dark respiration (R_d, CO_2 efflux) was studied in Scirpus olneyi (C_3) and Spartina patens (C_4) grown in open top chambers and exposed to normal ambient or elevated CO_2 (=normal ambient +340 ppm). R_d measured on detached shoots of both species at different CO_2 concentrations (C_a) decreased reversibly as C_a increased. The C_a during growth had a long-term effect on the C_3 sedges, Scirpus olneyi: R_d measured at constant C_a was higher in plants grown in elevated CO_2 than in those grown in normal ambient CO_2 only during the first 24 days of growth and during the remainder of the season it was the same or less.

WILKENS, RICHARD T., STEPHEN HALBREICH, GABRIEL O. SHEA, and NANCY E. STAMP. Binghamton University, Binghamton, NY, 13901, USA. Resource availability affects the glandular trichome defense of tomato plants.

We conducted two experiments to determine how resource availability influences the glandular trichome defense of tomato plants. In the first experiment, we grew plants under two light conditions and two water conditions (high and low). We collected several leaf discs and stem sections from basal, intermediate, and apical portions of each plant. Then using scanning electron microscopy, we measured glandular trichome density. We found that plants grown in high light or high water conditions had leaves and stems with significantly denser trichome growth. Apical leaves and basal portions of the stem had more densely packed glandular trichomes, whereas basal leaves and apical portions of the stem had sparser glandular trichome growth. In the second experiment, we did a short-term behavioral experiment to determine how glandular trichomes influenced the movement and behavior of first and third instars of tobacco hornworm caterpillars. We tallied the behaviors and movement rate of caterpillars traversing 12cm stem sections with glandular trichomes present or removed. Glandular trichomes were a significant impediment to the caterpillars' movement rate (particularly first instars) and also altered their behavioral patterns. These studies demonstrate that: 1) plant allocation to physical defenses are influenced by resource availability, 2) there is large within plant variation in glandular trichome density, and 3) these changes in glandular trichome density can influence caterpillar behavior and movement.

WILKER, JOHN R. and BETH A MIDDLETON Southern Illinois University at Carbondale, Carbondale, IL, 62901, USA. Seed density patterns within an alluvial cypress-Tupelo swamp in southern Illinois.

Seed dispersal by water, hydrochory, is directional with respect to water current speed and direction, but has been shown to be affected by water surface currents as well as emergent stems. Spatial patterns of vegetation affect the dispersion of seeds across the water surface. Wind currents are the most important cause of seed movement for seeds such as bald cypress (*Taxodium distichum* (L.) Rich.), water tupelo (*Nyssa aquatica* L.) and buttonbush (*Cephalanthus occidentalis* L.). The hypothesis that seed dispersion over the water sheet is non-random and affected by the independent variables of; water and wind direction and speed, emergent stem density, amount of *Lemna* coverage and seed rain was evaluated by collecting floating seeds and all independent variable values along 5 transects at permanent locations and mapping them using the Kriging process with a geostat spatial analysis program.

WILLIAMS, DAVID G. and JAMES R. EHLERINGER. University of Utah, Salt Lake City, UT, 84112, USA. Patterns of water use by aridland trees along a summer precipitation gradient.

Climate change models predict an intensification of the Arizona summer monsoon that could potentially alter patterns of water use and productivity in aridland vegetation. Using *Pinus edulis* (Colorado pinyon) and *Juniperus osteosperma* (Utah juniper) we tested the hypothesis that use of summer rains along a broad summer precipitation gradient depends on the long-term average proportion of total precipitation received in summer. D/H isotope ratios of xylem water were compared to that of potential water sources (i.e., summer rains and ground water) throughout the growing season to quantify the use of summer rains by these trees. Populations of *Pinus* and *Juniperus* in Utah where the summer monsoon is typically weak did not take-up moisture from summer rains; D/H of xylem water indicated exclusive use of ground water in these populations despite significant inputs of summer moisture into surface soil layers. Populations in Arizona , however, shifted to complete reliance on summer moisture following summer rains indicating that individuals in these populations maintain a functionally dimorphic rooting pattern throughout the summer. Our data suggest that the use of summer precipitation along a continuous summer precipitation gradient follows a step function where a threshold summer moisture input is required for the expression of a functionally dimorphic root system in these trees.

WILLIAMS, E.H. Hamilton College, Clinton, NY, 13323, USA. Taxonomic vs. phytochemical definitions of dietary specialization for two butterflies.

When one herbivore uses multiple species as hostplants and a second herbivore uses only one plant species, the first is always said to be more generalized in diet than the second. This description applies to two nymphalid butterflies, *Phyciodes tharos* and *Chlosyne harrisii*; both oviposit on *Aster* exclusively, with 13 reported hostplants for *P. tharos* but only 1 for *C. harrisii*. A different interpretation of diet was suggested by phytochemical studies and feeding experiments that measured growth, consumption, and feeding efficiencies of larvae on leaves of five different *Aster* species and on artificial diets with plant extracts. The plants were easily grouped into three different phytochemical classes, and larvae of each butterfly species grew best on plants from one of these chemical classes. One class, that with the sesquiterpene germacrene D, includes more plant species, so the herbivore that grows best on this phytochemical class has a longer list of potential hostplants. When specialization is defined by the chemical classes of their hostplants, there is no difference in the degree of specialization between these two herbivores. Phytochemical specialization, which is likely more important to herbivores, is not the same as taxonomic specialization.

WILLIAMS, ERNEST H. Hamilton College, Clinton, NY, 13323, USA. Collaborative environmental education using the Utica, NY, Marsh.

A collaborative project in Utica, NY, among diverse environmental educators has been fruitful in both process and product. The project was to promote environmental education in public schools by focusing on activities at a local marsh. The collaborating individuals represented different teaching levels, including four-year and community college faculty, junior high and elementary teachers, a cooperative extension agent, and state environmental employees. The most tangible product was a manual that provides information and serves as a teacher's guide to the marsh; in addition, the manual has been used for continuing workshops that promote outdoor environmental education. As a result, there is increased use of the marsh and enhanced environmental awareness within schools of the Utica area. This project illustrates: (1) the value of collaboration in environmental education; (2) useful ways to help adult leaders feel comfortable and knowledgeable with environmental information; (3) the importance of providing school-age children first-hand experience outdoors. This approach and some of the specific results are transportable to other cities.

WILLIAMS, KATHY S. San Diego State University, San Diego, CA, 92182, USA. Terrestrial arthropods as indicators of riparian habitat restoration in southern California.

Terrestrial arthropods were used to evaluate the progress of riparian habitat restoration in southern California. Arthropods were sampled at reconstructed sites and natural or reference habitats using pan traps and sweep nets and communities were compared to evaluate the establishment and maintenance of critical processes. Abundances of assemblages of taxa were used to monitor ecosystem processes, such as pollination, herbivory, predation, and quantify potential prey of endangered birds. Over 300,000 arthropods were identified to order or family. Although after 4

yr, abundances of arthropods remained lower at reconstructed sites than at reference sites, at least for riparian habitats, the same orders were present in proportions similar to reference sites. However, outbreaks of certain insects indicated plant stress and the possible lack of predator or parasite establishment. Insects and allied taxa may be valuable indicators of restoration success and provide early warnings of potential management problems.

WILLIAMS, KIMBERLYN and MICHELINA R. MACDONALD. University of Florida, Gainesville, FL, 32611, USA. Immediate and projected long-term effects of a large storm-surge, an infrequent episodic event, on the rate of coastal forest decline on the Gulf Coast of Florida.

Forest death along the coastal margins of north-central Florida has been attributed to sea level rise. Periodic storms and hurricanes extensively damage the coastal forest, but the extent to which these catastrophic events interact with sea level rise to cause permanent forest loss is unknown. A storm surge that occurred in March 1993 provided an opportunity to study such effects. Nine 20x20 m forested plots at Waccassassa Bay State Preserve were censused during the spring of 1993. All trees and tree seedlings within the plots were tagged and measured. One week after the plots were censused, the site experienced a 2-4 m storm surge. We measured depth of silt and litter deposition and noted tree damage within the plots one week after the storm. We recensused plots one year later. Many trees in previously healthy stands were uprooted and young seedlings were killed. However, saplings sustained little damage. Sapling resilience and the deposition of soil-building material suggest that effects may be transient and may perhaps even slow rates of forest death due to sea level rise.

WILLIAMS, RAY S. and DAVID E. LINCOLN. University of South Carolina, Columbia, SC 29208, USA. Potential effects of global change on an important plant-insect interaction: White Oak and Gypsy Moth.

As atmospheric CO_2 rises, the interactions between tree species and herbivorous insects may be altered due to changes in leaf quality. In two experiments, a widespread, important insect pest of oaks, Gypsy Moth, was fed White Oak grown under three levels of CO_2, one ambient and two elevated ($+150\ \mu l\ l^{-1}$ and $+300\ \mu l\ l^{-1}$). For the first experiment, second instar larvae were fed young, expanding foliage, while fifth instar larvae received older, mature foliage. The early instar larvae responded with a significant reduction in relative growth ($P<0.02$) on elevated CO_2 grown plants, while neither relative consumption or growth efficiency were different between treatments. There were no significant differences in insect performance for the older larvae on mature leaves. In the second experiment, larvae were reared from first instar to pupation on leaves from the three treatments. Although female pupal weight declined in insects feeding on the plants grown under elevated CO_2 growth conditions, the effect was non-significant. Developmental rate was also not related to treatment conditions. These experiments suggest that although some negative effects on this important herbivore may be expected, overall there are no substantial deleterious effects and that future elevated CO_2 atmospheres may not alter this important tree-herbivore interaction.

WILMOTH, M. SUZANNE and WILLIAM G. EICKMEIER. Vanderbilt University, Nashville, TN, 37235, USA. Photosystem II function and desiccation in a desiccation-tolerant pteridophyte.

We examined photosystem (PS) II electron transport as a function of hydration level in the resurrection plant Selaginella lepidophylla. Electron transport in PS II-enriched thylakoid vesicles was measured with the artificial electron acceptor 2,6-dichlorophenol-indophenol. Alkaline Tris treatment was used to remove extrinsic oxygen-evolving complex (OEC) proteins and the artificial electron donor 1,5-diphenylcarbazide (DPC) was used to evaluate PS II integrity beyond the OEC. Electron transport increased in a time-dependent manner and reached maximal levels after 96 h of hydration. PS II preparations from fully desiccated plants had electron transport rates equal to 33% of fully hydrated control preparations. Tris treatment largely abolished electron transport (to 5% of control levels) for both desiccated and hydrated plants. The addition of DPC increased electron transport in desiccated, Tris-treated preparations only to a level equivalent to that for desiccated, non-Tris-treated preparations (33% of controls as above) and did not fully restore maximal electron transport. Thus detachment of OEC extrinsic proteins from the PS II core alone cannot explain the desiccation-induced decline in photochemical function. Temporary disruption of the reaction center, however, may be substantial following desiccation.

WILSEY, BRIAN J. and SAMUEL J. MCNAUGHTON. Syracuse University, Syracuse, N.Y., 13244, USA. Effects of C-additions on ecosystem processes in the Serengeti: the role of grazing mammals and implications for global change research.

Increases in atmospheric CO_2 are predicted to cause an increase in the C:N ratio of plant substrates entering the soil organic matter pool. We experimentally increased soil C:N ratios by adding 40 g C/m^2 as sucrose (metabolic C) or cellulose (structural C) in short-, mid-, and tall-grass plots in the Serengeti Ecosystem, and measured plant productivity, plant nutrient uptake rates, and mineralization rates. Experimental treatments also included fencing to exclude grazing and additions of 40 g N/m^2 as urea to simulate a urine hit from an average-sized ungulate. Productivity was only 60% of controls in C-addition plots, and was similar for sucrose and cellulose. However, this response was not observed in the short-grass site, an area of relatively low rainfall and high fertility. These results support the role of a plant-microbe negative feedback mechanism on plant growth in which increased C to microbes results in increased immobilization, reduced plant uptake, and lowered plant growth.

WILSON, CARLOS A., and H. LEE ALLEN. North Carolina State University, Raleigh, NC, 27695, USA. Nitrogen mineralization in a coastal plain forest soil following compaction and organic matter removal.

The interactive effects of soil compaction and organic matter removal on nitrogen mineralization, soil temperature and moisture were studied during the second growing season following the harvest of a pine forest on the Coastal Plain of North Carolina. The treatments strongly influenced soil temperature and, to a lesser degree, soil moisture conditions. Despite these effects, in situ incubations did not reveal significant differences in net mineralization between treatments and the amounts of inorganic N were generally low attesting to the relative infertility of the site. Likewise, laboratory incubations failed to demonstrate any appreciable effects of the treatments on specific N mineralization. Total pools of N did not change notably throughout the season. These results suggest that the residual organic substrate in the soil was already fairly recalcitrant by the second year, reducing amounts of available N and lowering the rates of N turnover in the soil.

WILSON, CATHLEEN J. and ROBIN S. REID. International Laboratory for Research on Animal Diseases (ILRAD), P.O. Box 30709, Nairobi, Kenya. Ecological consequences of controlling the tsetse fly in southwestern Ethiopia: influence of land cover/land-use on bird species richness.

Successful control of tsetse-transmitted trypanosomiasis in Ghibe Valley, Ethiopia, appears to accelerate conversion of woodland/grassland into cropland. Land conversion, in turn, may fragment wildlife habitat. Our objective was to assess the influence of different land cover/land-use types on bird species richness under different levels of conversion. We sampled bird species richness (using timed-species counts) and habitat structure (using ground surveys, remote sensing and GIS) in four land cover/land-use classes, in tsetse control and non-control areas. Across all sites there was no significant difference in bird species numbers between tsetse control and non-control areas. However, at peak vegetative growth, bird species numbers and vegetative complexity were greater in the small-holder, oxen-plowed fields and riparian woodlands than in woodland/grasslands or in tractor-plowed fields. These results suggest that moderate land-use by humans (e.g., small-holder field mosaics) increases habitat heterogeneity and bird species richness but that high levels of use (e.g., tractor-plowed fields) reduce habitat complexity and thus bird species richness. This implies that trypanosomiasis control that causes land conversion from woodland/grasslands to small-holder farming in this region may have no adverse impacts on bird biodiversity.

WINNER, WILLIAM E.[1], KEVIN L. GRIFFIN[2], RICHARD B. THOMAS[2], BOYD R. STRAIN[2] and J. TIMOTHY BALL[3]. [1]Oregon State University, Corvallis, OR, 97331, USA, [2]Duke University, Durham, NC, 27708, USA, and [3]Desert Research Institute, Reno, NV, 89506. Differences between loblolly pine and ponderosa pine responses to elevated CO_2 partitioned between biological and environmental factors.

Loblolly pine raised at the North Carolina field site and Ponderosa pine raised at the California field site show differences in their capacity to grow and sequester carbon. The contrast in CO_2 responses between species is related to both environmental differences between the field sites as well as biological differences between Loblolly and Ponderosa pine. We designed an experiment to isolate the biological differences between CO_2 responses of the 2 test species by raising them in common environments at the Duke University Phytotron. Both pine species were raised for 160 days in either 35 Pa or 70 Pa CO_2. Plants were also raised at 3 levels of N since N is known to affect CO_2 responses of plants. Seedlings were raised in 3.3 l pots filled with sand irrigated each morning with 1/2 strength Hoaglands solution made with N supplied at NH_4 at either 1 mm, 3.5 mm, or 7 mm. Root, stem, and foliar biomass, whole plant biomass, and leaf area were similar for both species across all CO_2 and N treatments at the final harvest. Thus biological differences between pine species responses seem to be small and N is not the environmental factor accounting for differences in CO_2 responses observed at tghe 2 field sites. Small biological differences between Loblolly and Ponderosa pine may be difficult to detect in experiments with seedlings, but scale to important differences between species as trees mature or when forest stands are considered.

WINSOR, JAMES A. and MAGNUS JOHANNSSON. Penn State University, Altoona, PA, 16601, USA and Penn State University, University Park, PA, 16802, USA. Genetic and environmental factors affecting pollen tube growth in Cucurbita spp.

We conducted in vitro pollen growth experiments to determine the effect of developmental and germination temperature on Cucurbita pepo, C. texana and F_1 hybrids. Pollen donors were grown at 20°C or 30°C. Pollen was then germinated on an agar medium at each of the two temperatures resulting in four treatments for each Cucurbita line. Growth rate was measured with an image analyzer. The effect of germination temperature on pollen tube growth was highly significant for all lines. At 20°C, growth rate increased 20% in C. pepo, more than 80% in C. texana, and 40% in the hybrid. The 20°C developmental temperature significantly increased growth rate in C. texana but not in C. pepo or the hybrid. The response in C. texana may reflect the relatively cool temperatures experienced just prior to anthesis. Also, pollen tube growth rate was both greater and more variable in the F_1 hybrid than in either parental line. Hybrid vigor of sporophytic traits in the pollen could explain this effect.

WINSTEAD, JOE E. Western Kentucky University, Bowling Green, Ky. 42101, USA. Integrating state of Kentucky's environment in K-12 ecology education.

Capitalizing on the 332 page State of Kentucky's Environment: A Report of Progress and Problems published by The Kentucky Environmental Quality Commission (EQC) in 1992, the EQC established a task force to develop a teacher's guide to accompany the report for distribution to all middle and high school science

teachers. The guide includes over 30 hands-on activities specific to Kentucky. Major topics include water resources, air quality, hazardous and solid wastes, toxics, agriculture, forestry, natural areas, threatened and endangered species, coal mining and energy. A prime focus of the guide is to meet mandated education reform which includes activity based learning experiences and to allow the state communty to view the environment in a holistic manner. As expected, vested economic groups have been critical.

WISE, SHARON E. and HENRY M. WILBUR. University of Southwestern Louisiana, Lafayette, LA, 70504, USA and Mountain Lake Biological Station, University of Virginia, Charlottesville, VA, 22903, USA. The effect of tail-autotomy on competition in the red-backed salamander, Plethodon cinereus.

Relative body size and territorial ownership can affect the outcome of competitive interactions in territorial species. In territorial species that utilize autotomy of body parts (such as the tail in salamanders) as an antipredator response, autotomy may lead to a decrease in the ability of residents to defend, or intruders to usurp territories. We used field enclosures to investigate the influence of relative body size (snout-vent length), presence or absence of a tail, and territorial ownership on growth in a territorial species of salamander exhibiting tail autotomy (Plethodon cinereus). After three months, regardless of the relative body size of residents and intruders, no change was found in body size or mass of intruders or in body size of residents, but residents did gain more mass when they were tailless. Additionally, when residents were much smaller than intruders in body size, tail regeneration by residents was hampered when intruders were tailed rather than tailless. Thus, tail loss seems to affect growth in residents, but not intruders.

WISHEU, IRENE, C. and PAUL A. KEDDY. Department of Biology, University of Ottawa, Ontario, Canada, K1N 6N5. Patterns of diversity along environmental gradients: testing three competing hypotheses using eastern North American wetlands.

There are at least three models of community organization that make predictions about how species richness will vary along environmental gradients. The centrifugal organization model, which describes changes in community composition along multiple resource gradients, predicts maximum diversity within low biomass habitats. The species pool hypothesis, which links diversity with opportunities for speciation, predicts that maximum diversity will occur within intermediate biomass communities. The productivity hypothesis, which correlates diversity with productivity and resource levels, predicts that high biomass communities will be most species rich. To test among these three hypotheses, biomass/species composition data were collected from 37 eastern North American wetlands. The resulting 628 data points produced a pattern of diversity inconsistent with the productivity model. The critical test needed to distinguish between the centrifugal organization model and the species pool hypothesis has been designed and is underway.

WITH, KIMBERLY A., ROBERT H. GARDNER, AND MONICA G. TURNER. Environmental Sciences Division, Oak Ridge National Laboratory, Oak Ridge, TN 37831-6038. Impact of landscape structure on the spatial dynamics of populations.

A spatially explicit simulation model was developed to determine the effect of landscape structure on the patterns of dispersion of animal populations. Landscape structure was simulated as a simple random or fractal distribution of 3 habitat types. Animal movement occurred at random based on the expected residence probability within a particular habitat type, the dispersal distance (maximum number of cells moved) for that species, and the carrying capacity of the habitat. Populations were more fragmented in the fractal landscapes than in the random ones. The most complex spatial dynamics occurred in fractal landscapes when the rare (10%) or moderately abundant (30%) habitats had the highest carrying capacity and were preferred by each species. Variation in dispersal distance affected the spatial dynamics of populations in fractal landscapes, but had little effect in simple random landscapes. Analysis of these spatially explicit models provides an important tool for characterizing the landscape effect of species responses to habitat heterogeneity.

WOHLENBERG, MARGARET A. and MARK E. HAY. University of North Carolina,Chapel Hill,NC, 27599, USA. Grazer/nutrient interactions in control of a temperate reef benthic community.

Nutrient and grazing regimes have been postulated to influence benthic community structure in both temperate and tropical reefs. We conducted a two-way factorial field experiment manipulating grazing and nutrients in a North Carolina temperate reef community where we monitored change in seaweeds and growth of the coral, *Oculina arbuscula*. Grazers had little influence on total standing stock of seaweeds, but they did cause a shift in species composition from primarily red to brown algal species. Grazers did have a significant effect on coral growth. The main effect of nutrient addition in this experiment was not significant per se, but there was a significant interaction of grazing and nutrients. These results support the notion that temperate seaweeds are less nutrient limited than their tropical counterparts and suggest that red and brown algae may differ in their degrees of nutrient limitation and in their competitive effect on corals.

WOOSTER, DAVID E. and ANDREW SIH. University of Kentucky, Lexington, KY 40506, USA. Effects of invertebrate and vertebrate predator presence on prey dispersal in streams.

In streams invertebrate predators have significantly greater impacts on invertebrate prey density than vertebrate predators. We present a model that partitions the impact that predators have on local prey density into two components: 1) prey emigration response to predators and 2) mortality due to predation. Our model suggests that when predator consumption of prey is low, prey emigration responses alone can generate large predator impacts. A review of 24 studies showed that invertebrate predators induce an increase in prey emigration significantly more often than expected. However, for vertebrate predators, no clear pattern emerges in their impact on prey emigration. Thus the greater impact that invertebrate predators have on prey density may be a function of the increase in prey emigration from invertebrate predators. A detailed analysis of data from two studies indicates that prey emigration response to invertebrate predators accounts for 54% of the variability in predator impact; however, there was no correlation between prey emigration response to vertebrate predators and predator impact. We suggest several avenues for future research in which both invertebrate and vertebrate predators are manipulated and prey emigration responses to predator presence are measured.

WRAY, FRANCIS P. University of Kansas, Lawrence, KS, 66045, USA. Are skewed juvenile sex ratios of the prairie vole (Microtus ochrogaster) a consequence of maternal condition?

Evolutionary theory predicts that natural populations should produce a 1:1 sex ratio if sons and daughters 'cost' the same in terms of parental investment. However, research shows that animals indeed vary the sex ratio under certain conditions (e.g. resource competition, maternal condition) and one of two contrasting theoretical models is most often applied to these findings. Unfortunately, the models themselves have not been rigorously tested. Both of the models base their assumptions on the physical condition of the mother. I used the prairie vole (Microtus ochrogaster) to test these models. In the study I released male and female voles into 12 same size enclosures, 4 each containing low, medium, and high densities (numbers of voles). The study consisted of 3, 12-14 week experimental replicates. The results revealed high density enclosures contained females in poor condition and male biased juvenile sex ratios while low and medium density enclosures had females in good condition and sex ratios differed little from parity. The results agree with an adaptive model based on local resource competition. However a more generalized model explains the results equally as well. It is suggested that if this generalized model is used as a null model rather than other restrictive models, we may indeed demonstrate adaptive trends in sex ratio variation in mammals.

Wu, Lin and Hong Lin. Department of Environmental Horticulture, University of California, Davis CA 95616. Salt tolerance and salt uptake of three buffalograss (*Buchloe dactyloides*) races.

Diploid, tetraploid, and hexaploid buffalograsses were collected from Central Mexico and the shortgrass prairie of New Mexico and Oklahoma of the United States. Seed samples were tested for salt tolerance in nutrient solution culture. Rates of seed germination and seedling establishment were severely reduced under 50 mM salt (NaCl). Established and vegetatively propagated clones were more tolerant up to 150 mM salt. Root growth was less inhibited by high salt concentration and high Na^+/K^+ ratios than the shoot growth. Salt tolerance was not found to be different among the three races and the populations. However, distinct difference in salt tolerance was detected among individual plants within the populations. This result suggests that salt tolerance in buffalograss seems not to be a cost for the natural populations and a rapid evolutionary change may occur if a selection pressure for salt tolerance operates upon the buffalograss populations of the three races.

WULLSCHLEGER, S.D., BALDOCCHI, D.D., KING, A.W. and POST, W.M. Oak Ridge National Laboratory, Oak Ridge, TN, 37831, USA and National Oceanic and Atmospheric Administration, Oak Ridge, TN, 37831, USA. Models - Another tool for use in global change research.

Models are increasingly being used in the plant sciences to integrate and extrapolate information derived from laboratory and field investigations. To illustrate the utility of models in global change research, a series of leaf, canopy, ecosystem, and global-scale models are used to explore the response of trees to atmospheric CO_2 enrichment. A biochemical model highlights the effects of elevated CO_2 and temperature on photosynthesis, the consequences of Rubisco down-regulation to leaf and canopy carbon gain, and the relationships among stomatal conductance, transpiration, leaf area, and canopy energy balance. A forest succession model examines the effects of CO_2 on species composition and forest productivity, while a model of the global carbon cycle illustrates the effects of rising CO_2 on terrestrial carbon storage and the interaction of this affect with temperature. We conclude that models are appropriate tools for use both in guiding existing studies and in identifying new hypotheses for future research.

WURTSBAUGH, WAYNE.A., HOWARD P. GROSS, CHRIS LUECKE, PHAEDRA BUDY, GEOFF STEINHART and THORSTON BLENCKNER. Utah State U., Logan, UT 84322-5210, USA. Effects of surface and deep lake fertilization on the epilimnetic and metalimnetic phytoplankton and periphyton communities.

Using 340-m^3 mesocosms we experimentally tested how nutrients added to the epilimnions and metalimnions of oligotrophic mountain lakes would affect their phytoplankton and periphyton communities. Surface N and P additions stimulated chlorophyll, algal biomass, and primary

productivity of the phytoplankton in the epilimnion significantly over controls. The surface additions also increased periphyton chlorophyll levels 10-500 times above control levels at depths < 5 m. Deep fertilizations enhanced productivity and algal biomass equally or greater than surface fertilization, but the effects were manifested primarily in the metalimnion. Hence, the deep fertilizations appear to increase productivity while minimizing aesthetic problems of reduced water clarity and periphyton scums. This procedure may thus prove useful for recovery of endangered sockeye salmon in pristine mountain lakes.

XU, ZHAORAN* and DONALD P. KELSO, GAYLE MARCELLA, L. KAY THOMAS, JR. (* All the cited authors are equal in referring to this paper). Department of Biological Sciences, The University of Alabama, Tuscaloosa, AL 35487, USA. A Study of the Historical Changes of Wetland Vegetation in Dyke Marsh by Utilizing the GIS Technology.

The technology of Geographic Information System (GIS) is used to identify the historical changes of wetland vegetation in Dyke Marsh, Fairfax, Virginia, USA. Different vegetation types are digitized from the aerial photos taken in 1958, 1976 and 1991. The result shows that Dyke Marsh lost 159 acres (37%) of vegetated wetlands between 1958 and 1976, and another 15 acres (6%) between 1976 and 1991. Study of the changing patterns of certain vegetation types reveals that muskrats must have been populated in this area in the history of Dyke Marsh, but the animal has disappeared in recent decades. This implies that a major alteration of the ecosystem in Dyke Marsh has happened in recent decades, which may be a direct result from certain environmental impacts related to human activities. The wetland ecosystem in Dyke Marsh is a vigorous system, in which natural succession of the vegetation has been observed in a relatively short time, though the Cat-tail community, being a climax vegetation, remains relatively stable. Convincing data are presented to prove that the technology and the methodology used in this study may be a reference to similar studies.

YANKOVICH, TAMARA L., JUREK KOLASA, and R. DOUGLAS EVANS. Watershed Ecosystems Graduate Program, Trent University, Peterborough, Ontario, K9J 7B8, Canada and Dept. of Biology, McMaster University, Hamilton, Ontario, L8S 4K1, Canada. Categorization of tropical intertidal pools using physical parameters as environmental indices for trophic status.

Aspects of the physical environment (i.e., dissolved oxygen, light availability, pH, salinity, conductivity, temperature, and basin volume and depth) can be used as indices to predict primary productivity and possibly community structure of a system. This assumption was tested using erosional coastal rock pools as a model system. Seventy Natural and 18 Artificial intertidal pools were sampled between 29 Dec. 1991 and 11 Jan. 1992 at Discovery Bay Marine Laboratory, Jamaica. Measurements of the variables listed above were compared to those in previous years. Water samples were randomly collected from undisturbed pools to assess diversity, density, and pigment proportions of suspended algae. For benthic phytoplankton, a 5x5 cm frame was randomly thrown into each pool and the rock area scraped to remove all benthic algae. Pools were then stirred to suspend the phytoplankton which was then sampled. The difference in pigment concentration represented the contribution of benthic algae. We used the results to devise a system of categorization for the pools with reference to pool physical parameters and productivities.

YANOSKY, THOMAS M., and JOHN K. CARMICHAEL, U.S. Geological Survey, Reston, VA, 22092, USA. Concentrations of elements within rings of flood-plain trees in western Tennessee, USA.

Concentrations of some nutrients and trace metals were determined within individual growth rings of sycamore, silver maple, and green ash trees sampled along the South Fork Forked Deer River in western Tennessee. Sycamores from frequently flooded surfaces generally contained greater concentrations of total P, Ca, K, and Fe than did sycamores from less frequently flooded surfaces; P was strongly translocated from inner to outer rings and was most highly concentrated near the cambium. Concentrations of nutrients in silver maples and ash trees did not seem related to flooding regime. The relative storage of elements in rings was estimated by weighting raw concentrations by ring area. This permitted an estimate of the relative amount of storage between inner and outer rings of a tree. For example, the concentrations of P were 223 and 2,450 ppm, respectively, within the 1976 and 1990 rings of a frequently flooded sycamore that began growth in 1970; however, the 1990 ring contained approximately 20-fold more P than did the 1976 ring, and accounted for an estimated 30% of total P in rings. These data could be used in conjunction with estimates of ring volumes to calculate the approximate total storage of elements within trees.

YARD, MICHAEL D., LAWRENCE E. STEVENS, ALLEN G. HADEN, DEAN W. BLINN, AND WILLIAM VERNEIU. Glen Canyon Environmental Studies, P.O. Box 22459, Flagstaff, AZ 86002, and Northern Arizona University, Flagstaff, AZ 86011. Light attenuation, sediment concentration and fluvial ecosystem responses in the regulated Colorado River, Grand Canyon, AZ.

Photosynthetically available radiation (PAR) affects benthic production in the Colorado River and is limited by suspended sediment load (SSL). PAR and SSL vary temporally and spatially, as a result of tributary discharge, flow regulation, distance from the dam, and reach geomorphology. Attenuation coefficients ranged from 0.238 (0.0022 g/L) to 26.217 (1.0241 g/L). Sediment discharge reduces total annual PAR by 70% below the Paria River (km 27), reducing benthic standing crop by 90%; PAR further decreases to 80% below the Little Colorado River

(km 126). Under optimum clarity (tributary baseflow) the compensation point for Cladophora glomerata at constant mainstream flows of 140 and 425 $m^3 \cdot s^{-1}$ ranged from 19.4 m to 17.6 m at the dam (respectively), and 6.3 m to 4.1 m (respectively) 388 km downstream. Fifty percent of the entire river bed is unavailable for Cladophora at discharges ≥ to 425 $m^3 \cdot s^{-1}$, a flow exceeded 70% of the days under normal dam operations.

YEAGER, P.E. and K.L. DICKSON. University of North Texas, Denton, Texas, 76203 USA. The interrelationship of macrobenthos, microbial communities and sediment character.

The dynamic relationship between the macrobenthic community, sediment character (particle size, organic matter content), microbial density and activity were analyzed to determine specific relationships. Pairwise correlation analysis and multivariate statistical techniques including cluster analysis, bootstrapping, cophenetic correlation, and multiple regression analysis were employed in an attempt to understand these relationships. Several relationships were detected between the macrobenthos, sediment character, and microbial density and activity of alkaline phosphatase, ß-glucosidase, ß-galactosidase. Significant ($\alpha = 0.10$) correlations were seen between macrobenthic distribution, sediment character and microbial parameters. Cluster analysis indicated two distinct macrobenthic communities related to sediment character, but not to microbial density or activity.

[1]YIN, YAO and [2]JOHN NELSON, [1]National Biological Survey, and [2]Illinois Natural History Survey. Changes in forests on the Mississippi River floodplain in southern Illinois.

We examined changes in floodplain forests that occurred between 1809 and 1993 for the Upper Mississippi River in southern Illinois. Presettlement forest conditions were reconstructed based upon General Land Office (GLO) survey records. Present forest conditions were determined using a sampling design similar to the GLO surveys. Results of our study reveal that in addition to an enormous acreage reduction, the composition and structure of floodplain forests have changed significantly. Compared to presettlement conditions, present forests bordering the river are comprised of more *Salix nigra* and *Acer saccharinum*, fewer *Populus deltoides* and *Platanus occidentalis*, and lack *Quercus spp.* and *Carya spp.*; present forests further away from the river, behind Federal levees, are comprised of more *Quercus palustris* and *Q. falcata*, and less *Celtis occidentalis*, *Ulmus rubra*, and *Populus deltoides*. These changes are directly affected by Federal levees, navigation improvement structures, and alteration of the natural hydrological environment in the Upper Mississippi River.

[1]YOSHIDA, LIDIA CEBALLOS, [2]C. P. ANDERSEN, and [3]J. A. GAMON. [1,3]California State University, Los Angeles, CA 90032-8201, USA. [2]U.S. Environmental Protection Agency, Corvallis, OR 97333, USA. Does ozone exposure alter growth and carbon allocation of mycorrhizal plants?

Ozone is known to adversely affect plant growth. However, it is less clear how ozone affects belowground processes. This study tests the hypothesis that ozone alters growth and carbon allocation of vesicular arbuscular mycorrhizal (VAM) plants. Two ecotypes of *Elymus glaucus* (blue wild rye) were exposed to mycorrhizal inoculation and episodic ozone exposures simulating atmospheric conditions in the Los Angeles Basin. Preliminary results show that effects of ozone on growth were subtle. In both ecotypes, growth of aboveground biomass was not affected by ozone while root growth was decreased. In most treatments, mycorrhizal inoculation decreased growth of leaves and stems, but had no significant effect on root growth. Three-way ANOVA tests indicated interactive effects between ecotype, mycorrhiza and ozone. Further experimental work is needed to reveal the biological processes governing these responses.

YOUNG,C.C. and R.W. KIMMERER Centre College, Danville, KY 40422 USA and State University of New York, College of Environmental Science and Forestry, Syracuse NY 13210 USA. Patterns of post-fire recovery in Andean paramo.

Community composition of paramo grassland in Cotopaxi National Park, Ecuador at 4000 m elevation was assessed on a burned and an adjacent unburned site. Sampling occurred 18 months after an intense wildfire. Percent post-fire survival and rate of vegetative regrowth of shrubs and grass tussocks differed by species. Vaccinium floribundum experienced a high rate of re-sprouting, while Composite shrubs demonstrated reduced success. Grass tussocks over a minimum diameter of 10 cm showed approximately 90 % survivorship. Flowering of Cortideria and Stipa grasses was stimulated on the burned site. While percent cover on the burned site was approximately 45% of the control, species diversity was significantly increased.

YOUNG, REBECCA A. University of Tennessee, Knoxville, TN. 37996, USA. The effect of spider presence on insect phytophagy in a garden test system.

During the summers of 1992 and 1993, the following study was undertaken to determine whether decreases in herbivory on host plants associated with spider presence were due solely to reduction in pest numbers or to an effect of mere presence alone. Three different species of host plant were bagged with fine mesh netting in replicates of five and six. Pest insects chosen for the appropriate plant were introduced to the bags in numbers corresponding to typically observed densities. Each bag was assigned to one of three treatments: 1) no spiders- in which no spiders were introduced, 2) free spider- one who was not constrained in any way, and 3) constrained spider-

a spider whose chelicerae were waxed closed with paraffin applied with a heated pin was introduced. The third treatment made it possible to observe the effect of a foraging spider who could not consume prey. In each case, the spider species chosen was one known to prey on the insect under observation, and commonly found foraging on the test host plant. Results indicate that the mere presence of a foraging predator may be important in decreasing plant damage for some insect-spider combinations.

YUAN, SHAOMIN and GRACE S. BRUSH. The Johns Hopkins University, Baltimore, MD, 21218, USA. Postglacial migration of a Coastal Plain river.

Ancient abandoned river channel positions have been established by analyses of grain size distributions of sediment and radiocarbon dates of bottom peat deposits in 14 sediment cores collected in a medium size riverine swamp, that is part of the Anacostia River floodplain close to Washington DC. During the last 12,000 years, the river channel has migrated 320 m to the east. Three migration stages have been established that coincide with changes in vegetation and climate reconstructed from pollen and charcoal records. A relatively fast migration rate of 8 cm yr^{-1} occurred between 12,000 and 10,000 years go when a cold, wet climate resulted in increased flooding and high sedimentation. A relatively stable meandering belt, with an average migration rate of 0.8 cm yr^{-1}, developed between 10,000 and 5,000 years ago, a period of decreased water discharge and increased vegetation cover. A major shift in the meander belt occurred after 5,000 years ago, when climate became wetter throughout the mid-Atlantic region, signifying a high frequency of large flood events.

YU, ZICHENG and JOHN H. McANDREWS. University of Toronto and Royal Ontario Museum, Toronto, ON M5S 2C6, CANADA. Holocene development of a lakeside swamp in southern Ontario.

Sediment lithology, pollen and plant-macrofossils from Paynter Swamp reveal three wetland stages during the past 10 000 yr. A Carex and Eleocharis dominated marsh (>10 000 - ca.7930 cal yr BP) was followed by a Verbena hastata and Mentha arvensis marsh (ca. 7930 - 7460 cal yr BP) before succession to a cedar (Thuja occidentalis) swamp (since 7460 cal yr BP). There was no evidence for succession in the diverse marsh for ca. 2000 yr; its high taxon richness was maintained by fluctuating water levels. The succession from marsh to swamp was caused by warm/dry climate during the mid-Holocene Hypsithermal, which corresponds with cedar expansion elsewhere in Ontario. Early development of this swamp was interrupted at ca. 6800 cal yr BP by declining water levels. A dry period was indicated by a sandy layer (no wetland deposition) and rare macrofossils. The gradual redevelopment of the cedar swamp since 3890 cal yr BP corresponds with the recovery of water levels due to the late Holocene cool/warm climate and isostatic tilt. Dam-induced high and stable water levels caused the development of modern cedar swamp with abundant Alnus rugosa and other new taxa.

YUCEL, ERSIN. Anadolu University, Faculty of Sciences, Department of Biology, Eskisehir 26470, Turkiye. Structural characteristics of the communities of Ehrami Karacam (Pinus nigra ssp. pallasiana var. pyramidata (Acat.) Yaltirik).

Ehrami Karacam (Pinus nigra Arnold. subsp. pallasiana (Lamb.) Holmboe var. pyramidata (Acat.) Yaltirik) is one of the endemic plants in Turkiye. This variety, which grow naturally between 980 m and 1350 m in Rendsina, Pararendsina, Calc braunerde, Terra rossa and Terra fusca soil types around Kutahya City, could reach as much as 20 m in height and 50 cm in truck diameter. The sociabilities of var. pyramidata have been found in small groups, a uniform and large groups, individually even totally isolated in P. nigra ssp. pallasiana forest and anthropogene disclimax. Quercus pubescens or P. nigra ssp. pallasiana or var. pyramidata are the dominant species of these areas. The vitalities of var. pyramidata have been investigated and it is found that they were developing well, but their life cycles were incompleted. Although there were eight stratifications, the natural grown areas could be considered as two stratifications. In this study, the structural characteristics of the communities of var. pyramidata have been investigated for the first time.

YUNGER, JOHN A. and PETER L. MESERVE. Northern Illinois University, DeKalb, IL, 60115. The effects of predation, competition, and lunar light levels on the foraging behavior of a small mammal assemblage.

Aside from numerical effects, predators and competitors can influence the behavior of prey populations in a variety of ways including spatial activity patterns. As part of a large scale manipulation being conducted in north-central semi-arid Chile, we had the opportunity to examine how interspecific competition, lunar light levels, and predator exclusion altered the foraging behavior of small mammals. The giving-up-density, or grams of seeds remaining in a small seed tray, were used as a measure of foraging activity. The exclusion of a large, diurnal rodent, Octodon degus, resulted in increased foraging activity of a smaller rodent, Akodon olivaceus. As compared to a new moon, foraging under a full moon resulted in increased feeding levels out in the open vs. under shrubs for Phyllotis darwini. Overall, A. olivaceus foraging was greater during a new moon as compared to a full moon, presumably due to decreased predation risk. Predator exclusion altered the foraging of A. olivaceus, but not P. darwini; A. olivaceus foraged more on predator access grids, presumably due to increased O. degus densities on predator exclusion grids.

ZAK, DONALD R., and KURT S. PREGITZER, University of Michigan, Ann Arbor, MI 48109, USA and Michigan State University, E. Lansing, MI 48824, USA. Responses of soil microorganisms to changes in plant production with rising atmospheric CO_2.

In most ecosystems, the amount of C (i.e., energy) entering the soil from plant production is only sufficient to meet the maintenance energy requirements of soil microorganisms, allowing for no net annual growth of microbial populations. Because the rising atmospheric CO_2 concentration has the potential to alter patterns of plant production and C allocation, it also has the potential to influence plant litter production and the amount of energy available for microbial growth in soil. We have developed a conceptual model describing the influence of rising atmospheric CO_2 on plant production, soil microorganisms and the cycling of C and N within soil. It is based on the premise that increases in plant production provide the primary link between the rising atmospheric CO_2 concentration and changes in the microbially-mediated transformations C and N within soil. We have argued that increased root growth at elevated atmospheric CO_2 should increase soil C availability, microbial populations, and rates of net N mineralization. Others have proposed alternative ideas, suggesting that elevated atmospheric CO_2 will lead to the production of recalcitrant plant litter and a reduction in rates of C and N cycling. We present evidence from a set of recent of experiments providing support for larger microbial populations and faster rates of C and N cycling in response to rising atmospheric CO_2. We also summarize the literature, bringing these differing views into perspective. It seems clear, however, that plants mediate the response(s) of soil microorganisms to rising atmospheric CO_2.

ZARIN, DANIEL J. and ARTHUR H. JOHNSON. University of Pennsylvania, Philadelphia, PA, 19104, USA. Post-disturbance recovery of aboveground biomass and nutrient capital in forest ecosystems.

From our own work and the available literature we have compiled datasets for study areas where aboveground biomass and nutrient capital were determined in both aggrading and mature forest sites. The eleven study areas represented in our data compilation include equatorial, subtropical, temperate and boreal forests. We found that percent recovery of aboveground biomass and nutrient capital in the aggrading sites to levels present in their representative mature forest stages was positively correlated with growing season degree-years, a temperature summation variable which is the product of site age, growing season length and growing season temperature. For the ten study areas undergoing secondary succession growing season degree-years explained 85, 77, 69, 85, 89 and 80 percent of the variability in the data for biomass, N, P, K, Ca, and Mg respectively (linear regression, n=30). A landslide chronosequence, the only primary succession study in our data compilation, recovered more slowly ($P < .001$, test for slope homogeneity for all variables). Our analysis suggests that, during secondary succession, aboveground biomass and nutrient capital may be expected to recover to pre-disturbance levels more quickly in the aseasonal wet tropics than in temperate or boreal regions.

ZHANG, JIANWEI, JOHN D. MARSHALL, and LAUREN FINS. University of Idaho, Moscow, ID, 83843, USA. **Correlated population differences in dry matter accumulation, allocation, and water-use efficiency in three sympatric conifer species.**

Populations of three sympatric conifer species, *Pseudotsuga menziesii* (Mirb.) Franco, *Pinus ponderosa* Laws., and *Larix occidentalis* Nutt., were studied. Seedlings from seed collected from across the respective natural distributions were grown under two watering regimes; in addition, mature trees were sampled from experimental plantings. *Pseudotsuga* populations differed in all measured variables under both watering regimes (all $P \leq 0.04$); correlations between measurements under well-watered and water-stressed conditions were high ($r = 0.69$ to 0.99). *Pinus* populations differed consistently in carbon allocation to roots and leaves (all $P \leq 0.02$), less consistently in dry matter and height ($P = 0.00$ to 0.35), and did not vary in relative growth rate ($P = 0.07$ to 0.41); only leaf weight ratio and height were significantly correlated between watering regimes ($P < 0.05$). *Larix* populations differed inconsistently in carbon allocation ($P = 0.01$ to 0.15), size ($P = 0.00$ to 0.82), and relative growth rate ($P = 0.00$ to 0.10); however, population differences in total dry matter, above-ground dry matter, relative growth rate, and leaf weight ratio were correlated between watering regimes ($r = 0.56$ to 0.75, $P < 0.05$). Plant size was generally correlated with water-use efficiency in *Pseudotsuga* and *Larix* ($r = 0.11$ to 0.81 and 0.23 to 0.85, respectively), but not in *Pinus* ($r = 0.06$ to 0.46). The varied patterns of correlation in these results lead to the conclusion that no single adaptive interpretation based on suites of related traits can be applied to these widely distributed sympatric species.

ZHANG, QISHUI., and JOHN C. ZAK. Texas Tech University, Lubbock, TX, 79409, USA. Linking root decomposition, root growth, and microbial activity within a semi-arid ecosystem.

A sand-shinnery oak dominated community in West Texas is being used to elucidate the potential relationship between root growth, root decomposition, and attendant microbial activity associated with shrubs in a semi-arid ecosystem. Five, 40 meter long transects with varying stem densities were established in 1992 on a 30 acre virgin, ungrazed, sand-shinery oak site southwest of Lubbock, Texas. Root growth of shinnery-oak was lower for the period of Apr. to June and Sep. to Dec., and higher in June and Sep. Root decomposition exhibited no significant differences among the 5 transects after 5 months and ranged between 10-15% of initial weight. Nitrogen mineralization rates decreased fron Aug. to Oct. with net immobilization occurring at the time of plant senescence in Oct. Subsequently, N mineralization increased from Oct. to Dec. Ammonification and nitrification followed the same pattern as N mineralization. There were no significant differences among the transects for any aspects of soil nitrogen dynamics. Microbial biomass C and N did differ among the transects with lower microbial biomass-C and N in Aug., peaking in Nov. for 2 of the 5 transects. The other 3 transects did not exhibit any temporal variation in microbial biomass. Results to date suggest that in semiarid ecosystems, soil microbial mediated processes may not vary significantly within a habitat irrespect of spatial differences in microbial biomass.

ZIMMERMAN, J.K., T.M. AIDE, L.J. HERRERA, M.A. ROSARIO, and M.I. SERRANO. University of Puerto Rico, San Juan, PR, 00936, USA. Effects of land use on forest structure and composition in the Luquillo Experimental Forest (LEF), Puerto Rico.

We studied areas of the LEF purchased in the 1930's by the U.S.D.A Forest Service that were formerly in pasture, in shade coffee, and in forested areas not used for coffee cultivation.

Forest stands in each land use type were sampled at three localities at varying distances (5-20 km) from the path of Hurricane Hugo (September 1989). Modern forest structure (stem density and biomass) in old coffee plantations and forested areas was strongly affected by their proximity to the hurricane, but that of the former pastures was not. Old pastures had a very different species composition and had lower species richness than other land use types. Particularly striking was the almost complete lack of the pioneer tree, Cecropia schreberiana, in any of the old pastures, a species that was otherwise common in sites near the hurricane path. These results demonstrate a pronounced effect of pastures on recovering tropical forest communities and the interactions of these communities with a natural disturbance.

ZITZER, STEPHEN and STEVE ARCHER. Texas A&M University, College Station, TX 77843-2126 USA. Response of contrasting woody plant growth forms to varying resource (nitrogen, light and water) ratios.

Invasion of south Texas savannas by woody plants begins with establishment of Prosopis glandulosa under high light/low nutrient conditions. Subordinate shrub growthforms subsequently establish beneath Prosopis as light levels decline and soil N increases. In an attempt to relate species appearance sequence to their physiological amplitudes, we quantified seedling growth of P. glandulosa and three understory shrubs, Condalia hookerii, Celtis pallida and Mahonia trifoliolata, to varying levels of N (3), light (3) and water (2). Total biomass (120 days) was greatest for P. glandulosa (8.2 g/seedling) followed by C. hookerii (3.9g), C. pallida (3.7g) and M. trifoliolata (0.2g). P. glandulosa growth was not limited by low nitrogen, but was constrained at low light levels (15% full sun). In contrast, C. hookerii and M. trifoliolata growth was optimal at intermediate levels of light and N. Survival of M. trifoliolata decreased with increasing in light levels, while survival of the other species was not effected by any of the treatments. C. pallida growth was optimial under high light (full sun), high N conditions. Watering regime alone did not effect the growth response, but was interactive with species, N level and light level. Observed differences in species growth responses were generally matched to environmental conditions associated with autogenic habitat modifications initiated by Prosopis.

ZIV, YARON and JUDITH L. BRONSTEIN. University of Arizona, Tucson AZ 85721. Do infertile seeds of a yucca plant have a function in the moth-yucca mutualism interaction?

The mutualism between the yucca moths, *Tegeticula yuccasella* and *Parategeticula pollenifera*, and *Yucca schottii* is characterized by both pollination and seed predation by the moths. Within a yucca fruit, fertile and infertile, and eaten and uneaten seeds can be defined. We studied seed distribution within fruits, focusing on the distribution of infertile seeds. We recorded the location of each seed, whether or not it was eaten, and what fraction of the seed was eaten. Infertile seeds were distributed throughout both-infested and uninfested rows. An average infertile seed was eaten significantly less than a fertile seed, and the proportion of infertile seeds eaten was less than the proportion of fertile seeds eaten. Significantly fewer seeds were eaten when the "eaten-seed sequence" was blocked by infertile seeds than by fertile seeds. We also found that when more infertile seeds were present, significantly fewer fertile seeds were eaten. The results suggest that moth larvae less prefer, or even avoid eating infertile seeds. We suggest that infertile seeds function as blocking units within seed rows, reducing the number of fertile seeds eaten by moth larvae.

ZOGG, GREGORY P., DOUGLAS R. PEARSALL, and BURTON V. BARNES. University of Michigan, Ann Arbor, Michigan, 48109, USA. Classification and analysis of wetland ecosystems in northern Lower Michigan.

The wetland ecosystems of the University of Michigan Biological Station (4000 ha tract) were identified using a multi-factor approach. Field reconnaissance, transects and plot sampling were used to characterize the diversity of wetlands in this glacial landscape. Ecosystem types were described and classified on the basis of climate, physiography, hydrology, soils and vegetation. Univariate and multivariate analyses were used to determine the distinctness of ecosystems as identified in the field, and to compare the ability of different ecosystem components to discriminate among types. Relationships between groundflora composition and environmental gradients were also examined. Ecosystem types were poorly discriminated on the basis of overstory physiognomy or hydrology, despite the prevalent use of these criteria in single-factor wetland classifications; groundflora species provided better discrimination. Analysis of vegetation-environment relationships indicated that soil type, in addition to light, water chemistry, and depth to water table, was important in influencing plant community composition in these ecosystems.