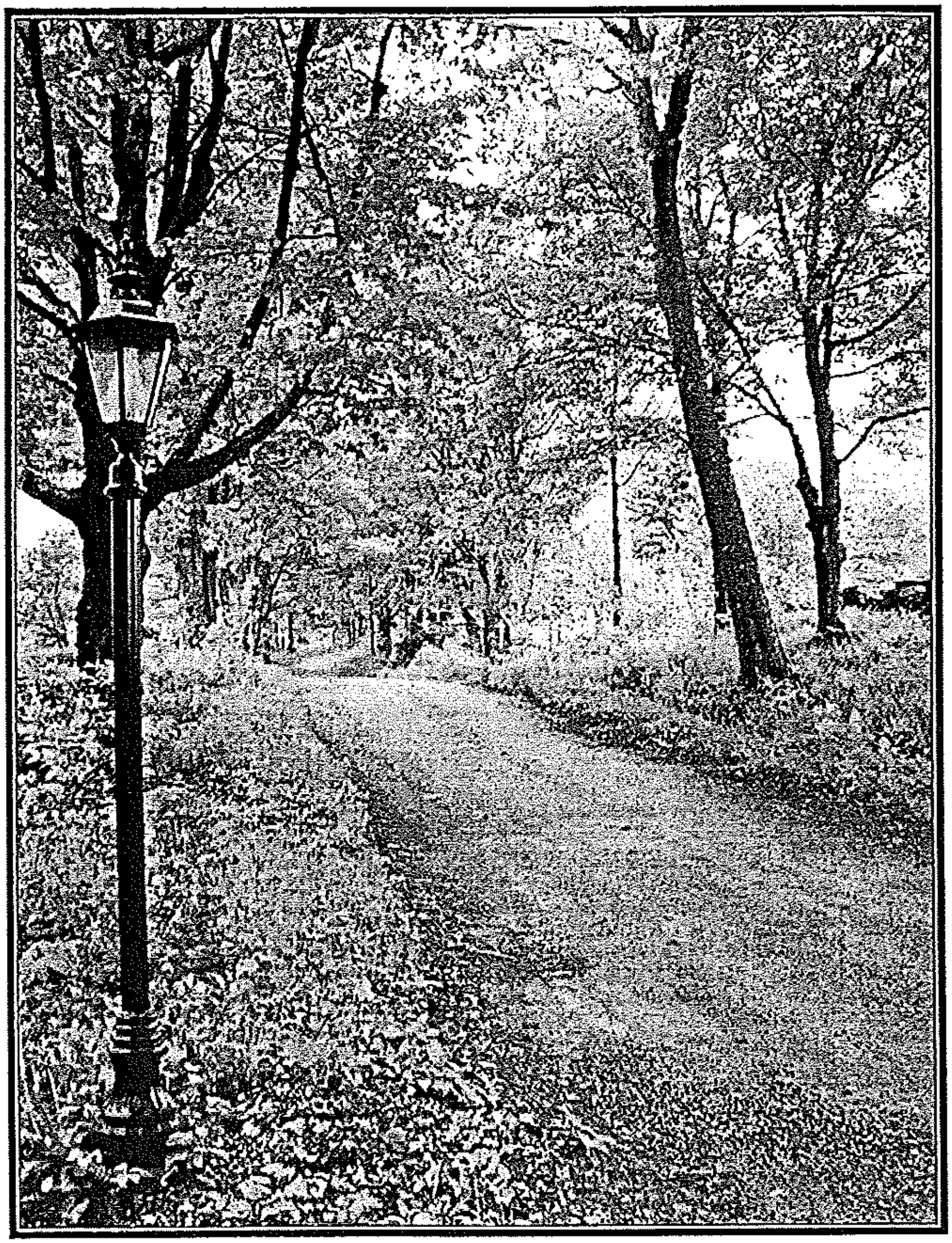
# HARVARD FOREST

# SUMMER RESEARCH PROGRAM



*Abstracts from the 11th Annual*
*Harvard Forest Summer Research Program*
*13 August 2003*

# ELEVENTH ANNUAL HARVARD FOREST SUMMER RESEARCH PROGRAM

## 14 August 2003

## HARVARD FOREST, FISHER MUSEUM



*Photography by Jakara Hubbard*

# INTRODUCTION TO THE HARVARD FOREST

Since its establishment in 1907 the Harvard Forest has served as Harvard University's rural laboratory and classroom for research and education in forest biology and ecology. Through the years researchers have focused on forest management, soils and the development of forest site concepts, the biology of temperate and tropical trees, plant ecology, forest economics, landscape history, conservation biology and ecosystem dynamics. Today, this legacy of activities is continued as faculty, staff, and students seek to understand historical and modern changes in the forests of New England and beyond resulting from human and natural disturbance processes, and to apply this information to the conservation, management, and appreciation of natural ecosystems. This activity is epitomized by the Harvard Forest Long Term Ecological Research (HF LTER) program, which was established in 1988 through funding by the National Science Foundation (NSF).

Physically, the Harvard Forest is comprised of approximately 3000 acres of land in the north-central Massachusetts town of Petersham that include mixed hardwood and conifer forests, ponds, streams, extensive spruce and maple swamps, fields and diverse plantations. Additional land holdings include the 25-acre Pisgah Forest in southwestern New Hampshire (located in the 5000-acre Pisgah State Park), a virgin forest of white pine and hemlock that was 300 years old when it blew down in the 1938 Hurricane; the 100-acre Matthews Plantation in Hamilton, Massachusetts, which is largely comprised of plantations and upland forest; and the 90-acre Tall Timbers Forest in Royalston, Massachusetts. In Petersham a complex of buildings that includes Shaler Hall, the Fisher Museum, and the John G. Torrey Laboratories provide office and experimental space, computer and greenhouse facilities, and lecture room for seminars and conferences. Nine additional houses provide accommodations for staff, visiting researchers, and students. Extensive records, including long-term data sets, historical information, original field notes, maps, photographic collections and electronic data are maintained in the Harvard Forest Archives.

Administratively, the Harvard Forest is a department of the Faculty of Arts and Sciences (FAS) of Harvard University. The Harvard Forest administers the Graduate Program in Forestry that awards a masters degree in Forest Science and faculty at the Forest offer courses through the Department of Organismic and Evolutionary Biology (OEB), the Kennedy School of Government (KSG), and the Freshman Seminar Program. Close association is also maintained with the Department of Earth and Planetary Sciences (EPS), the School of Public Health (SPH), and the Graduate School of Design (GSD) at Harvard and with the Department of Natural Resource Conservation at the University of Massachusetts, the Ecosystems Center of the Marine Biological Laboratory and the Complex Systems Research Center at the University of New Hampshire.

The staff and visiting faculty of approximately fifty work collaboratively to achieve the research, educational and management objectives of the Harvard Forest. A management group meets monthly to discuss current activities and to plan future programs. Regular meetings with the HF LTER science team, weekly research seminars and lab discussions, and an annual ecology symposium provide for an infusion of outside perspectives. The six-member Woods Crew and Facilities Manager undertake forest management and physical plant activities. The Coordinator of the Fisher Museum oversees many educational and outreach programs.

Funding for the Harvard Forest is derived from endowments and FAS, whereas major research support comes primarily from the National Science Foundation, Department of Energy (National Institute for Global Environmental Change), U.S. Department of Agriculture, NASA, Andrew W. Mellon Foundation, and other granting sources. Our Summer Program for Student Research is supported by the National Science Foundation, the A. W. Mellon Foundation, and the R. T. Fisher Fund.

**Summer Research Program**

The Harvard Forest Summer Student Research program, coordinated by Edythe Ellin and assisted by Laurie Miskimins and Jakara Hubbard attracted a diverse group of students to receive training in scientific investigations, and experience in long-term ecological research. All students worked closely with researchers while many conducted their own independent studies. The program included weekly seminars from resident and visiting scientists, discussions on career issues in science, and field exercises on soils, land-use history, and plant identification. An annual field trip was made to the Institute of Ecosystem Studies (Millbrook, NY) to participate in a Forum on Careers in Ecology. Students presented major results of their work at the Annual Summer Student Research Symposium in mid August.

**ELEVENTH ANNUAL**
**HARVARD FOREST SUMMER RESEARCH PROGRAM SYMPOSIUM**
**13 August 2003**
**Fisher Museum**

| Time | Speaker | Title | Mentor(s) |
|---|---|---|---|
| **8:30 a.m.** | **Dave Orwig** | **Introduction: Hemlock Woolly Adelgid** | |
| | Don Niebyl | Hemlock woolly adelgid's migration across the Central Massachusetts landscape | Dave Orwig |
| | Nick Povak | Eastern hemlock: surviving by grassroots | Dave Orwig |
| | Joe Brown | Developing an HWA sampling plan | Scott Costa |
| | David Franklin | Rain, rain, go away; we don't want anymore HWA: the effects of the hemlock woolly adelgid on throughfall N concentrations | Dave Orwig, Sultana Jefts |
| | Amanda Park | Vegetation and ecosystem dynamics following selective hemlock logging | Dave Orwig, Sultana Jefts |
| | Chris Petit | The effect of hemlock woolly adelgid (*Adelges tsugae*) on the hydraulic properties of eastern hemlock (*Tsuga canadensis*) | Missy Holbrook |
| **10:00** | **Missy Holbrook** | **Introduction: Plant physiology and invasive species** | |
| | Nora Lahr | Testing the segmentation hypothesis in *Acer saccharum*: cavitation thresholds of xylem vessels in different regions of the tree | Brendan Choat |
| | Teresa Abbott | The effects of $CO_2$ and $O_2$ on sapwood respiration in forest trees | Rachel Spicer |
| **10:30** | | **COFFEE BREAK** | |
| **10:45** | Luke Durbin | Response of a New England understory community to the removal of the invasive species *Alliaria petiolata* | Kristina Stinson |
| | Gui Woolston | The influence of habitat on the demography, meristem allocation, and fecundity of *Alliaria petiolata* | Kathleen Donohue |

| Time | Speaker | Title | Mentor(s) |
|---|---|---|---|
| | Julia Nelson | Effects of soil disturbance and mowing on demographic structure and seeding performance in garlic mustard (*Alliaria petiolata*) populations | Kristina Stinson |
| | Becca Lohnes | Investigation of *Robinia pseudoacacia* impact on understory vegetation of Cape Cod National Seashore | Betsy Von Holle |
| **12 noon** | | **LUNCH** | |
| **1:00 p.m.** | **Glenn Motzkin** | **Introduction: Land disturbance and conservation** | |
| | Kristin Wilson | Effects of the 1938 hurricane on long term forest dynamics, Harvard Forest, Petersham, MA | Audrey Barker Plotkin |
| | Joanna Bate | Timber harvesting: a study of the effects of socio-economic characteristics and forest ownership patterns in Massachusetts and New Hampshire | Dave Kittredge |
| | Nicholas Malizia | Assessing the effectiveness of land conservation in the North Quabbin region: 1993-2003 | David Foster, Glenn Motzkin |
| **1:45 P.M.** | **Julian Hadley** | **Introduction: Ecosystem processes (soil respiration, and carbon cycling)** | |
| | Eric Saas | Chronic nitrogen enrichment alters the functional capacity of the litter decomposer community | Serita Frey |
| | Margaret Graham | Contributions of litter input and root activity to carbon cycling in a temperate mixed hardwood forest | Paul Steudler, Jerry Melillo, Heidi Lux |
| | Naomi Clark | Comparing root respiration of three tree species | Eric Davidson, Kathleen Savage |
| | Chris Graham | Effects of selected above- and below-ground forest properties on soil respiration in a mixed New England forest | Julian Hadley |
| | Brady Hardiman | Photosynthetic rates of *Betula lenta*: effects on canopy carbon storage rates in a changing environment | Julian Hadley |
| **3:00** | | **BREAK** | |

| Time | Speaker | Title | Mentor(s) |
|---|---|---|---|
| 3:15 P.M. | Jennifer Clowers | Spatial variation of sunflecks in forests of different age and disturbance history | Tim Sipe |
| | Kathryn McKain | Short term effects of a selective harvest on tree growth in a mixed deciduous forest adjacent to Harvard Forest | Steve Wofsy, Christine Jones |
| **4:00** | **Aaron Ellison** | **Introduction: Hydrology, bogs and ants** | |
| | Daberat Perez-Rivera | Exploratory study to assess the role of evapo-transpiration in the water budget of Harvard Forest | Ana Barros |
| | Alana Belcon | Distribution and diversity of bog vegetation at Tom Swamp | Aaron Ellison |
| | Dan Atwater | Spatial distribution patterns of two moths associated with the northern pitcher plant (*Sarracenia purpurea*) | Aaron Ellison, Jess Butler |
| | Matt Lau | The mycorrhizal status of a carnivorous plant, the northern pitcher plant (*Sarracenia purpurea*) | Aaron Ellison |
| | Jonathan Chen | Changes in ant species richness along a successional gradient in New England | Aaron Ellison |
| **5:30** | | **BBQ** | |

## Effects Of $CO_2$ And $O_2$ On Sapwood Respiration in Forest Trees

*Teresa Abbott*

Parenchyma cell death is the defining factor in heartwood formation, but little is known regarding the mechanisms regulating this transition from the physiologically active sapwood to the nonliving heartwood core. Although respiration has been shown to decline with age, the effects of *in vivo* gas concentrations (high $CO_2$ and low $O_2$) on respiration are unknown. Cores were extracted from 10 trees each of *Fraxinus americana*, *Quercus rubra*, *Pinus strobus*, *Tsuga canadensis* and *Acer rubrum* at Harvard Forest. Innermost and outermost sapwood samples were equilibrated to four gas treatments (percent $O_2$/percent $CO_2$: 5/0, 5/10, 10/0, 10/10) and rates of $O_2$ consumption were measured with a fiber optic oxygen probe over 36 hours. The effect of $CO_2$ was dependent on $O_2$ concentration (but not species or tissue age), such that 10% $CO_2$ had an inhibitory effect only at 10% $O_2$. Ten percent $CO_2$ reduced respiration by about 14% (mean [± se] respiration rates for the 10/10 and 10/0 treatments were 4.7 ± 0.2 and 5.4 ± 0.2 x $10^{-7}$ mol/hr $cm^3$, respectively [adjusted p-value $< 0.05$, ANOVA, n=100]). Only *Acer rubrum* showed higher respiration for outer relative to inner sapwood, both on a per tissue and per parenchyma cell volume basis. Results illustrate parenchyma cells can respire at similar rates despite large age differences, suggesting heartwood formation is not a function of gradual metabolic decline. The synergistic effects of $CO_2$ and $O_2$, and the small inhibitory effect of $CO_2$ overall, do not support the hypothesis of parenchyma death due to elevated $CO_2$.

## Spatial Distribution Patterns of Two Moths Associated with the Northern Pitcher Plant (*Sarracenia purpurea*)

*Dan Atwater*

The northern pitcher plant, *Sarracenia purpurea*, is eaten by two moth species, *Exyra fax* and *Papaipema appassionata*, which both live in and feed upon plant tissue during larval development. *E. fax* feeds on the leaves of the plant and *P. appassionata* feeds on the rhizome of pitcher plants. The feeding habits of each moth cause distinct damage to the host plant. The goal of this study was to determine whether a pattern exists in the distribution of each species of moth in the southwest portion of Harvard Pond. A map of the islands in this portion of the pond was made by marking each island with a flag and relating the position of that flag to those located on other islands. The location of each pitcher plant on an island was determined by relating the position of the plant to the flag at the center of the island. Subsequently, each plant was checked for the presence of *E. fax* and *P. appassionata*. Of 111 study plants, 38 contained *E. fax* and 0 contained *P. appassionata*. The mean nearest-neighbor distance was determined to be 0.649 m for the plants containing *E. fax*. From the 111 possible plant locations, 38 were chosen randomly and mean nearest-neighbor distances were calculated. This was repeated 1000 times. Of these trials, only 4 had a mean nearest-neighbor value lower than that observed in the field, significantly indicating spatial clustering of *E. fax* infested plants ($p = 0.004$).

## Timber Harvesting: a Study of the Effects of Socioeconomic Characteristics and Forest Ownership Patterns in New Hampshire and Massachusetts

*Joanna Bate*

While Massachusetts and New Hampshire are both heavily forested states (62% and 84%, respectively), relatively little timber is harvested in their forests. Urbanization has led to greater levels of parcelization of land ownership, resulting in previously contiguous tracts of forest being owned by several owners with diverse management interests. This project seeks to identify the effects of urbanization on timber harvest through the processes of parcelization, forest fragmentation, and changes in management values.

For the last two summers, data were collected, mapped, and analyzed for all Massachusetts and New Hampshire towns on harvesting patterns and forest characteristics. Harvesting data was compiled from Massachusetts' timber cutting plans (1997-2001) and New Hampshire tax information (2001) to create several dependent variables (e.g., harvest intensity, number of operations per forest area). A sample of 55 towns distributed by population density was selected for a study of parcelization indicators based on assessing records.

While variation in town harvest levels cannot be singularly explained by one variable, high levels of forest fragmentation and land parcelization are associated with a drop-off in harvest activity. Early results have shown that one parcelization indicator, # parcels/town ha, explains a significant amount ($R^2$=0.717, $p<0.05$) of the variation in harvest intensity ($m^3$/forest ha). Correlations of parcelization and forest fragmentation were not conclusive, which suggests that the effect of diverse owners is more clearly affecting harvesting patterns than increased forest edges at this point in our analysis.

Further analysis of the data collected on socioeconomic factors and parcelization in relation to harvesting patterns will clarify the extent of the relationship between urbanization and harvesting activity. Historical data for land use change and shifting urbanization pressures should be mapped to model the past and future effects on harvesting. The results from studies such as these can provide a better understanding of how human actions impact the harvest potential of forests.

## Diversity and Distribution of Bog Vegetation at Tom Swamp

*Alana Belcon*

Bogs and other peat-based wetlands are major carbon storage areas and any modification of these ecosystems can have large-scale impacts on the global climate change. In an effort to increase our understanding of these environments and their role in the global carbon cycle, it has been proposed that 60 wetlands across the United States and Canada be studied. Tom Swamp, an ombrogenic bog located 42°30'N, 72°12'W in Harvard Forest, Petersham, Massachusetts is one of these proposed sites. My summer research consisted of mapping the vegetation of Tom Swamp, south of the causeway - Tom Swamp Road.

Seven transects were laid parallel to each other running south from the causeway. The transects were 50 meters apart and on average 400m long. Every 50m along each transect a $25m^2$ plot was delineated and all the vegetation within this area identified. Three $1m^2$ quadrats were randomly thrown within the $25m^2$ area and the percent cover for each species recorded. A total of 47 $25m^2$ plots and 139 $1m^2$ quadrats were sampled.

The most abundant species found was *Chamaedaphne calyculata*, accounting for 66% of the total vegetation cover in the bog. *Myrica gale*, *Vaccinium corymbosm* and *Decodon verticillatus* together comprised a further 26%. The remaining 8% was distributed between 12 additional species (Fig. 1). A complex spatial distribution exists for species richness and no significant relationship was found between location of a plot and biodiversity. It is unlikely that any one factor is responsible for the spatial distribution of any given species or for species richness at Tom Swamp.

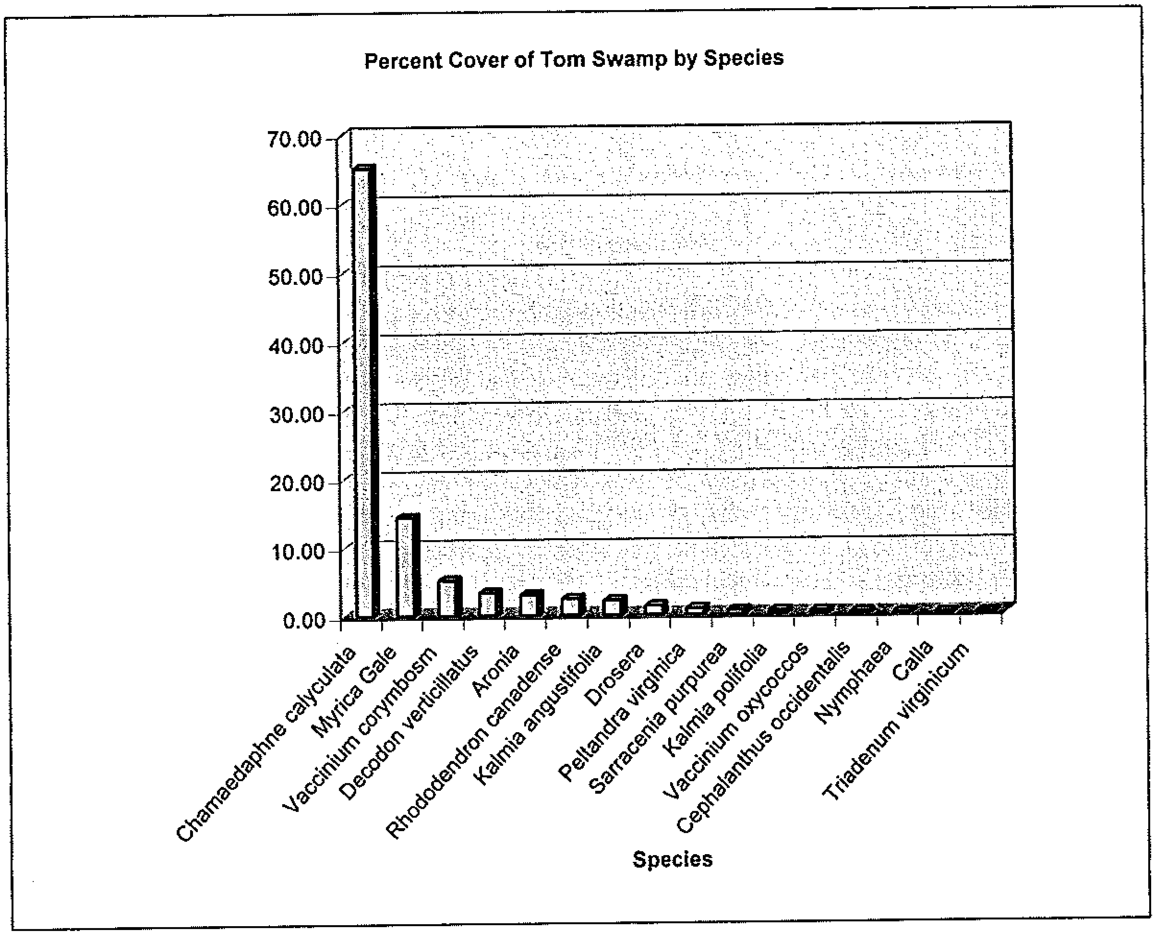



**Figure 1.** (Belcon)

## Developing an HWA Sampling Plan

*Joseph Brown*

Currently no sampling plan exists for detecting and assessing field populations of hemlock woolly adelgid (HWA), *Adelges tsugae*. We addressed two questions: 1) what is the minimum detection threshold and 2) what are the attributes, such as sample size and type, and the number of samples needed to assess the percentage and level of infestation. Observations were made in hemlock stands across the Connecticut River Valley and Quabbin Reservoir region of Massachusetts. The presence/absence of HWA signs (white woolly masses) on 100 trees in 17 sites were made at the level of tree, 2 branches/tree and 5 fronds/branch. Also, the number of HWA on each branchlet was recorded so that HWA population levels could be related to the percentage of trees infested. Our findings suggest that the most reliable method for sampling involves examining 2 lower branches per randomly selected tree. The minimum detection threshold based on a 75%

probability of detecting one or more infested trees within a 100 tree sample of a given site is slightly lower than a 2% infestation rate. A binomial model was used to relate observed population counts to predicted % trees infested by applying Taylor's Power Law. There was no significant (alpha=0.05) difference between observed and predicted infestation levels based on either tree, branch, or frond sampling units. Based on optimum sampling size analysis a minimum of 25 and a maximum of 150 samples are recommended for characterizing HWA populations down to 10% trees infested with precision=0.25 for assessment and management initiatives.

## Changes in Ant Species Richness Along a Successional Gradient in New England

*Jonathan Chen*

Succession is the replacement of the biota of an area by one of a different nature. Each stage along a successional gradient is unique and is inhabited by species adapted to that particular ecosystem. Transformations in plant composition alter the characteristics of the habitat, which can change the composition of faunal species. It has been hypothesized that there is a positive relationship between successional stages and invertebrate species richness. I wanted to test this hypothesis in the temperate zone of North America by sampling ant communities. Four successional stages were chosen for this experiment: an old-field, a white pine stand, a mixed forest, and a hardwood stand. I collected ants using cookie baits, pitfall traps, sorting through the leaf litter, and by hand. The results showed a negative relationship between successional stages and ant species richness. This may be correlated with the decreasing light intensity and herbaceous diversity along the gradient.

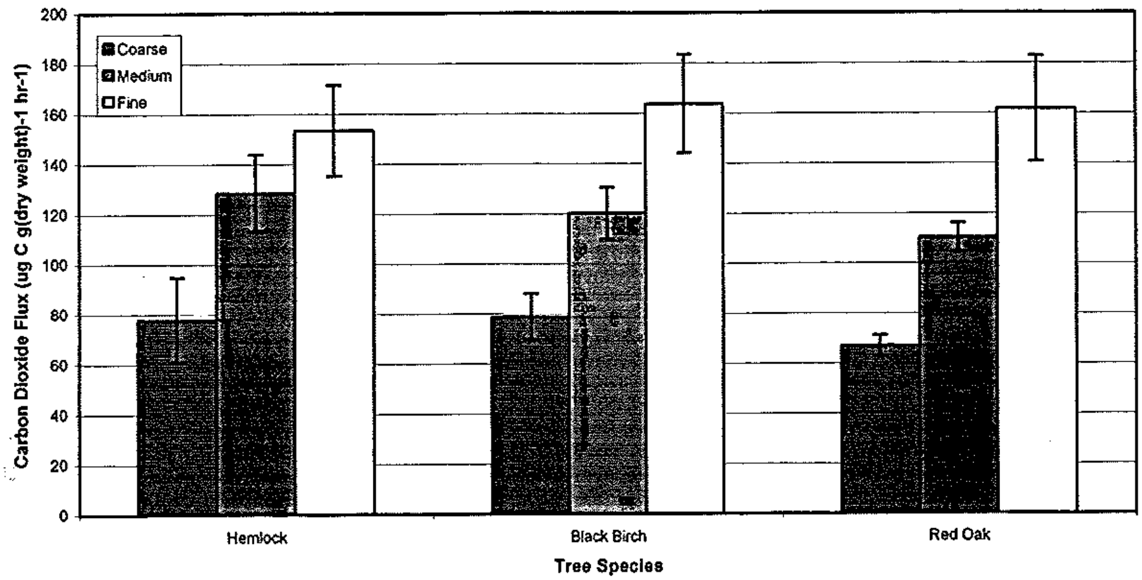
## Comparing Root Respiration of Three Tree Species

*Naomi Clark*

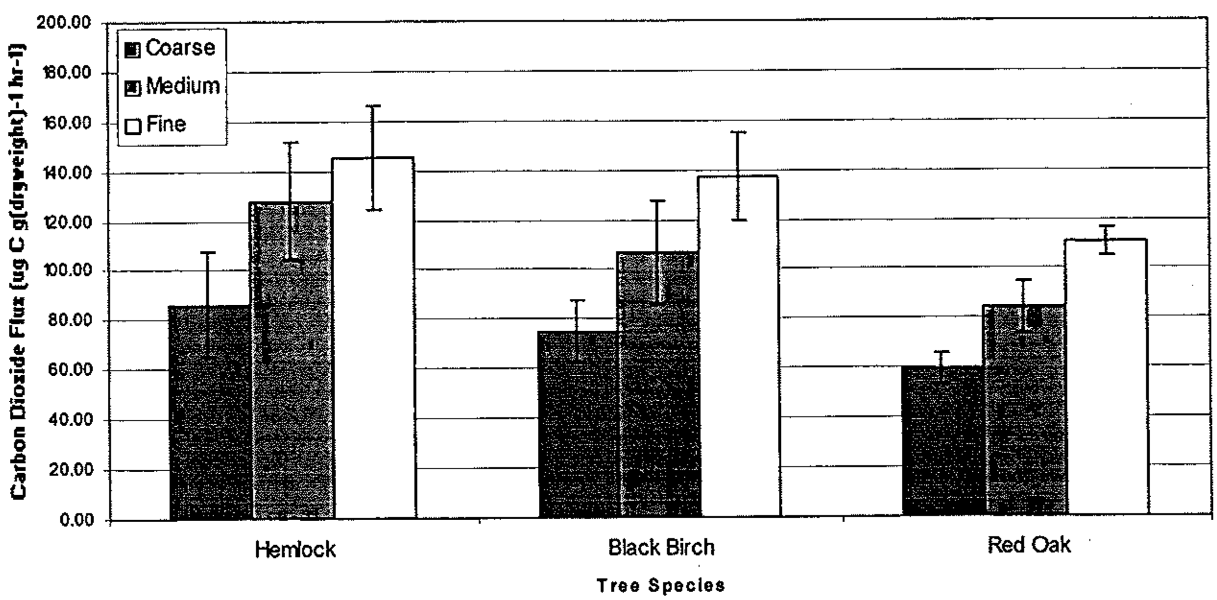
Soil respiration is the combination of root (autotrophic) and microbial (heterotrophic) respiration and is an important component of the global carbon cycle. Root respiration often represents approximately 50% of soil respiration. The objective of this project was to examine the variation in root respiration among three tree species (hemlock, black birch, and red oak) and among three root diameter classes (2-4mm, 1-2mm, <1mm). Roots were collected from each species ($n = 3$ replications per species), separated into size class, rinsed with deionized water, and incubated ($n = 3$ replications per root class) in a closed chamber. Changes in chamber [$CO_2$] were measured every 12 seconds over a 10 minute interval. Roots were incubated at ambient concentrations and at the approximate soil [$CO_2$] determined at root depth. Higher respiration rates under ambient chamber concentrations relative to approximate soil concentrations were marginally significant ($p = 0.023$). No significant differences in root respiration rates were detected among the three species ($p = 0.123$), but a significant relationship between root respiration and size class ($p < 0.000$) was observed. Coarse roots showed lower respiration rates than medium and fine roots in all three species (Fig. 1). These differences may be attributed to a physiological difference among root sizes, such as nitrogen content or varying rates of $CO_2$ diffusion. Consistency of respiration rates across tree species suggests that it may be possible to extrapolate root respiration rates to the stand level at the Harvard Forest using root biomass data, stratified only by size class.

**Figure 1**

Tree Species vs. Root Respiration in Ambient Laboratory CO2 Concentrations




Tree Species vs. Root Respiration in Approximate Soil CO2 Concentrations




(Clark)

## Spatial Variation of Irradiance and Sunflecks in Forests of Different Disturbance History and Age

*Jennifer Clowers*

Considerable research has been done on forest light regimes, including some studies of sunfleck patterns. However, in spite of the strong effects that sunflecks may have on photosynthesis and growth, few comparative data exist on sunfleck regimes in forests differing in disturbance history, age, and composition. We measured sunfleck regimes in 6 stands with different disturbance history at Harvard Forest: 15 year old red pine clearcut; 15 year old hurricane pulldown; 46 year old post-burn stand; 90 year old hurricane control; 145 year old formerly plowed site; and 200 year old uncleared hemlock. A Decagon AccuPAR probe with 80 quantum sensors spaced 1 cm apart was programmed to average 5 photosynthetic photon flux (PPF) readings per sensor over an interval of 1 second and store the average. One probe sample was measured at 20 random locations along a 50-m transect once in each stand between 11 am and 3 pm across two clear days in July. Stand-level mean PPF was determined by averaging all sensor PPF values (N = 1600). Mean PPF (N = 80), the number of flecks, mean fleck size (cm), and mean PPF of flecks were calculated for each probe sample. A PPF threshold of 50 μmol $m^{-2}$ $s^{-1}$ was used to define flecks. Stands were compared for all these variables using one-way ANOVA. Spatial irradiance variation was calculated as the coefficient of variance (C.V.) of PPF at two scales: within each probe sample (N = 80, $CV_{within}$) and across probe samples (N = 20, $CV_{across}$). $CV_{within}$ was also compared among stands using one-way ANOVA (N = 20).

Stand-level mean PPF ranged from 49 μmol $m^{-2}$ $s^{-1}$ (clearcut) to 130 μmol $m^{-2}$ $s^{-1}$ (hemlock), but did not differ significantly overall ($p = 0.54$). Stands also did not differ significantly in mean number of flecks ($p = 0.17$) or mean fleck irradiance ($p = 0.80$) within the probe samples. However, the hurricane control ($x = 24$ cm) and hemlock stands ($x = 18$ cm) had significantly larger flecks than all others ($p = 0.0009$). Spatial variation of PPF was high overall (CV = 78-320%), and all stands showed greater $CV_{across}$ (mean = 228%) than $CV_{within}$ (156%) (Fig. 1). There was a four-fold range among stands in $CV_{within}$, but the difference was not statistically significant ($p = 0.42$). $CV_{across}$ varied two-fold among stands. Neither $CV_{within}$ nor $CV_{across}$ showed a consistent trend with stand age. However, the $CV_{across}/CV_{within}$ ratio declined significantly with stand age from 2.0-2.2 to 1.0 (linear regression, p = 0.0 xx , $R^2 = 0.86$).

These results suggest an important successional trend in spatial PPF heterogeneity. Recently disturbed sites (clearcut and hurricane pulldown) show intermediate small-scale variation ($CV_{within}$) but high variation at scales larger than 1 m ($CV_{across}$), mid-successional sites (burn, hurricane control) show the least heterogeneity at both scales, and older forests (plow, hemlock) show high variation at both scales. Successional changes in mean stand-level PPF are at least partially decoupled from changes in spatial variation at different scales. Understanding these relationships is likely to improve predictions of population- and community-level responses to disturbance for both herbaceous and woody species.

## Response of a New England Understory Plant Community to the Removal of the Invasive Species *Alliaria petiolata*

*Luke Durbin*

*Alliaria petiolata* (garlic mustard) is an exotic invasive herb that is invading areas of eastern North America. While there is some evidence that garlic mustard negatively affects native plant communities, few studies have investigated its direct impact on native species diversity in New England. We conducted removal experiments to test whether *A. petiolata* reduces native species diversity. Three removal treatments resulting in high (no removal), medium (partial removal), and low (full removal) *A.*

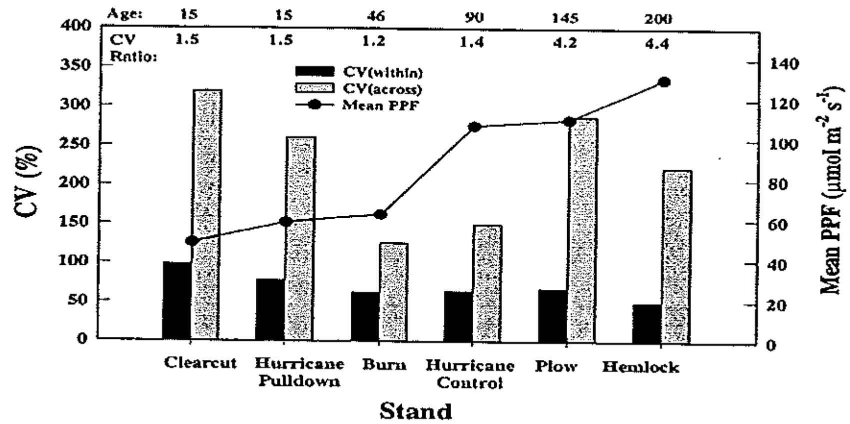



**Figure 1. Mean PPF and spatial heterogeneity of PPF across six stands differing in disturbance history and age in Prospect Hill. CV = coefficient of variation. See abstract for explanations of CV(within) and CV(across). CV Ratio is calculated as CV(across)/CV(within). (J. Clowers)**

*petiolata* densities were set up during the summer of 2002 in a highly invaded forest in Berkshire Co., MA. A diversity census was conducted on all of the plots in July 2003 from which species richness, Shannon diversity index, and Shannon equitability index were calculated. Light intensities measured for each plot were significantly greater in the high density plots suggesting *A. petiolata* decreases the amount of light available to native species (ANOVA, F=3.4259, P=0.0337). Species richness did not differ significantly between treatments (ANOVA, F=2.5700, P=0.1309). The low density *A. petiolata* plots had a significantly greater Shannon diversity index than the medium and high density plots (ANOVA, F=8.4645, P=0.0086). This was attributed to significantly greater equitability in the low density plots (ANOVA, F=15.0792, P=0.0013). When the low density plots were compared to previously un-invaded plots, no significant difference in diversities was found (t-test, F=0.2294, P=0.6489). Results from this experiment demonstrate that garlic mustard invasion reduces native species diversity in New England forest understory. The results further suggest that from a management perspective, full removal of *A. petiolata* can restore biodiversity in invaded areas within as little as one growing season.

**Rain, Rain, go Away: We Don't Want any More HWA; the Effects of the Hemlock Woolly Adelgid on Throughfall N Concentrations**

*David Franklin*

The Hemlock Woolly Adelgid (HWA) is an invasive insect that infests and ultimately kills the eastern hemlock (*Tsuga canadensis*). However the effects of infestation and ultimate mortality on nutrient cycling are not well known. The goal of this study was to determine if infestation leads to increased throughfall N concentrations, which could have large-scale ecosystem implications. There is a possibility that increased N in throughfall may lead to a worse HWA infestation through a potential positive feedback loop. The study area consisted of three forests in southern Connecticut in the Connecticut River watershed. Soil cores and resins were used to assess nitrogen availability and mineralization rates. They were collected and analyzed for $NH_4$-N and $NO_3$-N. Due to site differences, we weren't able to gain a clear picture of N in throughfall and the effects on soil for all three sites, but trends could be ascertained from the data. Following increased N deposition by throughfall, we expected to see increased rates of nitrification in the soils. The control showed very low rates of nitrification, typical of hemlock forest systems. Both of the infested sites showed an increase in soil nitrification, supporting our hypothesis that increased N in throughfall leads to increased nitrification rates. Additionally, in the infested sites, a higher amount of $NO_3$-N was leaching out of the soils, as evidenced by high collection rates in bottom resin bags. The top resin bags indicating throughfall did not follow a clear trend of infested vs. uninfested. However the N in throughfall collected demonstrated higher amounts of $NH_4$-N compared with $NO_3$-N entering the soils in throughfall.

**Effects of Selected Above- and Below-Ground Forest Properties on Soil Respiration in a Mixed New England Forest**

*Chris Graham*

Soils comprise a major component of global carbon (C) stocks, accounting for two to three times as much C as is found in the atmosphere (Batjes, 1996; Eswaran *et al.*, 1993). Given concerns over global climate change, the flux of soil C released by respiration, as well as possible changes of this flux due to climatic drivers, have become increasingly important topics in ecosystem science. In New England deciduous and conifer forests, soil respiration has been found to account for greater than 70-80% of net ecosystem respiration (Hadley and Schedlbauer, 2002; Wofsy *et al.*, 1993). However, much more attention has been paid to temporal variation in soil respiration and its drivers in these ecosystems (e.g. soil temperature and moisture; see Savage and Davidson, 2001; Boone *et al.*, 1998) than to the effects of small-scale spatial variations on soil respiration. I investigated the effects of several local above- and below-ground quantities on soil respiration, as measured in chambers with an infrared gas analyzer. Twelve sites (at which respiration had previously been measured) were excavated, and dead organic mass, root mass, and root length at those sites determined. Surrounding forest stands were also characterized by measuring total basal area (ba) and distance of trees from respective chambers. Linear and simple non-linear regressions evinced no significant effect of measured below-ground properties on annual soil respiration averages. However, several above-ground stand properties were found in single-variable linear regressions to influence soil respiration significantly. These include number of trees within one and two meters of soil respiration chambers and total basal area of trees within two meters of the chambers (p-values from 0.005 to 0.021) (Fig. 1). While root mass and length were not found to be directly related to soil respiration, the highly significant effect of nearby trees indicates indirectly that root activity can be an important predictor of soil respiration. More work is needed to measure the effects of other root properties, such as root growth rates and symbiotic mycorrizal activity, on soil respiration.

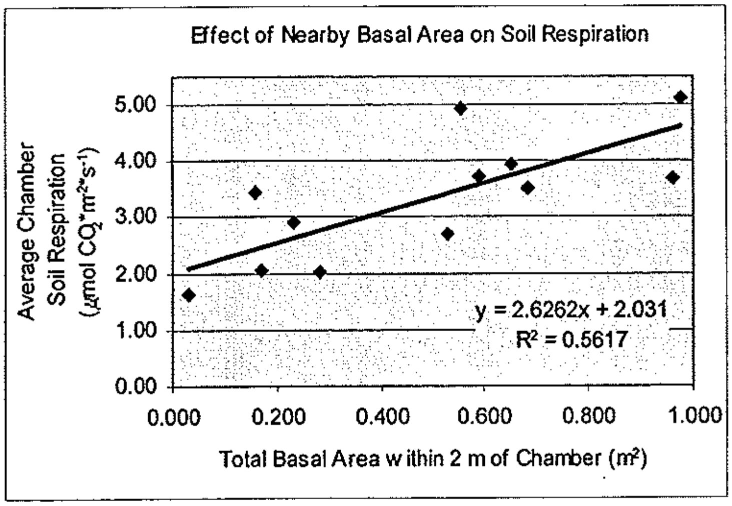



Figure 1: Linear relationship between nearby basal area and soil respiration at 12 sites. Respiration values represent averages of measurements made at 11 times during summer 2002. (C. Graham)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## Contributions of Litter Input and Root Activity to Carbon Cycling in a Temperate Mixed Hardwood Forest


*Margaret Graham*


Soil-atmosphere gas exchanges are an important component of the carbon cycle, but it is difficult to separate these processes from total ecosystem functioning. The exchange of methane and carbon dioxide between the atmosphere and soils was measured at the DIRT (Detritus Input, Removal and Trenching) site at Harvard Forest. The eighteen 3 x 3 m plots at DIRT consist of 3 replicates of 6 treatments: control, no litter (annual aboveground litter inputs excluded), double litter (twice the annual aboveground litter input), no roots (trenched plots), no inputs (trenched plots with annual aboveground litter inputs excluded), and OA-less (soil O and A horizons removed and replaced with B-horizon material from nearby excavations).

These treatments affect the soil temperature, soil moisture, and nutrient availability in the plots, and thereby impact the carbon cycle. Once a week the eighteen plots were sampled using an in situ static chamber incubation technique, and the air drawn was analyzed for methane and carbon dioxide. Significant differences were found among the treatments (Figs. 1, 2).

Carbon storage dynamics were explored using the control treatments and no input treatments. The no input treatments are an ideal setting for quantifying the short-term, labile carbon pool in soil, since they are using up this available carbon but are not able to replenish it.

**Figure 1. Average $CO_2$ respiration to date, 2003**

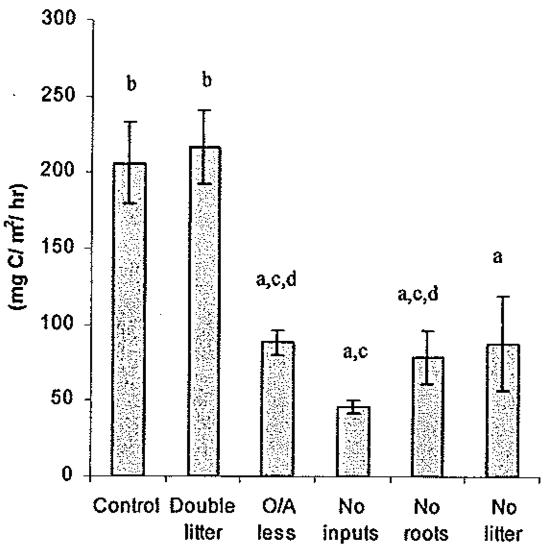
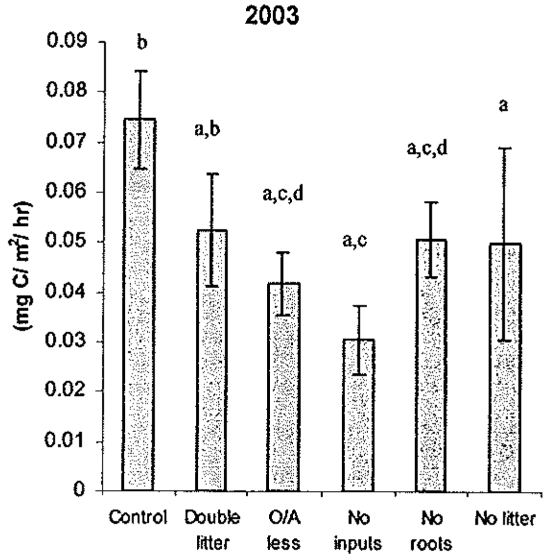



**Fig. 2. Average $CH_4$ uptake to date, 2003**




Means with the same letter are not significantly different (ANOVA). (M. Graham)

## Photosynthetic Rates of *Betula lenta*: Effects on Ecosystem Carbon Storage Rates in a Changing Environment

*Brady S. Hardiman*

As Hemlock Woolly Adelgid (*Adelges tsugae*) spreads northward, hemlock (*Tsuga canadensis*) stands face decimation, and black birch (*Betula lenta*) is the predicted primary successor (Orwig and Foster, 1998). Black birch is moderately shade intolerant, as compared to the shade tolerant hemlock, and this implies different photosynthetic rates, as well as the potential for higher rates of atmospheric carbon uptake. Seven black birch and four red oak (*Quercus rubra*) trees in the Harvard Forest, Petersham, MA within reach of a canopy lift were selected for comparison. The photosynthetic rates of these trees were measured with a Li-6400 Photosynthesis Machine (Li-Cor). Light curves at 25, 30, 35°C were obtained from leaves in the upper canopy of each tree. Curves were fitted to the data using S-Plus 6.1. Black birch light curve data at different temperatures were compared to similar data from hemlock trees taken from Hadley and Schedlbauer (2002). Black birch showed higher light saturated photosynthesis rates at a given temperature and lower light compensation points (Fig. 1a, b [page 18]). Black birch also showed an increase in its photosynthetic rate from 25°C to 30°C, an interval over which a decline in hemlock rates was observed. Rates for both species declined from 30°C to 35°C, though the decline was greater for hemlock. A comparison of red oak, black birch, and hemlock light curves illustrates that both deciduous species, though not significantly different from each other, are significantly higher at light saturation than hemlock (Fig. 2 [page 19]), implying an increase in carbon fixation rates per unit leaf area as hemlocks die and are replaced by black birch. As the total leaf area of the successional black birch forest approaches that of the current hemlock forests, canopy carbon assimilation may increase to rates higher than those currently observed in hemlock forests, and is likely to maintain a higher carbon uptake rate in a warmer climate.

Hadley, J. L. and J. L. Schedlbauer. 2002. Carbon exchange of an old-growth eastern hemlock (*Tsuga canadensis*) forest in central New England. Tree Physiology 22: 1079-1092.
Orwig, D. A. and D .R. Foster. 1998. Forest response to the introduced Hemlock Woolly Adelgid in southern New England, USA. Journal of the Torrey Botanical Society 125: 60-73.

**Testing the Segmentation Hypothesis in *Acer Saccharum*: Cavitation Thresholds of Xylem Vessels in Different Regions of the Tree**

*Eleanor Lahr*

The segmentation hypothesis was proposed by Martin Zimmerman to explain how plants protect themselves from the spread of embolism through their water transport systems. He suggested that as water travels from the roots to the canopy under increasing negative pressure, the cavitation threshold of xylem vessels should decrease. In times of stress or injury a tree would preferentially sacrifice distal branches before main trunk sections. To test this hypothesis I measured cavitation thresholds of pit membranes at vessel junctions in *Acer saccharum* by observing the positive pressure required to force gas across a bordered pit field.

Previous work on *Acer saccharum* had shown that current year xylem transports more water than older years. I used the single vessel technique to measure resistance of current year xylem in 1, 3, 7, 11, and 25-year-old sections of the tree, as well as in the main trunk, roots, and petioles. Cavitation thresholds were lowest in the most distal organs of *A. saccharum*, with mean values of 3.05 MPa for current year extensions and 2.95 MPa for small roots. Older areas of the tree had higher cavitation thresholds; xylem from the trunk showed the greatest resistance with a mean cavitation threshold of 4.82 MPa. These findings support the segmentation hypothesis that distal areas of a tree have a lower cavitation threshold and are more vulnerable to the formation of embolism.

**The Mycorrhizal Status of a Carnivorous Plant, the Northern Pitcher Plant (*Sarracenia purpurea* L.)**

*Matthew K. Lau*

Mycorrhizae are mutualistic symbioses in which plants exchange organic energy for soil minerals from fungi. Mycorrhizae are found in almost all natural habitats where plants are found. Mycorrhizae in wetlands, especially carnivorous plants, are understudied. The purpose of this study was to determine the mycorrhizal status of *Sarracenia purpurea*, a carnivorous plant that primarily inhabits nutrient poor wetlands. *Sarracenia purpurea* were collected from Tom Swamp in Petersham, MA during the month of July 2003. Roots from each plant were washed, cut from the main primary root, cleared, stained, macerated and mounted for viewing under a compound microscope. Both arbuscules and vesicles were present in the lateral roots of the *S. purpurea* sampled, but colonization was extremely sparse. *Sarracenia*

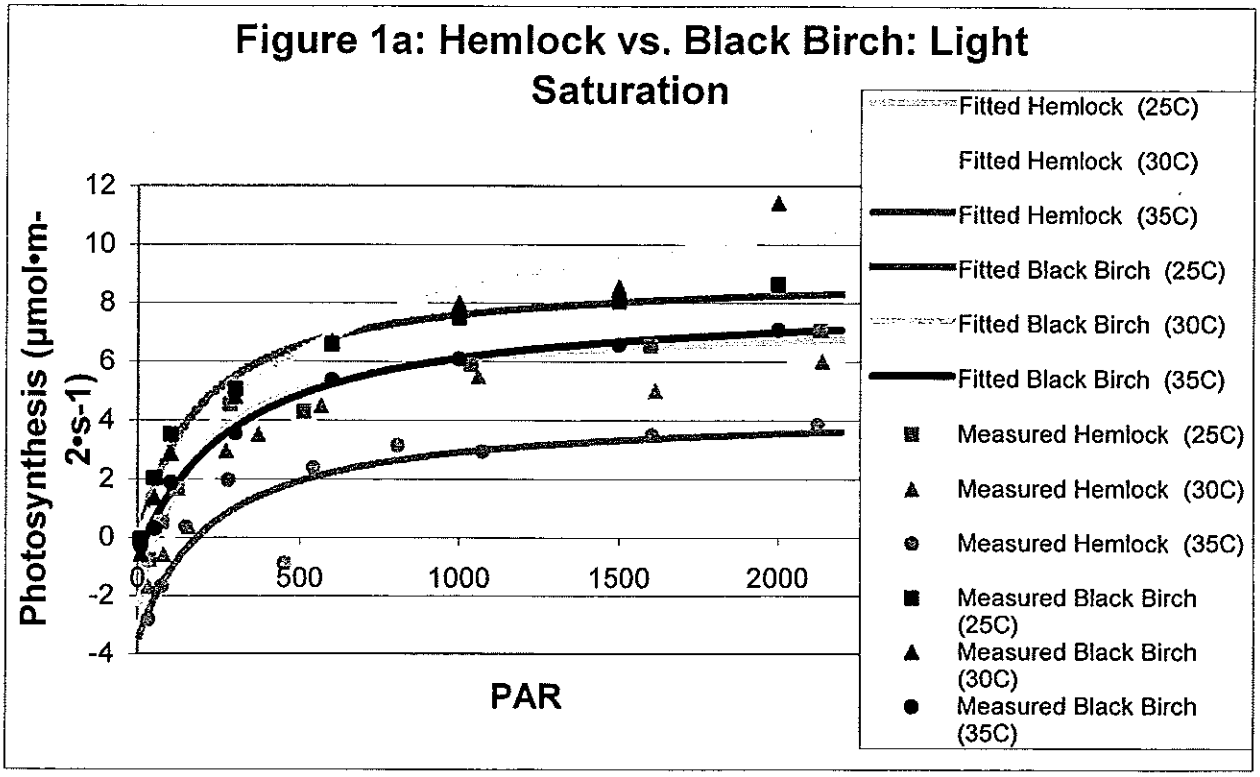



**Figure 1a.** Hemlock and black birch photosynthetic rates at high light levels at 25, 30, 35°C. (Hardiman)

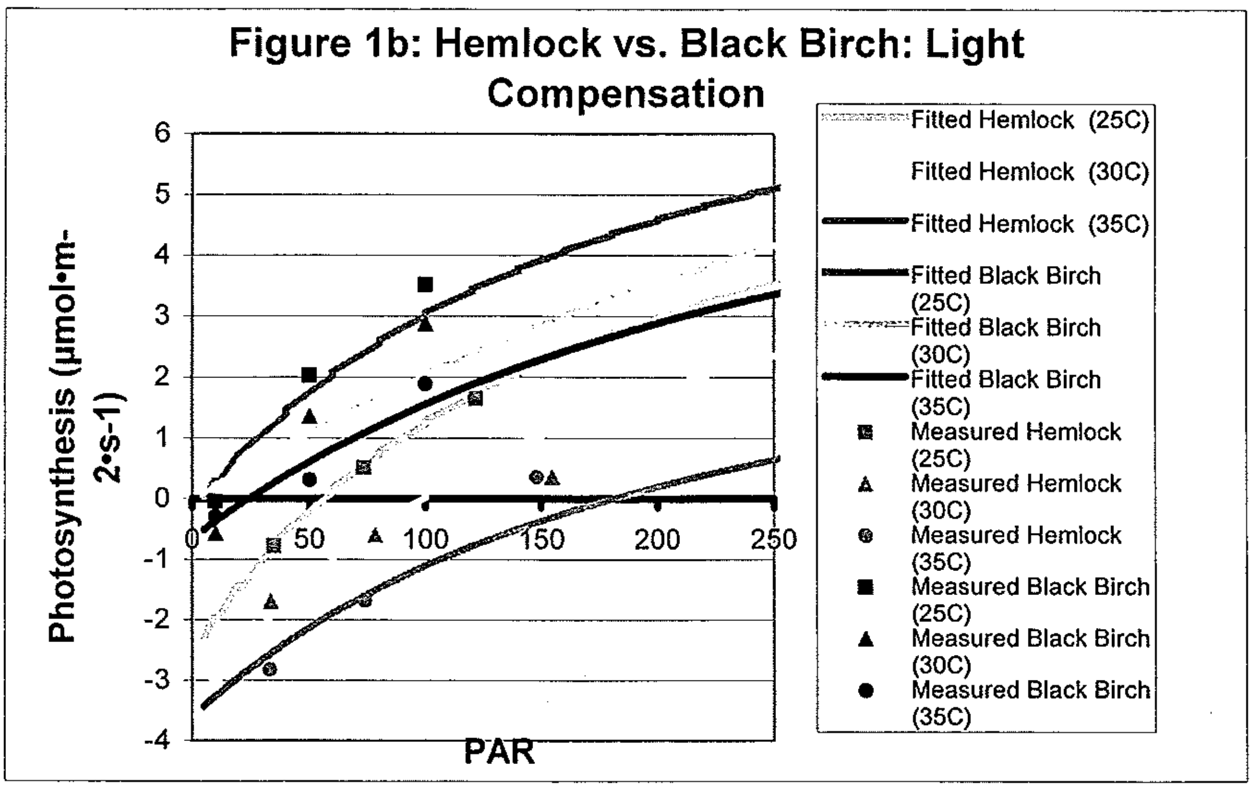



**Figure 1b**: Light compensation values of hemlock and black birch at 25, 30, 35°C. The light compensation point of each curve is where it intersects the x-axis, meaning no net photosynthesis and no net respiration. (Hardiman)

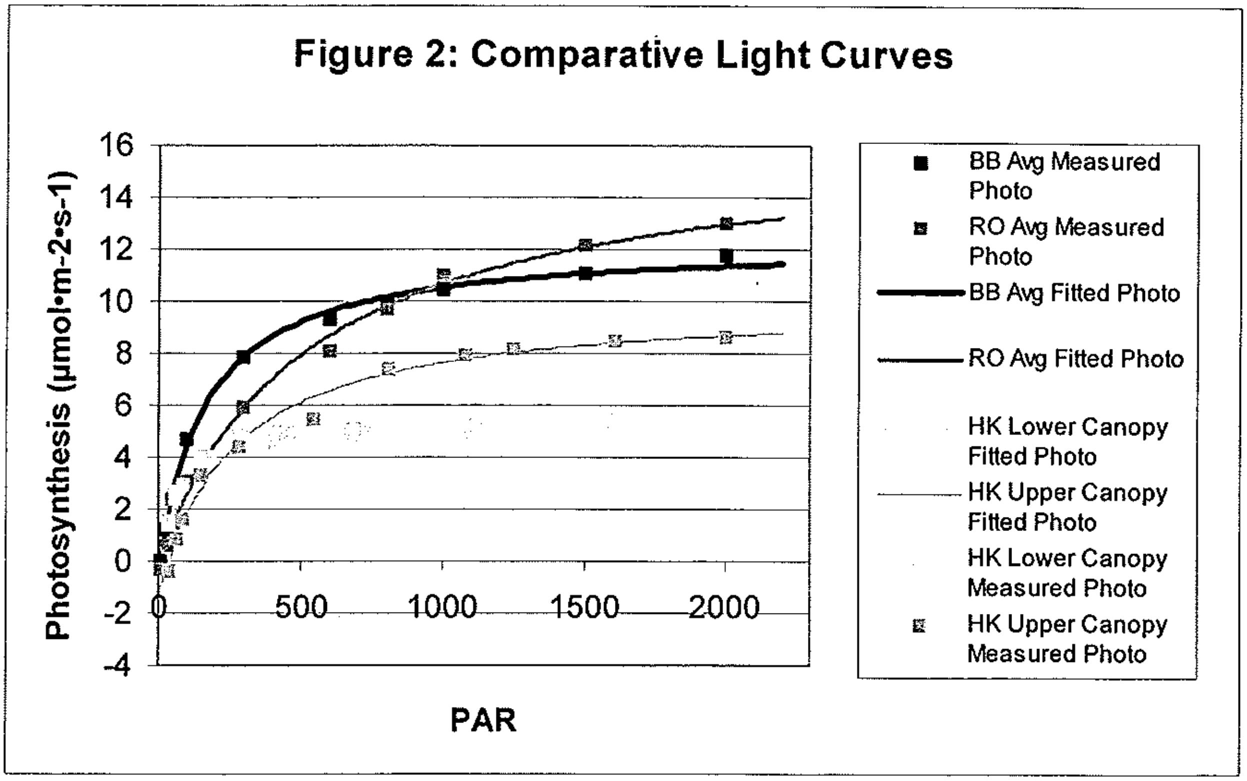



**Figure 2.** Light curves of red oak, black birch, and upper and lower canopy hemlock. (Hardiman)

*purpurea* is most likely endomycorrhizal, forming mutualisms with arbusular mycorrhizal fungi; however mycorrhizal colonization of *S. purpurea* during the time in which this study was conducted was low. This is perhaps a result of the low phosphorus availability in Tom Swamp. The naturally low nutrient level in nutrient-poor wetlands may present an opportunity to test the effects of nutrient levels on mycorrhizae through controlled nutrient addition experiments.

## The Effect of Selective Logging on Coarse Woody Debris Dynamics

*Zachary Liscow*

The issue of anthropogenic global climate change is of imminent importance as policy-makers seek methods to slow the increase of atmospheric greenhouse gas concentrations in order to mitigate the potential effects of this increase. As New England forests mature, it may be beneficial to utilize active management techniques to promote carbon uptake in forest regrowth in order to maintain what appears to be a terrestrial carbon sink. This study quantified the coarse woody debris component of the carbon budget and determined the decay rates of both a selectively logged forest and a control non-logged site. A Markov model was used to predict how coarse woody debris would transition through decay classes.

The amount of carbon stored in coarse woody debris was quantified using field measurements of all coarse woody debris found in eight randomly placed plots at the cut site and fifteen randomly placed plots at the control site. Dimension and decay class measurements were taken at the logged site in 2001 and 2003 and at the control site in 2000 and 2003. The measurements show that the total amount of carbon stored as coarse woody debris has not changed significantly at either site since the previous surveys. The Markov model considered pieces of coarse woody debris present in both surveys to predict decay class transitions and estimate decay rates. The initial estimated decay rate, 0.0811 $yr^{-1}$ is lower than that of the non-logged plots, 0.142 $yr^{-1}$. However, because of the larger amount of carbon stored in coarse woody debris in the cut site, the total amount carbon decayed is higher in the logged site, 1.31 MgC/ha/yr, as compared to the control site, 0.81 MgC/ha/yr.

These results suggest that the coarse woody debris that accumulates as a result of selective logging persists longer than the coarse woody debris in the control site due to the apparently slower decay rate. They also emphasize the importance of considering coarse woody debris when assessing the efficacy of using active forest management techniques to increase the ability of northern hardwood forests to act as a carbon sink.

## Investigation of *Robinia pseudoacacia* Impact on the Understory Vegetation of Cape Cod National Seashore

*Rebecca Lohnes*

*Robinia pseudoacacia* (black locust) is a nitrogen fixing canopy-height tree that is not native to Massachusetts. It was identified as the most abundant invasive plant species in Cape Cod National Seashore (CCNS). Contiguous *R. pseudoacacia* stands occur throughout the CCNS within a greater matrix of *Pinus rigida*, *Quercus velutina* and *Q. alba* forest. We investigated the effects of *R. pseudoacacia* on understory vegetation in contiguous stands of this species by conducting botanical surveys throughout the CCNS during the Summer of 2003.

We selected *R. pseudoacacia* stands within 250 meters of former Harvard Forest study sites in order to get a sense of the land use history and environmental conditions. Twenty by twenty meter plots were established within 18 *R. pseudoacacia* stands (>25% cover) and within seven paired native pine-oak stands (data on more native, *R. pseudoacacia*, and other nonnative stands is pending). Paired native stands were located within close proximity to the *R. pseudoacacia* stands and were assumed to have shared similar land-use histories. Within each plot, all plant species were identified and percent cover was estimated for each species. We then compared the nonnative, native and total species richness and abundance using Wilcoxon Signed Rank tests.

Nonnative understory richness is significantly higher in stands of *R. pseudoacacia* (Z-value= -2.2012, p= 0.0277), as is nonnative understory abundance (Z-value=-2.366, p=.0180, see Fig.1). Non-native shrubs including *Lonicera morrowii* and *Rosa multiflora* and the vine *Celatrus orbiculatus* were most common in *R. pseudoacacia* stands. This preliminary finding suggests that the understories of *R. pseudoacacia* stands have more introduced species than paired native pine-oak stands. Further studies will investigate whether this increased invasiblity of *R. pseudoacacia* stands in CCNS is due to historic land use (the stands are all in former agricultural land) or the biology of the tree itself (its nitrogen fixing properties or its tendency to have a sparse canopy and a sunny understory).

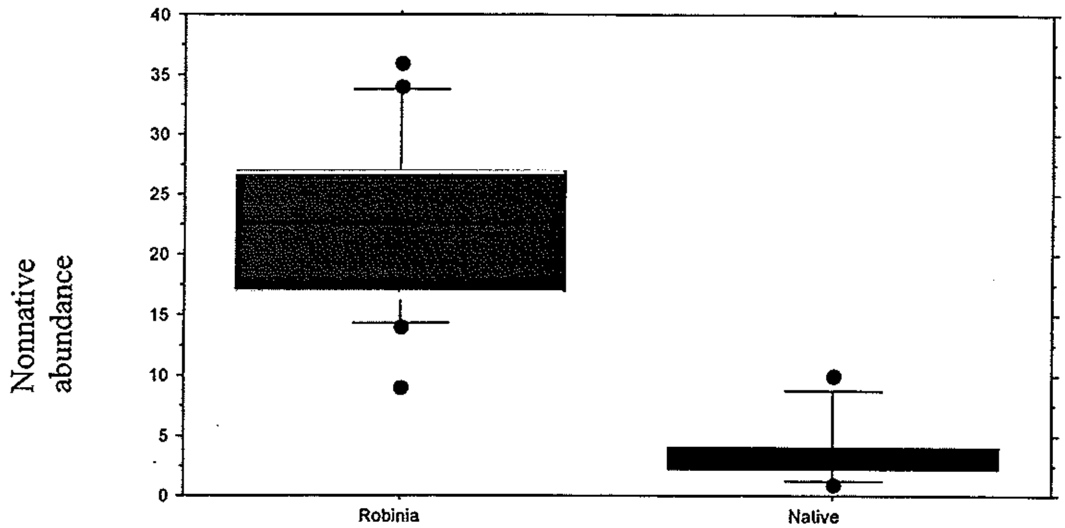



Figure 1. (Lohnes)

**Assessing the Effectiveness of Land Conservation in the North Quabbin Region of Massachusetts, from 1993 to 2003**

*Nicholas Malizia*

Through the efforts of numerous land conservation organizations, the North Quabbin Region of Central Massachusetts has become one of southern New England's largest protected bioreserves. This study developed a methodology to assess the effectiveness of lands acquired in the region between 1993 and 2003 in contributing to the protection of a diverse ecological and cultural landscape. An index was developed to assess the value of the protected areas in terms of their land cover characteristics (whether the land is forested, used for agriculture, a riparian zone, or viable wildlife habitat) as well as other landscape factors such as the size of the area and proximity to already protected lands. Geographic Information System (GIS) technology was used to assign weights to, and then combine, layers containing spatial information of the index components. A number of weightings were used and different indexes were developed to identify areas of conservation priority based on a number of ecological and cultural concerns.

The relative operating characteristic (ROC; Pontius and Schneider, 2001) was used to evaluate the effectiveness of recent land protection efforts; in all cases, lands protected between 1993 and 2003 scored better than random, indicating that parcels protected during this time were concentrated on areas of high ecological or cultural value. To date, this methodology has only been used to assess the value of lands that are currently protected; however, it will also serve as a useful tool to prioritize lands for future conservation action.

Pontius, Jr., R. G. and L. Schneider. 2001. Land-cover change model validation by an ROC method for the Ipswich watershed, Massachusetts, USA. Agriculture, Ecosystems and Environment. 1778: 1-10.

## Short Term Effects of a Selective Harvest on Tree Growth in a Mixed Deciduous Forest Adjacent to the Harvard Forest

*Kathryn McKain*

The carbon dynamics of forested ecosystems may be manipulated through management. Harvesting these carbon sinks results in the transfer of stored carbon pools from live wood to timber removals and accrual in dead wood on site, in addition to the remaining live biomass. Some authors have hypothesized that following a harvest, these remaining trees will experience increased growth rates due to the release of resources such as light and nutrients (Harmon *et al.* 1990). Furthermore, shade tolerant tree species that reside in the sub-canopy prior to harvesting, such as beech (*Fagus grandifolia*) and red maple (*Acer rubrum*), may experience a competitive release upon the opening up of the canopy.

In 2001 a selective harvest occurred in a plot of land adjacent to the Harvard Forest. The cut removed approximately 26% of the live biomass, typical for harvest operations of the North Quabbin region of Massachusetts (Curry 2002). Eight circular, 10m radius plots were installed on the cut site, following the same methods used for the 34 plots installed on adjacent, uncut land. Tree growth, measured via the expansion of dendrometers, was measured on a weekly basis during the growing season from 1999 through 2003. The data was analyzed for changes in growth rates within tree species and size classes. The data from two years following the harvest show little evidence for increases in growth rates of oak species, but possible increases in red maple and beech, especially among larger size classes. Further analysis of growth rates during reforestation in the coming years will help to predict future species composition and provide insight into changing carbon dynamics.

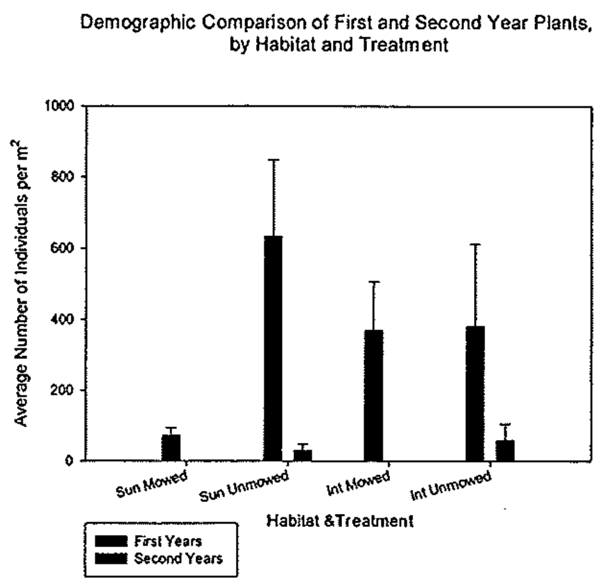
Curry B. 2002. The initial impact of selective harvest on aboveground carbon storage in a northern temperate forest. Notre Dame (IN): University of Notre Dame. 34 p.

Harmon M. E., W. K. Ferrell and J. F. Franklin. 1990. Effects on carbon storage of conversion of old-growth forests to young forests. Science 247: 699-702.

## Effects of Soil Disturbance and Mowing on the Demographic Structure and Seedling Performance in Garlic Mustard (*Alliaria petiolata* (Brassicaceae)) Populations

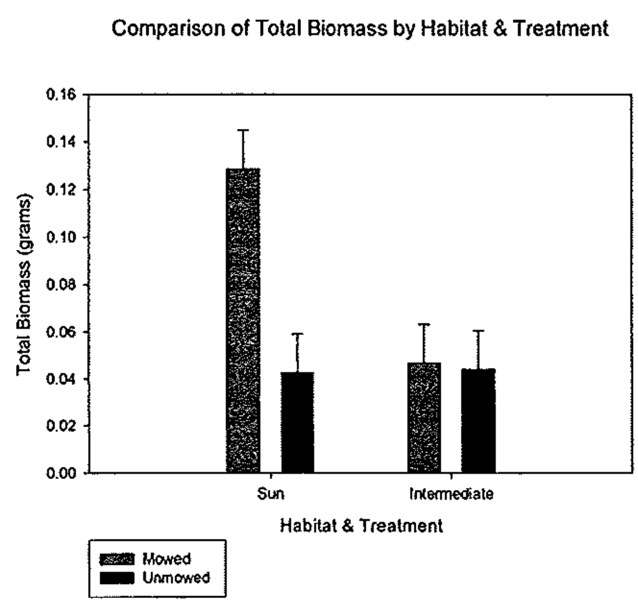
*Julia K. Nelson*

Studies show anthropogenic disturbances often correlate with the presence of invasive species, yet no studies have explored human influences on the distribution, demography, or performance of garlic mustard (*Alliaria petiolata)*, an invasive Eurasian biennial. This study examined the effects of human-generated soil disturbance and mowing on demographic structure and seedling performance in garlic mustard populations in the mixed deciduous Harvard Forest. We selected adjacent mowed and unmowed sites in sun and intermediate habitats, and disturbed and undisturbed sites in two intermediate habitats, one recent, with vegetation stripped and topsoil eroded, the other excavated 6-8 years ago. Demographic data was taken in a midsummer survey of 1 $m^2$ plots established randomly along transects at each site, with 4-10 replicates according to size of population. We harvested twenty seedlings per site and measured leaf area and biomass as indices of performance and resource allocation. Mowing significantly affected second years in both habitats, eliminating adult plants (Fig. 1). Aboveground biomass was higher in first years in sunny mowed sites, due to increased light (Fig. 2). Surface disturbance also positively affected number of first years and their performance by increasing aboveground biomass (Fig. 3). In the older excavation disturbance, however, soil disruption negatively impacted establishment and performance of first year garlic mustard (Fig. 4). A high root/shoot ratio indicated allocation of resources to roots, perhaps to counteract poor soil conditions (Fig. 5). Some anthropogenic disturbances may increase first year performance and help establish new self-sustaining source populations, while others may be so disruptive that disturbance sites remain sinks. In predicting invasive spread, habitat and specific disturbance history are important factors to consider.




| ANOVA (First Years): | | | ANOVA (Second Years): | | |
|---|---|---|---|---|---|
| **Habitat:** | **P=0.9077** | **NS** | **Habitat:** | **P=0.4676** | **NS** |
| **Treatment:** | **P=0.1464** | **NS** | **Treatment:** | **P=0.0311** | ** |
| **Habitat x Treatment:** | **P=0.1651** | **NS** | **Habitat x Treatment:** | **P=0.4676** | **NS** |

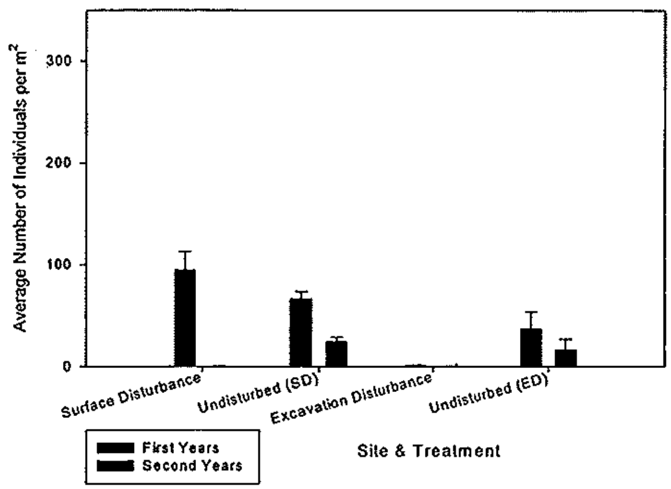
Figure 1. (Nelson)




| ANOVA: | | |
|---|---|---|
| **Habitat:** | P=0.0162 | ** |
| **Treatment:** | P=0.0083 | ** |
| Habitat x Treatment: | P=0.0128 | ** |

Figure 2. (Nelson)

Demographic Comparison of First & Second Year Plants, by Site & Treatment

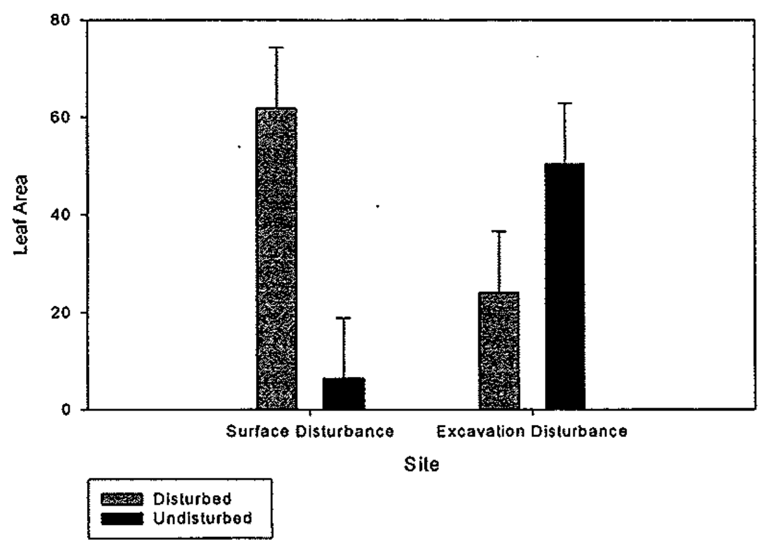



**ANOVA**

| | |
|---|---|
| **Site:** | **P=0.0003 **** |
| **Treatment:** | **P=0.8013 NS** |
| **Site x Treatment:** | **P=0.0406 **** |

**Figure 3.** Nelson)

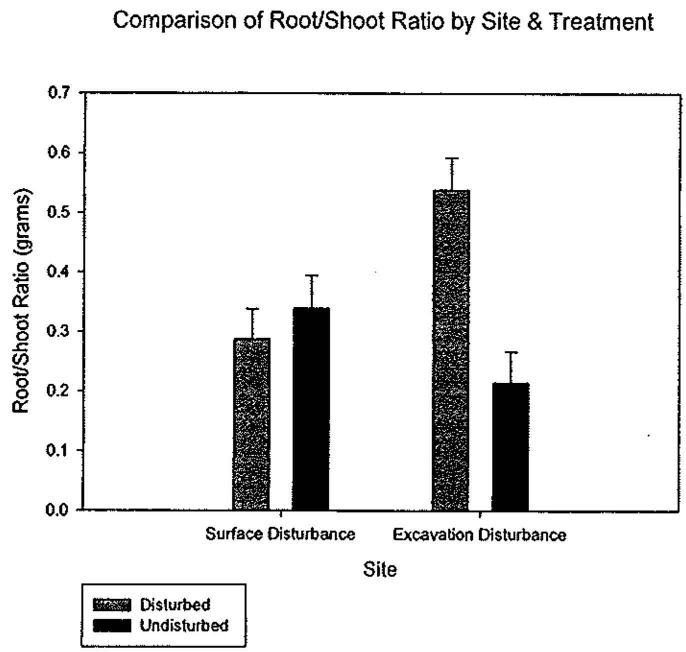
Comparison of Leaf Area by Site & Treatment




**ANOVA:**

| | |
|---|---|
| **Site:** | **P=0.7863 NS** |
| **Treatment:** | **P=0.2374 NS** |
| **Site x Treatment:** | **P=0.0016 **** |

**Figure 4.** (Nelson)




| | |
|---|---|
| **ANOVA:** | |
| **Site:** | **P=0.2320 NS** |
| **Treatment:** | **P=0.0116 **** |
| **Site x Treatment:** | **P=0.0006 **** |

Figure 5. (Nelson)

## Hemlock Woolly Adelgid's Migration Across the Central Massachusetts Landscape

*Don Niebyl*

The hemlock woolly adelgid (*Adelges tsugae*, HWA), an invasive aphid-like insect from Asia, appeared in southern Massachusetts in 1989, migrating farther north every year since its discovery. This insect targets the eastern hemlock (*Tsuga canandensis)*, feeding on the tree's sap, depleting its resources, causing eventual mortality. The objectives of this study are to: (1) track and map the northern migration of HWA across central Massachusetts; (2) obtain baseline information concerning local hemlock stands; and (3) determine whether stand level characteristics affect the spread of HWA.

Hemlock stands throughout the entire area of central Massachusetts were mapped on USGS topographic maps using color infrared aerial photos. Then, fifty plots were selected across the study area based on hemlock density, stand size, and accessibility. HWA infestation and stand level characteristics were measured using fixed-radius plots and 20-meter by 20-meter square plots.

Of the fifty stands visited, 49% were infested with HWA, and of that 49% infested, 20% were experiencing HWA related damage or mortality. The average percent overstory composition of hemlock ranged from 36% to 79% and averaged 57%, with red maple (*Acer rubrum*) and red oak (*Quercus rubra*) both averaging ~10%. The average aspect in all stands was 202 degrees, with 42% of stands occurring on a west aspect. The average slope was 19%, and the average humus depth was 5 cm. It was concluded from this study that higher damage and mortality rates were associated with stands in the southern part of the state, where HWA has existed longer while it was migrating north. Additionally, there were no correlations found between HWA infested sites and any stand level characteristics.

## Vegetation And Ecosystem Dynamics Following Selective Hemlock Logging

*Amanda Park*

Since its arrival to Connecticut in the mid-1980s, the hemlock woolly adelgid (HWA) has caused major damage to hemlock-dominated forests and has resulted in increased logging practices (Orwig *et al.*, 2002). As HWA migrates north into Massachusetts, subsequent hemlock logging can be anticipated. This study is a preemptive investigation of the consequences of selectively removing hemlock from forests in central Massachusetts. I investigated the changes that occurred in vegetation and nitrogen cycling following selective hemlock logging in non-HWA infested hemlock dominated forests. Two five-year old and two twelve-year old logged areas in central Massachusetts were selected for study during the summer of 2003. At each site, two-400 $m^2$ plots were established and sampled for overstory and understory vegetation. Soil cores were used to evaluate net nitrification and net mineralization. Results were compared to vegetation and ecosystem changes following HWA infestation observed by Kizlinski *et al.* (2002). Selective hemlock logging led to overall higher seedling densities than HWA infestation. In both five and 12 year-old logged sites, hemlock seedlings had the highest relative density, followed by black birch. Logged sites exhibited sapling densities nearly 20 times those of HWA infested sites. Selective logging also generated higher percent cover of high-light species of shrubs and herbs such as *Rubus* species and hay-scented fern than HWA. Logged sites had low levels of available nitrate and net nitrification values of zero, while available ammonium and net mineralization values were much higher, especially in more recent cuts. Due to time constraints, nitrogen data are inconclusive because of a shortened incubation period and only one round of analysis. Established plots and data collected in this study will be used in further investigations by Harvard Forest researchers.

Kizlinski, M. L, D. A. Orwig, R. C. Cobb, and D. R. Foster. 2002. Direct and indirect ecosystem consequences of an invasive pest on forests dominated by eastern hemlock. Journal of Biogeography 29: 1489-1503.

Orwig, D.A., D. R. Foster and D. L. Mausel. 2002. Landscape patterns of hemlock decline in New England due to the introduced hemlock woolly adelgid. Journal of Biogeography 29: 1475-1487.

## Exploratory Study to Assess the Role of Evapotranspiration in the Water Budget of Harvard Forest

*Daberat Perez-Rivera*

Vegetation plays a vital role modulating the effects of climate change over the water and energy balance of the ecosystems. We want to understand how the water table changes due to evapotranspiration. Our study area is in an intermittent stream near trees of eastern hemlock and red oak on both sides of the streams along observational wells spread in Harvard Forest in Petersham, MA. This project aims to understand how the water table changes due to evapotranspiration. This is the first stage of a LTER hydrological project, and analysis of historic data stored in the Harvard Forest archive is being carried out in order to introduce into the project the knowledge accumulated by previous researchers 30 years ago. This analysis allows us to gain insight into the functioning of the ecosystems through observations taken from the variability of the ground water table level on a daily basis at different wells in the forest. We compare this data with data available for precipitation and temperature for the same period of time and we determine the expected values of actual transpiration for the immediate surrounding vegetation and analyze the variation of the water level. We found periods when the precipitation is greater than the evapotranspiration and the water level increases. Also, when the evapotranspiration is greater than precipitation the water level decreases. On the other hand we have different effects when snowmelt occurs and the base flow contribution affects the water level.

### The Effect of Hemlock Woolly Adelgid (*Adelges tsugae*) on the Hydraulic Properties of Eastern Hemlock (*Tsuga canadensis*)

*Chris Petit*

Eastern hemlock is a dominant species found within New England forests. Hemlock stands provide microclimates characterized by unique wildlife habitat, wildlife cover, and soil geochemistry due to the dense shade found beneath their canopy. Hemlock woolly adelgid (HWA) is an introduced aphid-like pest from Japan, which kills eastern hemlock indiscriminately and has been causing a rapid decline in hemlock populations. Though the patterns of infection and mortality of hemlock in New England forests have been investigated, the direct cause of death from HWA is unknown. Because HWA feed exclusively on xylem parenchyma at the base of the needles, HWA may disrupt the xylem leading to lower photosynthetic rates and reduced growth. We tested the hypothesis that the water transport capacity of hemlock is reduced by HWA by comparing the hydraulic conductivity of small branches and leaves of healthy and infected trees. There were no significant differences between healthy and infected trees in either the xylem specific conductivity or the leaf specific conductivity of small branches. Nor were there differences in the hydraulic conductivity of the leaves themselves or in the vulnerability of small leaf-bearing branches to cavitation. These data suggest that HWA does not negatively impact hemlock's water transport system. More research is needed to determine how HWA infestation leads to the decline and ultimate death of hemlock trees.

### Eastern Hemlock: Surviving by Grassroots

*Nick Povak*

With the encroaching problem of the hemlock woolly adelgid (HWA; *Adelges tsugae*) on eastern hemlock (*Tsuga canadensis*) forests, many landowners are faced with a problem that, as of yet, science has failed to provide a solution for. Many landowners have relied on a single salvage harvest prior to infestation to deal with HWA. These preemptive cuts abruptly remove the overstory with little regard given to the future regeneration of the forest. Orwig (2002) found that hemlocks can be infested for 10-15 years before mortality occurs. This indicates that landowners have ample time to develop a management plan for their hemlock forests. While silvicultural methods have not been proven effective against the spread of the adelgid, they do have a role in securing a more desirable future forest. To promote these practices, an easy-to-use guide was developed specifically for local landowners. This guide will help them make informed management decisions by introducing them to forestry theory and its application in hemlock forests. Landowners will be given management options that are specific to their current forest characteristics and landowner objectives. A final goal of this guide is to promote other management and research groups to follow suit and produce additional helpful resources specifically designed for landowners and their hemlock forests.

Orwig, D. A. 2002. Stand Dynamics Associated with Chronic Hemlock Woolly Adelgid Infestations in Southern New England. *In: Symposium on the Hemlock Woolly Adelgid in Eastern North America Proceedings*. New Jersey Agricultural Experiment Station, New Brunswick, New Jersey.

### Chronic Nitrogen Addition Alters the Functional Capacity of the Litter Decomposer Community

*Eric Saas*

The objective of this study was to examine the function of the microbial community in decomposing foliar litter in both pine and hardwood forest stands under varying levels of N addition. Leaf litter samples were collected from the Harvard Forest Chronic Nitrogen Addition Plots, an LTER site located in Petersham, Massachusetts. For each forest stand there are three N addition plots: control (no N added), low N (5 g N $m^{-2}$ $yr^{-1}$ as $NH_4NO_3$), and high N (15 g N $m^{-2}$ $yr^{-1}$ as $NH_4NO_3$). Four replicate samples were collected from each plot and the microbial response to 25 carbon sources (two carbohydrates, eight amino acids, and fifteen carboxylic acids) was determined. This procedure allowed us to examine the effect of N additions on total microbial biomass and the functional capacity of the litter microbial community. A significantly higher amount of microbial biomass was found in the hardwood control plot versus the nitrogen-addition hardwood plots. There was no significant effect of N addition on biomass in the pine stand. There was a trend toward increasing functional diversity in the hardwood stand as N availability increased. In summary, the nature of the microbial community in the hardwood stand has changed through N addition. Our results indicate that under certain conditions chronic nitrogen addition alters the constitution and functional capacity of the litter decomposer community.

### The Effects of Wind on Nearground Atmospheric $CO_2$ in a Mature Hardwood-Conifer Forest in Central Massachusetts

*Alex Sanchez*

Carbon dioxide is a spatially and temporally dynamic resource in forest ecosystems, but little is known about how weather, soil properties, and the plant community interact to regulate diurnal fluctuations in naturally-enriched near ground $CO_2$ (NEC) levels. We measured diurnal patterns of NEC concentrations, soil temperature and wind speed across July 1-5, 2003 in a permanent woodlot site in Prospect Hill, with a particular focus on daytime and nighttime effects of wind speed on NEC concentrations. $CO_2$ was measured every 30 min simultaneously at two heights (10, 30 cm) at 23 locations spaced regularly across a 30 x 50 m grid. Soil temperature (5 cm) was measured with thermistors every 10 s and averaged every 10 min at 8 locations. Wind speed was measured continuously at 40 cm and averaged every 10 min with DC-output cup anemometers at 3 locations. Mean $CO_2$, soil temperatures, and wind speeds were calculated every 10-30 min across the five days for the 3 locations with anemometers to provide an average 24-hr cycle for these three variables. Soil temperature was used to estimate soil respiration rates using empirical relationships for similar soils in the Harvard Forest. NEC concentrations were plotted against the predicted soil $CO_2$ flux and regression residuals were calculated for each data point. The $CO_2$ residuals were then plotted against wind speed to estimate the effects of wind on temporal NEC variation once soil temperature, and thus estimated $CO_2$ flux to the near ground environment, was accounted for.

NEC concentrations showed a near sinusoidal cycle (100 ppm range) that peaked at ~1:30 am EST and reached a minimum 12 hours later, with a somewhat faster rate of change in the early morning than in the evening (Fig. 1). Soil temperature was about 6.5 hrs out of phase with NEC, peaking at 8 pm. Wind speeds were negligible on most nights and present in the understory on all but the calmest days. NEC levels fall throughout the early morning hours due to declining soil temperatures and possibly because of cold air subsidence from the upper canopy into the lower strata. Net photosynthesis and wind may both contribute to the midday NEC depression. Rising soil temperatures, calmer conditions, and photosynthetic shutdown combine to cause the relatively rapid rise in NEC in the early evening. There was no significant relationship between wind speed and $CO_2$ residuals for either the daytime (6 am–8 pm) or nighttime (8 pm–6 am) hours (Fig. 2). The mean $CO_2$ residual during the daytime (-55 ppm) was very large compared to the negligible mean residual at night (+3 ppm). The mean $CO_2$ residual during the day was approximately the same for calm conditions (-56 ppm) as it was when some wind was present (-52 ppm), suggesting that photosynthetic uptake was more important for near ground depletion of $CO_2$ than any mixing due to the relatively low wind speeds measured during this 5-day period. Analysis of diurnal patterns on other sample nights with more wind showed that even though wind speeds are usually much greater during the day, their relative impact on NEC concentrations is more pronounced at night.

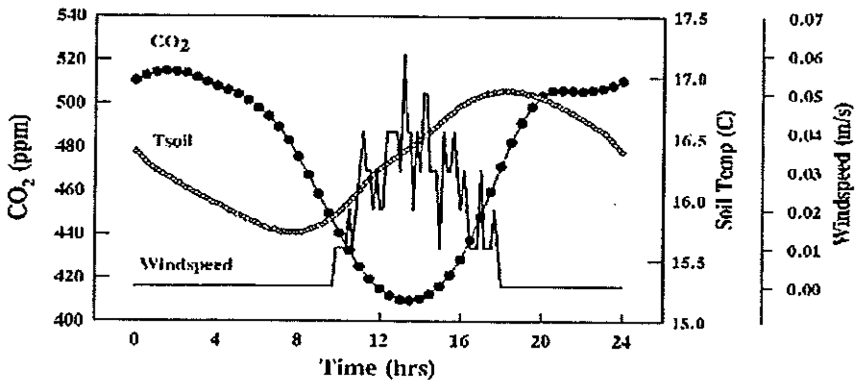



Figure 1. Diurnal patterns of nearground $CO_2$ (10-30 cm), soil temperature (5 cm) and windspeed (40 cm) averaged across July 1-5, 2003 in a permanent woodlot site in Prospect Hill. The $CO_2$ curve is smoothed (N=7). (A. Sanchez)

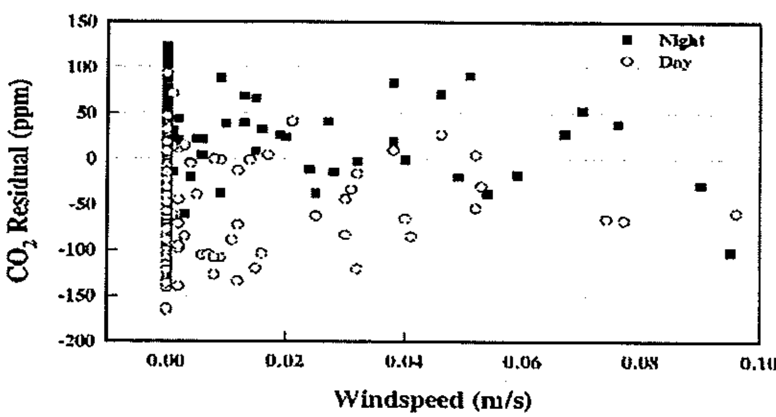



Figure 2. Relationships between windspeed (40 cm) and residual nearground $CO_2$ concentration (10-30 cm) during daytime (6 am-8 pm) and nighttime (8 pm-6 am) hours measured over July 1-5, 2003 in a permanent woodlot site in Prospect Hill. See abstract for explanation of the $CO_2$ residual. (A. Sanchez)

**Effects of the 1938 Hurricane on Long-Term Forest Dynamics, Harvard Forest, Petersham, MA**

*Kristin Wilson*

Hurricane blowdown is a frequent, large-scale, and intense natural disturbance event that affects New England forests. Few studies have examined the long-term effects of hurricane damage on forest dynamics. Here we use a 2.9ha permanent plot to illustrate the persistent effects of hurricane damage 30-60 years after the 1938 Hurricane. Established in the 1960s, the area was differentially damaged by the 1938 Hurricane: low damage (11-25%, 1.7 ha), moderate damage (51-75%, 0.9 ha), and severe damage (91-100%). Diameter at breast height, condition, and location were recorded for all live and dead stems ≥5cm in 1969, 1975, 1987-1992, and 2001. Stand development followed different trajectories in the severe area versus the low and moderate areas. Structurally, the severe area lagged about 30 years behind the low and moderate areas, with lower basal areas and much higher stem densities thinning at a faster rate (Fig. 1). Compositionally, *Quercus rubra* and *Acer rubrum* were the dominant species across the site, but *Q. rubra* was more important in the low and moderate damage areas, whereas *A. rubrum* and *Betula* species were more important in the severe damage area. The different damage areas did not converge over time; *B .lenta* and *B. alleghaniensis* became more important in the severely damaged area over time, whereas a growing number of later-successional species (*Fagus grandifolia, Tsuga canadensis,* and *A. saccharum*) recruited into the low and moderate damage areas. This study indicates that forest recovery following hurricane disturbance is a gradual process extending beyond the timeframe of most studies.

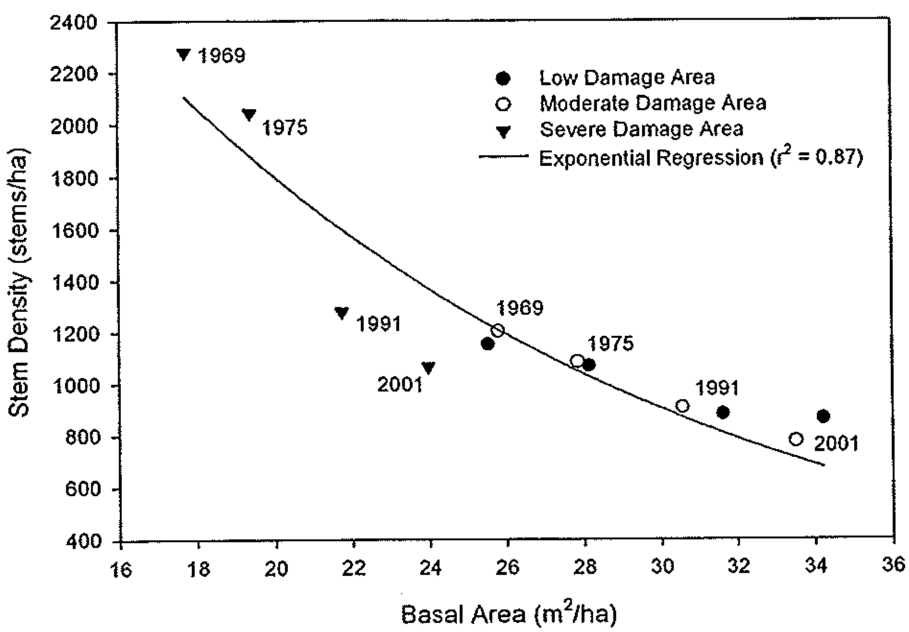



**Figure 1.** (Wilson)

## The Influence of Habitat on the Demography, Meristem Allocation, and Fecundity of *Alliaria petiolata*

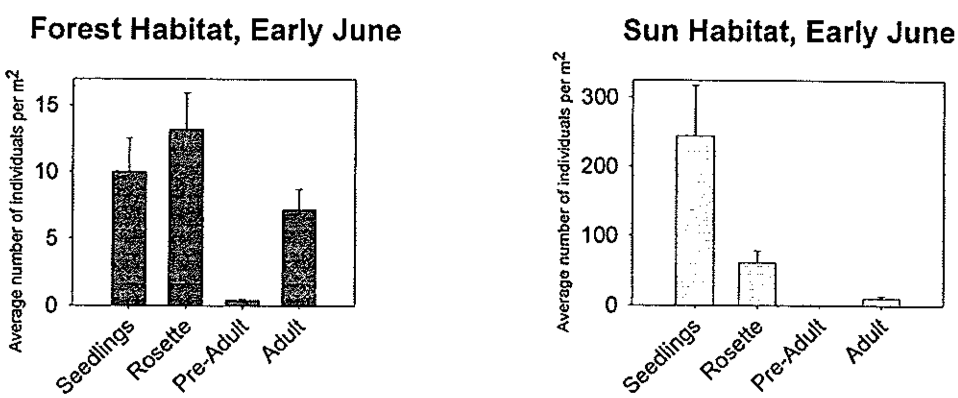
*Gui Woolston*

Although *Alliaria petiolata* (garlic mustard) has successfully invaded understory communities in western Massachusetts, this biennial exotic weed is less successful in central and eastern Massachusetts. One possible mechanism accounting for the success of garlic mustard is a source-sink dynamic; although populations in the understory may not be self sustaining, a flow of seeds from adjacent sun populations may enable garlic mustard to maintain a population at the forest edge. I investigated whether understory populations are self-sustaining, estimated population size and stage-specific mortality and fecundity, and identified which life stages vary between sun, intermediate, and shade habitats. To study the demography, I randomly selected 30 1 $m^2$ plots in each habitat across three locations and counted the number of individuals in each age class in early June and late July. To collect data on individuals, I randomly chose 75 adults in each habitat across three locations.

In early June, sun populations had an average of 165 individuals per $m^2$ whereas forest populations had only 24. The sun populations had a higher proportion of first year plants (96%) than did the shade populations (75%) (Fig.1). Between early June and late July, assuming a typical biennial life cycle, 27% of first year individuals died in the forest habitat compared to 49% first year mortality in the sun populations; mortality rates for second years were essentially equal across habitats (Chart 1). Adults grown in the sun produced more seeds and devoted more of their meristems to reproduction than plants grown in the other habitats (Figs. 2 and 3). Seeds matured in the forest were more massive than seeds matured in other habitats.

The high fecundity of adults grown in the sun and the comparatively low mortality of seedlings grown in the forest suggest a possible source-sink dynamic between adjacent sun and understory habitats. Nonetheless, more massive seeds may confer a competitive advantage to seedlings whose mothers grew in the forest, reducing the potential impact of the source-sink dynamic on the sustainability of understory populations. Further research on seed dispersal, age specific mortality, and seedling survivorship will help address the possible source-sink dynamic between garlic mustard populations.

**Figure 1.** (Woolston)




Ratio of 1st year individuals to 2nd year individuals
Forest 3.05 Sun-27.3

Chart 1

| Stage-Specific Mortality—Early June to Late July | | |
|---|---|---|
| | 1st year | 2nd year |
| Sun | 49% | 7% |
| Forest | 27% | 8% |

**Figure 2.** (Woolston)

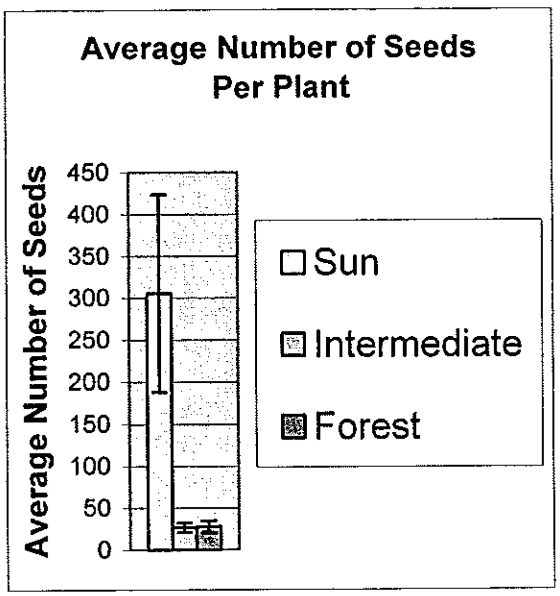
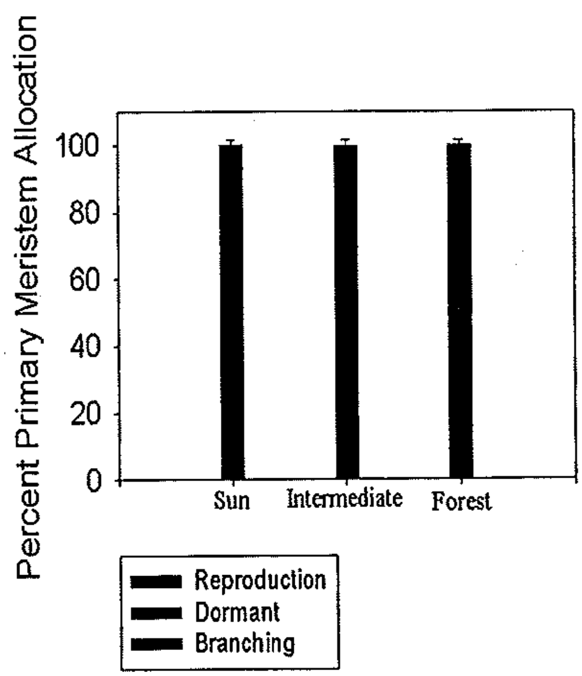



**Figure 3.** (Woolston)



**2003 STUDENT SUMMER PROGRAM**

**SEMINARS AND WORKSHOPS**

| Date | Program | Speaker |
|---|---|---|
| **Wednesday, June 4** | **Lecture 1. History of New England Land Use Change** | **David Foster** |
| **Tuesday, June 10** | **Workshop 1. How to do a Literature Search** | **Rachel Spicer** |
| **Wednesday, June 11** | **Workshop 2. Harvard Forest Tree and Plant ID** | **John O'Keefe and Glenn Motzkin** |
| **Wednesday, June 18** | **Workshop 3. How to Design an Experiment** | **Aaron Ellison** |
| **Tuesday, June 24** | **Lecture 2. Invasive Species** | **Kristina Stinson** |
| **Thursday, June 26** | **Site Visit: LTER: DIRT and Hurricane** | **Pat Micks and Audrey Barker Plotkin** |
| **Wednesday, July 2** | **Site Visit: LTER Soil Warming and HWA** | **Heidi Lux and Sultana Jefts** |
| **Wednesday, July 9** | **Discussion Panel: Choosing and Applying to Grad School** | **Sultana Jefts and Kristina Wilson** |
| **Thursday, July 17** | **Lecture 3 and Site Visit. Forests and The Global Carbon Cycle** | **Steve Wofsy** |
| **Monday, July 21** | **Lecture 4. Weaving Spatial Patterns And Ecology** | **Richard Forman** |
| **Tuesday, July 29** | **Lecture 5. Plant Physiology** | **Missy Holbrook and Brendan Choate** |
| **Thursday, July 31** | **Workshop 4. How to Create a Scientific Paper** | **Dave Orwig** |
| **Wednesday, August 13** | **Summer Research Symposium** | |

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## PERSONNEL AT THE HARVARD FOREST 2002-2003

| | |
|---|---|
| Audrey Barker Plotkin | Research Assistant |
| Leann Barnes | Laboratory Technician |
| Sylvia Barry Musielewicz | Research Assistant |
| Emery Boose | Information & Computer System Manager |
| Jeannette Bowlen | Accountant |
| John Burk | Archivist & Librarian |
| Philip Burton | Bullard Fellow |
| Jessica Butler | Research Assistant |
| Richard Cobb | Research Assistant |
| Elizabeth Colburn | Bullard Fellow |
| Willard Cole | Woods Crew |
| Anthony D'Amato | Graduate Student |
| Elaine Doughty | Research Assistant |
| Ashley Eaton | Landscaper |
| Edythe Ellin | Director of Administration |
| Aaron Ellison | Senior Ecologist |
| Adrian Fabos | Facilities Manager |
| Ed Faison | Research Assistant |
| Samantha Farrell | Laboratory Technician |
| Barbara Flye | Librarian & Secretary |
| Richard Forman | Landscape Ecologist |
| Charles H. W. Foster | Associate |
| David Foster | Director |
| Peter Franks | Bullard Fellow |
| Kelli Graves | Secretarial Assistant |
| Lucas Griffith | Woods Crew |
| Julian Hadley | Ecophysiologist |
| Brian Hall | Research Assistant |
| Julie Hall | Research Assistant |
| Linda Hampson | Staff Assistant |
| Alice Ingerson | Bullard Fellow |
| Sultana Jefts | Research Assistant |
| Holly Jensen-Herrin | Research Assistant |
| Matthew Kelty | Bullard Fellow |
| David Kittredge | Forest Policy Analyst |
| Paul Kuzeja | Research Assistant |
| Oscar Lacwasan | Woods Crew |
| David Lindenmeyer | Bullard Fellow |
| Heidi Lux | Research Assistant |
| Dana MacDonald | Research Assistant |
| Glenn Motzkin | Plant Ecologist |
| John O'Keefe | Museum and Schoolyard Coordinator |
| David Orwig | Forest Ecologist |
| Julie Pallant | System and Web Administrator |
| Sarah Parnes | Graduate Student |
| Laura Pustell | Research Assistant |
| Francis Putz | Bullard Fellow |
| Dorothy Recos Smith | Staff Assistant |
| Michael Scott | Woods Crew |
| Judy Shaw | Woods Crew |
| Navjot Sodhi | Bullard Fellow |
| Rachel Spicer | Graduate Student |
| Bernhard Stadler | Bullard Fellow |
| Kristina Stinson | Research Associate |
| P. Barry Tomlinson | E.C. Jeffrey Professor of Biology, *Emeritus* |
| Betsy Von Holle | Post-doctoral Fellow |
| John Wisnewski | Woods Crew |
| Steven Wofsy | Associate |

# Institute of Ecosystem Studies

## FORUM ON OPPORTUNITIES IN ECOLOGY

**July 8, 2003**

| | | |
|---|---|---|
| **Welcome and Introductions:** | | Dr. Stuart Findlay – Institute of Ecosytem Studies |
| **Session One: 9:30-11:10 A.M.** | | |
| 9:35 | Dr. Eric Schauber | Assistant Professor (*Academia*)<br>Southern Illinois University, Wildlife Research Laboratory, Carbondale, IL |
| 9:48 | Mr. Marcus Phelps | Highlands Forest Conservation and Stewardship Coordinator (*Forestry*)<br>USDA Forest Service, Holdsworth Natural Resources Center, Amherst, MA |
| 10:01 | Ms. Mary Ford | Program Leader of Programs for Youth and Educators and<br>Ecology Education Fellows (*Environmental Education*)<br>Institute of Ecosystem Studies, Millbrook, NY |
| 10:14 | Dr. David Stern | Assistant Professor of Environmental Science (*Gov Research/Academia*)<br>William Paterson University, Wayne, NJ |
| 10:27 | Dr. Fred Lubnow | Director of the Aquatics Program (*Consulting*)<br>Princeton Hydro, Ringoes, NJ |
| 10:40 | Mr. Jon Polishook | Fungal Biologist (*Industry*)<br>Merck Research Laboratories, Rahway, NJ |
| **Break: 11:00-11:15 A.M.** | | |
| **Session Two: 11:15 A.M.- 12:30 P.M.** | | |
| 11:15 | Mr. Jason West | Mayor (*Policy*)<br>Village of New Paltz, New Paltz, NY |
| 11:28 | Ms. Drayton Grant | Partner (*Environmental Law*)<br>Grant & Lyons, LLP, Rhinebeck, NY |
| 11:41 | Mr. Dan Shapley | Environment, Science and Health Reporter (*Media*)<br>Poughkeepsie Journal, Poughkeepsie, NY |
| 11:54 | Mr. Jeff Anzevino | Regional Planner (*Planning*)<br>Scenic Hudson, Poughkeepsie, NY |
| 12:07 | Ms. Laura Heady | Biodiversity Educator (*Conservation*)<br>Hudsonia, Inc. |
| 12:20 | Mr. Dave Burns | Watershed Coordinator (*Applied Ecology*)<br>Dutchess County Environmental Management Council, Millbrook, NY |

## Afternoon Sessions: Small Discussion Groups

First Discussion Session: 1:30 - 2:05 P.M.

Group A - Conference Room
Group B - PSB Lobby
Group C - Classroom

Second Discussion Session: 2:10 - 2:45 P.M.

Group A - Classroom
Group B - Conference Room
Group C - PSB Lobby

Third Discussion Session: 2:50 – 3:30 P.M.

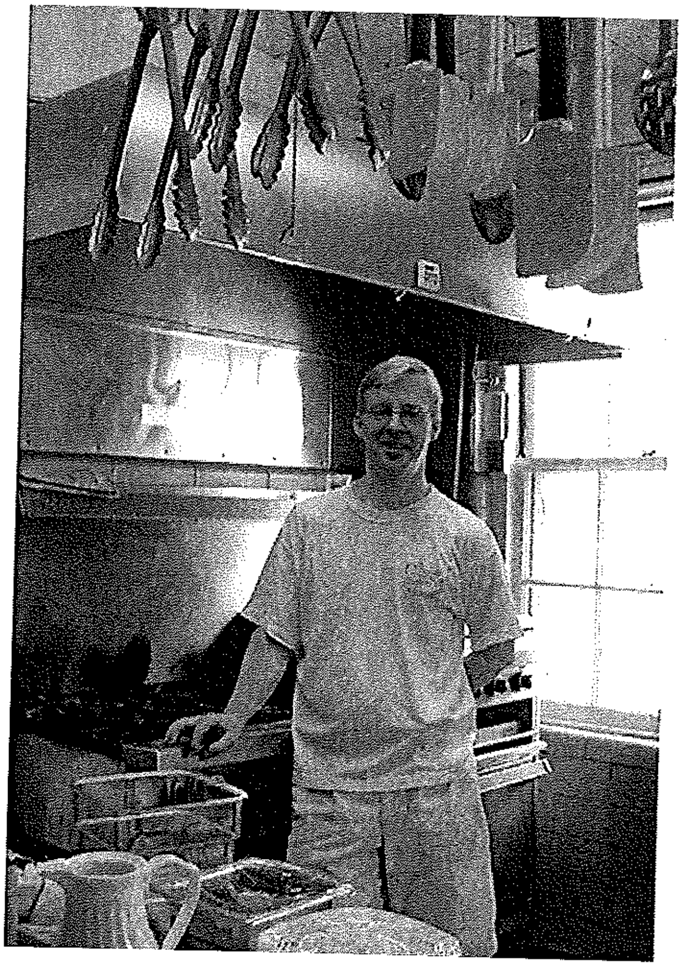
Group A - PSB Lobby
Group B - Classroom
Group C - Conference Room

Speaker Assignments:

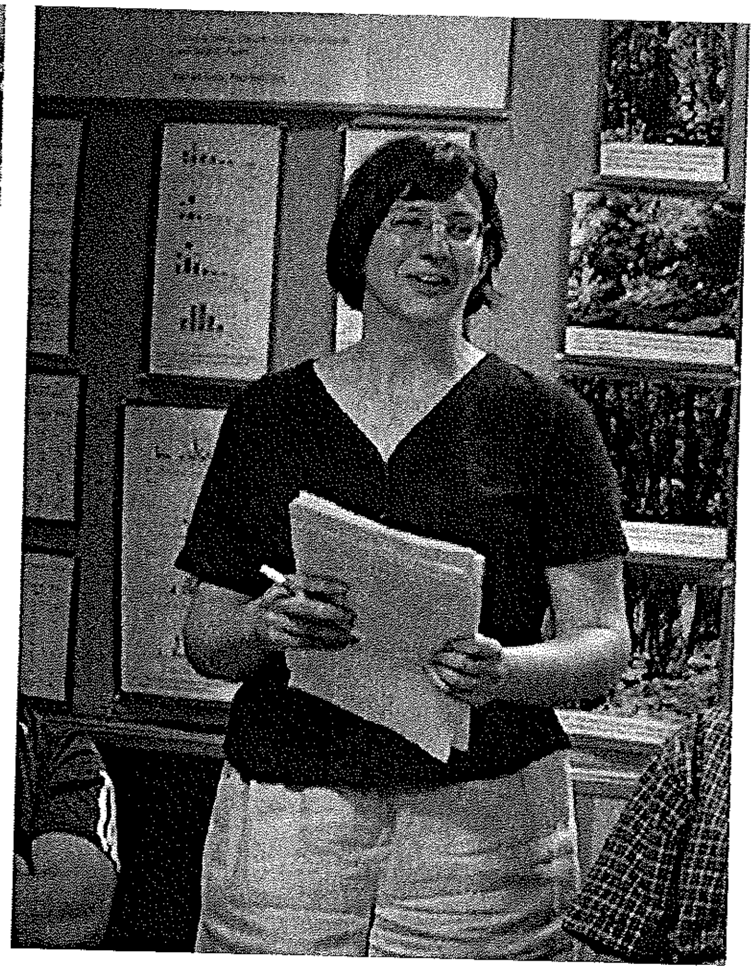
Conference Room – Jon Polishook, Fred Lubnow, Marcus Phelps

PSB Lobby – Dan Shapley, Jeff Anzevino, Jason West, Eric Schauber

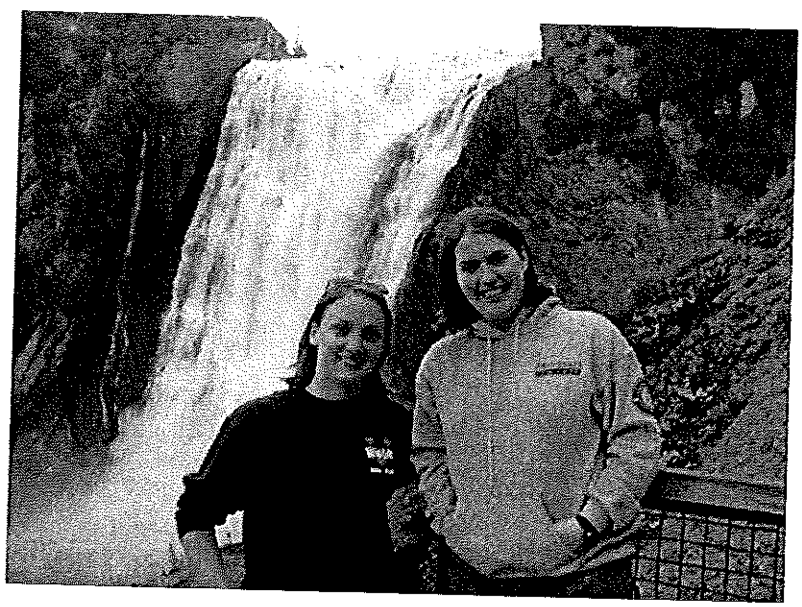
Classroom – Laura Heady, Drayton Grant, David Stern, Dave Burns



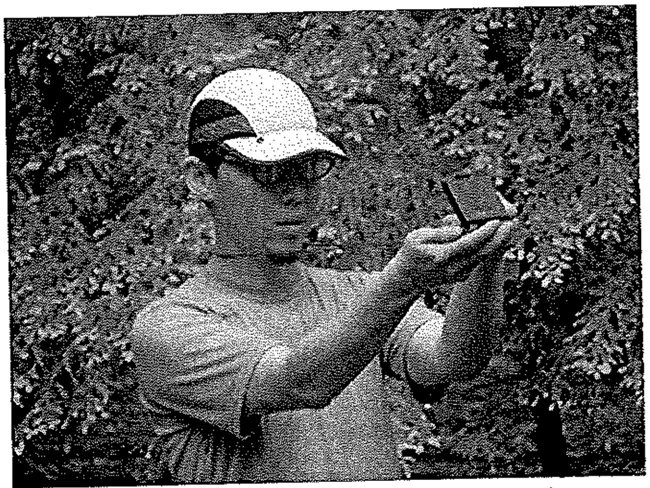
Summer Cook Tim Zima

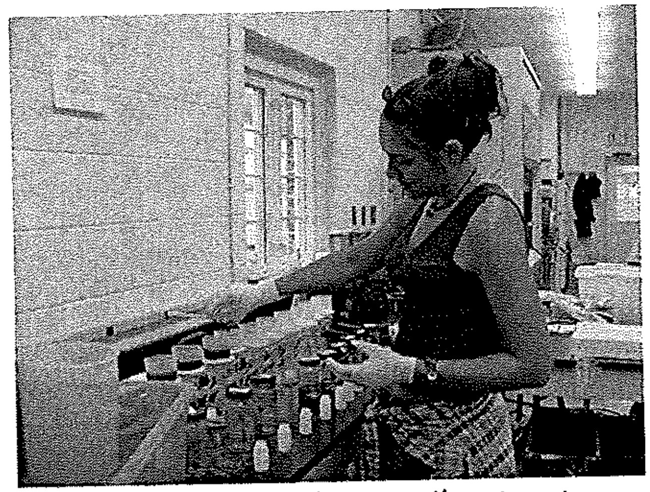


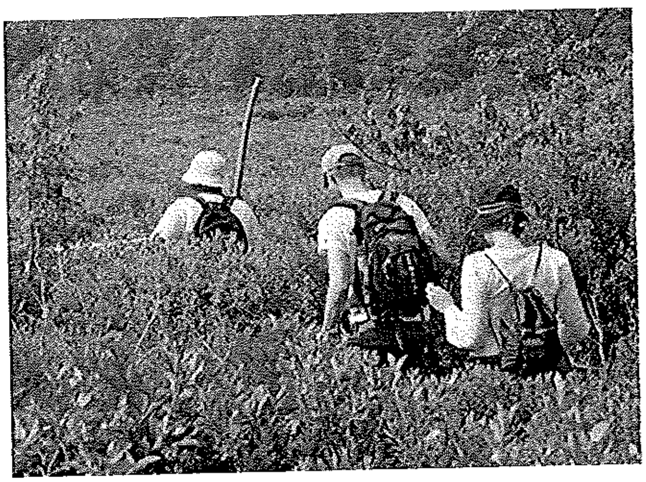
Summer Program Coordinator Edythe Ellin



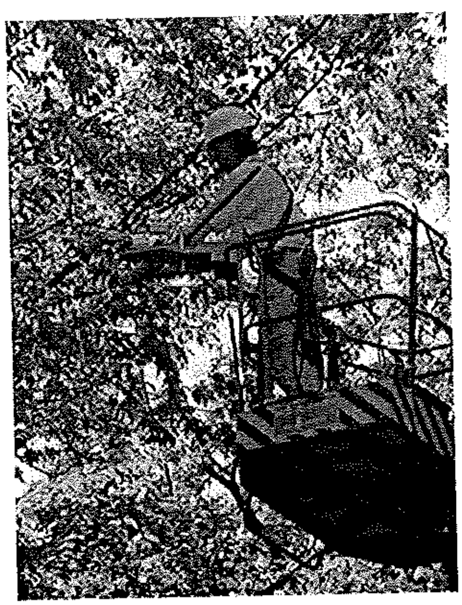
Summer Program Assistants
Jakara Hubbard & Laurie Miskimins


Matt Lau finds his way around


Amanda Park filters soil extracts

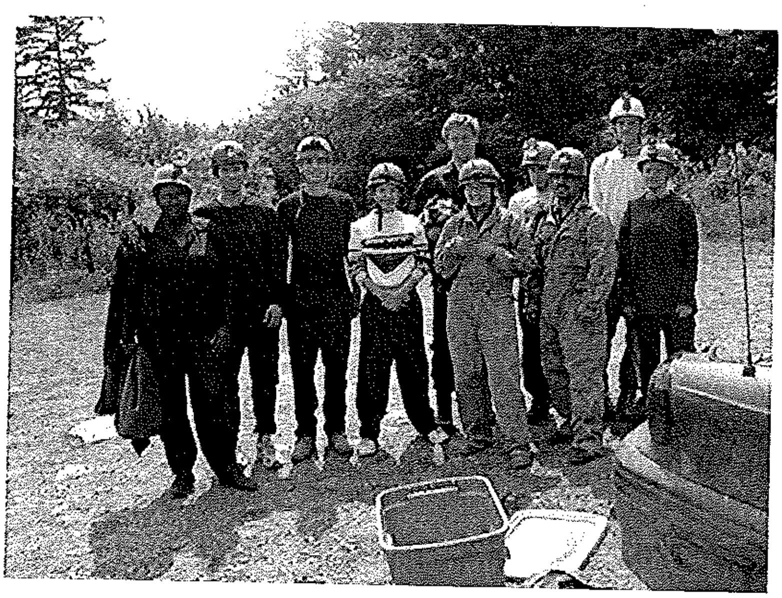

Wading through Tom Swamp


Interns help to set up a new experiment

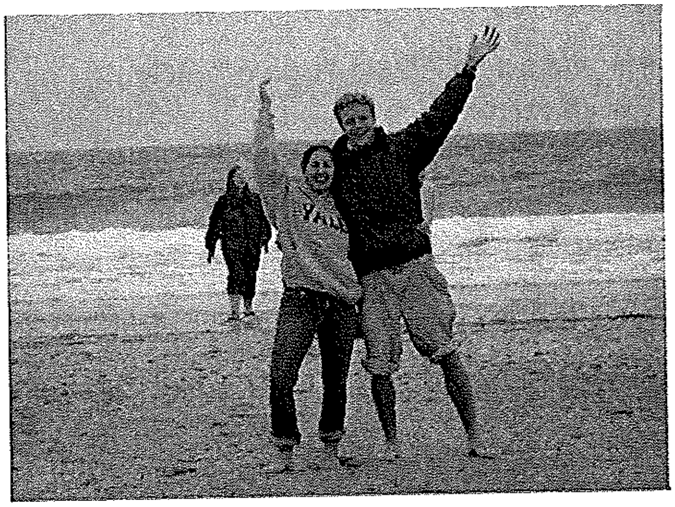

Brady Hardiman takes canopy photosynthesis measurements from 'Bucky'

Learning Aikido from a fellow intern

Out on the town

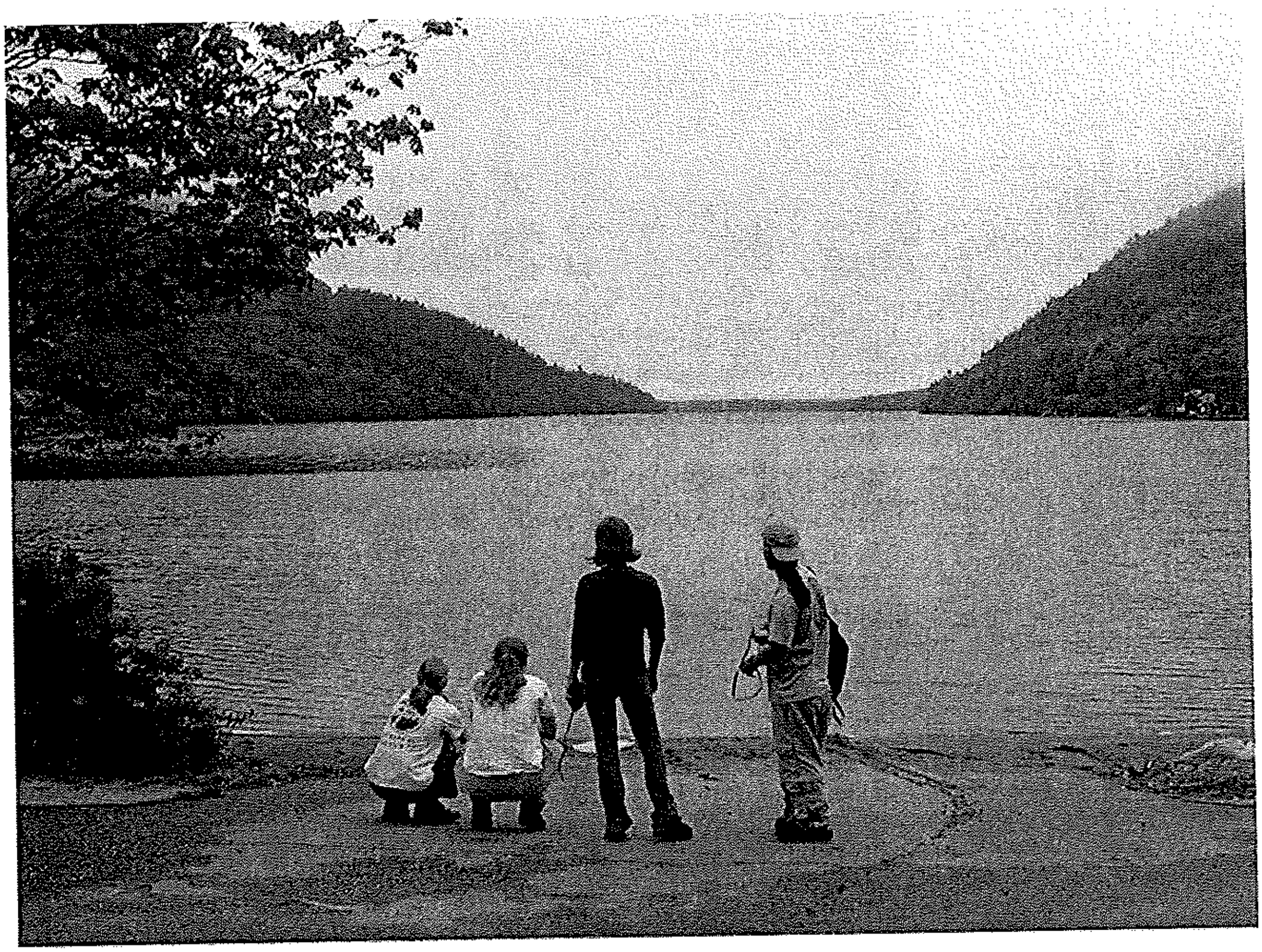


Off on a caving adventure



Julia Nelson and Gui Woolston on Cape Cod

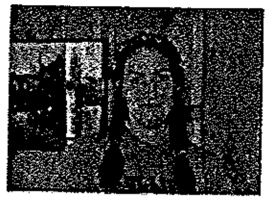
Looking down from the Fire Tower



In Acadia National Park


Alana Belcon


Alex Sanchez-Sierra


Amanda Park


Becca Lohnes


Brady Hardiman


Chris Graham


Chris Petit


Daberat Perez-Rivera

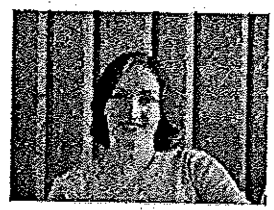

Dan Atwater


Dave Franklin


Don Niebyl


Eric Saas


Gui Woolston

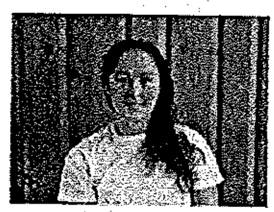

Jakara Hubbard (proctor)

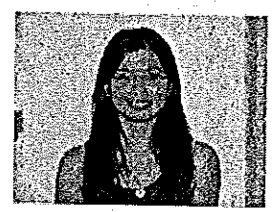

Jennifer Clowers


Joanna Bate


Joe Brown


Jonathan Chen


Julia Nelson


Julie Vuong


Kate Musgrove


Kathryn McKain


Kristin Wilson


Laurie Miskimins (proctor)


Luke Durbin


Margaret Graham


Matt Lau


Naomi Clark


Nick Malizia


Nick Povak


Nikki Nowinski


Nora Lahr


Teresa Abbott


Zachary Liscow