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Rapid Communication

A record of Lateglacial and early Holocene environmental and ecological change from southwestern Connecticut, USA

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ABSTRACT: Analyses of a sediment core from Highstead Swamp in southwestern Connecticut, USA, reveal Lateglacial and early Holocene ecological and hydrological changes. Lateglacial pollen assemblages are dominated by *Picea* and *Pinus* subg. *Pinus*, and the onset of the Younger Dryas (YD) cold interval is evidenced by higher abundance of *Abies* and *Alnus viridis* subsp. *crispa*. As climate warmed at the end of the YD, *Picea* and *Abies* declined and *Pinus strobus* became the dominant upland tree species. A shift from lacustrine sediment to organic peat at the YD–Holocene boundary suggests that the lake that existed in the basin during the Lateglacial interval developed into a swamp in response to reduced effective moisture. A change in wetland vegetation from *Myrica gale* to *Alnus incana* subsp. *rugosa* and *Sphagnum* is consistent with this interpretation of environmental changes at the beginning of the Holocene. Copyright © 2009 John Wiley & Sons, Ltd.

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Introduction

Environmental and ecological changes associated with the Younger Dryas (YD) climatic oscillation (12 900–11 600 cal. a BP) have been studied at many sites in eastern North America using a variety of approaches (e.g. Peteet *et al.*, 1990; Levesque *et al.*, 1993; Mayle *et al.*, 1993; Cwynar and Levesque, 1995; Shemesh and Peteet, 1998; Yu and Eicher, 1998; Lavoie and Richard, 2000; Newby *et al.*, 2000; Cwynar and Spear, 2001; Huang *et al.*, 2002; Shuman *et al.*, 2001, 2002; Hou *et al.*, 2007; Lindbladh *et al.*, 2007; Yu, 2007). Pollen records typically feature an increase in cold-tolerant taxa at the beginning of the YD and a shift to taxa indicative of warmer conditions at the YD–Holocene boundary (e.g. Shuman *et al.*, 2002). Quantitative reconstructions of temperature for this interval yield generally consistent results, indicating ~5°C shifts at the beginning and end of the YD (Shemesh and Peteet, 1998; Yu and Eicher, 1998; Cwynar and Spear, 2001; Yu, 2007). Lateglacial changes in moisture balance, on the other hand, have received less study. Lake-level reconstructions from southern Québec (Lavoie and Richard, 2000) and southeastern Massachusetts (Newby *et al.*, 2000; Shuman *et al.*, 2001) indicate relatively wet conditions during the YD and drier climate at the beginning of the Holocene, but other records of moisture balance shifts associated with the YD have not been developed. In this paper we report on a Lateglacial sedimentary record from a swamp in southwestern Connecticut, USA. Analyses of pollen and organic content provide additional insights into changes in moisture balance at the end of the YD.

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Study area

Highstead Swamp (41° 19.5′ N, 73° 23.75′ W) is located at Highstead, a 150-acre woodland preserve in Redding, Connecticut (Fig. 1). This area of southwestern Connecticut falls within the Northeastern Coastal Zone, an ecoregion that extends across southern New England (Griffith *et al.*, 1994).

The swamp is part of a 4 ha seasonally flooded basin; it has an intermittent outlet stream that drains into a 1 ha artificial pond

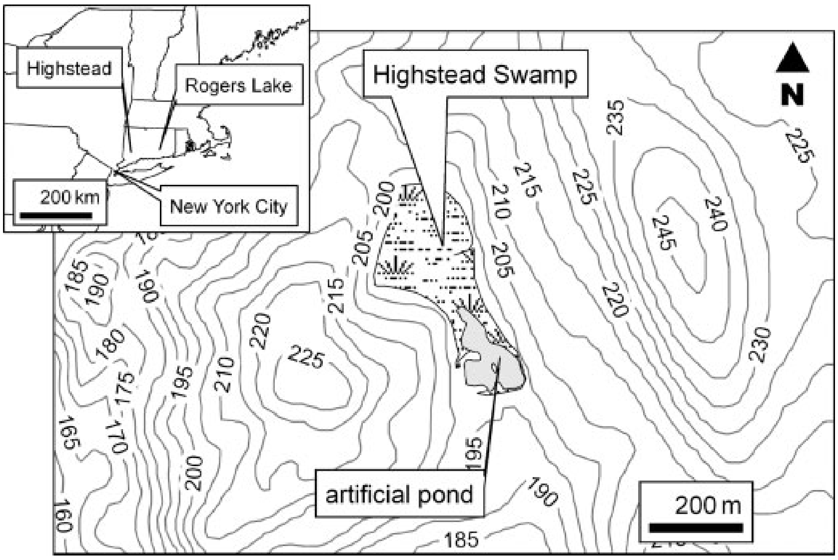

Figure 1 Map of the Highstead Swamp and surrounding topography in Redding, Connecticut, USA. Inset map shows location of Rogers Lake (Davis, 1969)

before continuing to the southeast. Soils range from muck to poorly drained and stony (Wolf, 1981). The swamp is bounded to the west by a rugged NE–SW trending ridge of Ordovician-age schist and granitic gneiss; to the east is a smooth, NW trending drumlin composed of Wisconsinan glacial till overlying Illinoian till (Rodgers, 1985; Stone *et al.*, 2005). The vegetation of the swamp features *Acer rubrum* and *Betula alleghaniensis* in the overstory, *Clethra alnifolia*, *Lindera benzoin*, and *Ilex verticillata* in the understory, and a ground layer of *Symplocarpus foetidus*, *Osmunda cinnamomea*, and *Carex* species. Dry, upland forest to the west consists of 70- to 90-year-old *Quercus rubra*, *Q. coccinea* and *Q. prinus*, with dense *Kalmia latifolia* in the understory. To the east, moist *Acer rubrum*, *Fraxinus americana* and *Liriodendron tulipifera* forest (45–85 years old) occurs on fine-grained soils. The *Quercus* forest was continuously forested during the European settlement period but was cut heavily for wood products, while the *Acer–Fraxinus* forest was open pasture during the settlement period and reverted back to woodland only in the 20th century.

Methods

We collected a sediment core from Highstead Swamp in June of 2006. We accessed the centre of the swamp using an established boardwalk and collected a 256 cm long core using a modified Livingston piston sediment sampler. Core segments were extruded horizontally in the field, wrapped in plastic and aluminium foil, and subsequently refrigerated.

The analyses presented here were performed on the interval of the core from 256 to 94 cm; the upper interval of the core appeared to be disturbed and therefore was not analysed. Sediment samples of 1 cm^3 were prepared for pollen analysis following standard procedures (Faegri and Iversen, 1989), and tablets containing *Lycopodium clavatum* spores were added during processing to allow calculation of pollen and spore concentrations (Stockmarr, 1971). Pollen residues were mounted in silicone oil and analysed at 400× magnification. At least 500 pollen grains and spores of upland plant taxa were counted for each sample, and pollen percentages were calculated relative to that sum. *Myrica*-type pollen, which is very abundant in samples from 134 and 138 cm, was not included in the sum used to calculate percentage values. Sediment organic content was estimated for 1 cm^3 samples at selected depths by percent weight loss-on-ignition (LOI) at 550°C.

Chronological control is provided by accelerator mass spectrometry ^{14}C analysis of four woody plant macrofossils sieved from the sediment (Table 1). Dates were converted to calibrated ^{14}C years before present (cal. a BP) with CALIB 5.0 (Stuiver and Reimer, 1993). The date of the uppermost sample (∼11 900 cal. a BP; 109 cm) is inconsistent with the age–depth relationship of the other dates and data from other sites, and is therefore rejected.

Results

The lower section of the core (256–210 cm; ca. 13 300–13 000 cal. a BP) is lacustrine sediment featuring pollen assemblages dominated by *Picea* (∼30%) and *Pinus* subg. *Pinus* (∼30%), with minor abundances of *Ostrya–Carpinus*, *Fraxinus*, *Quercus*, *Betula*, Poaceae, Cyperaceae and pteridophytes (Fig. 2). Organic content increases from ∼50% to 60% during this interval (Fig. 3). Various changes occur after ca. 13 000 cal. a BP (220–200 cm), including increased abundance of *Abies*, *Alnus*, *Nuphar* and *Myrica*-type and decreasing percentages for

Table 1 Results of ^{14}C dating for Highstead Swamp

Depth (cm)	Material	Lab number	$\delta^{13}C$	^{14}C age ± error	Cal. range (2σ)	Median cal. age
109–110[a]	Wood	OS-59498	−27.63	10 200 ± 35	11 760–12 050	11 910
142–143	Wood	OS-59484	−26.90	10 000 ± 50	11 270–11 710	11 480
209–210	Wood	OS-59499	−28.31	11 100 ± 50	12 910–13 110	13 010
257–258	Wood	OS-59500	−25.83	11 450 ± 50	13 210–13 410	13 300

[a] Rejected due to age reversal.

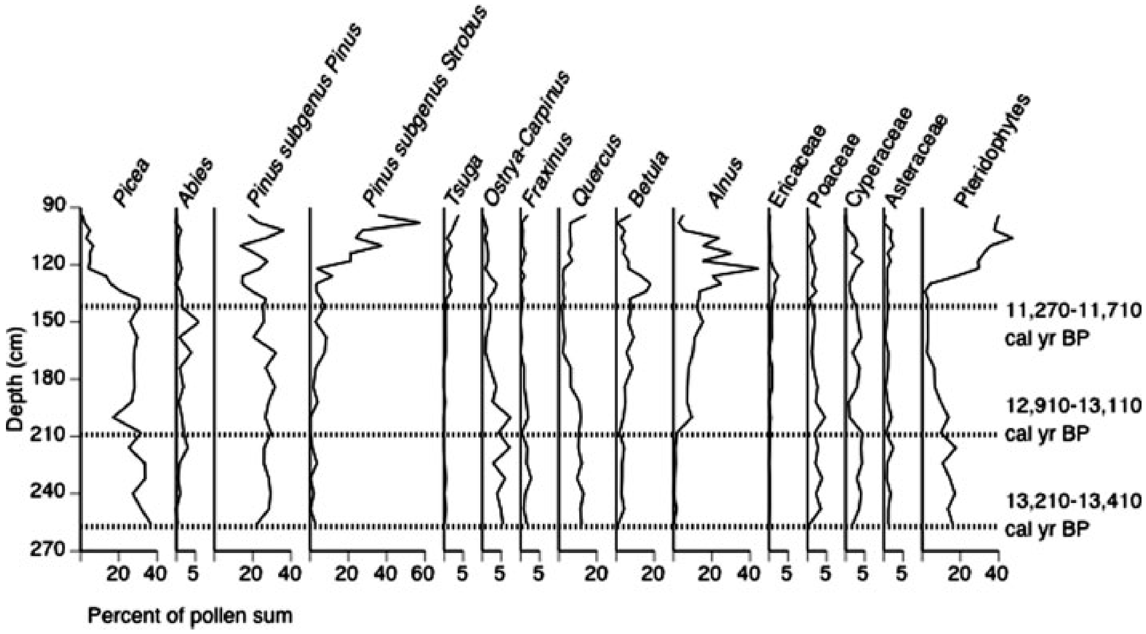

Figure 2 Pollen percentage diagram for selected taxa from the Highstead Swamp sediment record. Note changing scale for *x*-axes. Horizontal lines are depths of ^{14}C samples; the 2σ calibrated ^{14}C age ranges are shown

Ostrya–Carpinus, *Fraxinus*, *Quercus*, Poaceae and pteridophyes (Figs 2 and 3). Organic content declines abruptly between ~220 and 200 cm, then increases from ~50% to 70% between 200 and 140 cm. The upper section of the core (140–90 cm; <11 500 cal. a BP) changes abruptly to peaty sediment, with organic content increasing from ~70% to 90%. This interval has a dramatic decline in *Picea* pollen percentages (~30% to <5%) and a corresponding rise in *Pinus* subg. *Strobus* abundance (~5% to 60%). *Abies* abundance declines above 140 cm, whereas *Tsuga* pollen reaches ~2–3% and *Alnus* pollen peaks at ~40%. *Myrica*-type pollen becomes very abundant in samples at the beginning of this transition (Fig. 3), just before the peak in *Alnus* pollen percentages, while *Sphagnum* spores reach a peak coincident with the highest *Alnus* values.

Discussion

The changes observed in the Highstead Swamp record at ca. 13 000 cal. a BP, including declining percentages of *Ostrya–Carpinus* pollen and higher abundances of *Abies* and *Alnus* (presumably *A. viridis* subsp. *crispa*), are consistent with pollen data from sites in southern New England (e.g. Davis, 1969; Suter, 1985; Lindbladh *et al.*, 2007) and elsewhere in eastern North America (e.g. Mayle *et al.*, 1993; Peteet *et al.*, 1993). The ~5°C drop in temperature at the beginning of the YD (Shemesh and Peteet, 1998; Yu and Eicher, 1998; Cwynar and Spear, 2001; Yu, 2007) appears to have shifted vegetation assemblages across the region towards cold-tolerant taxa (Shuman

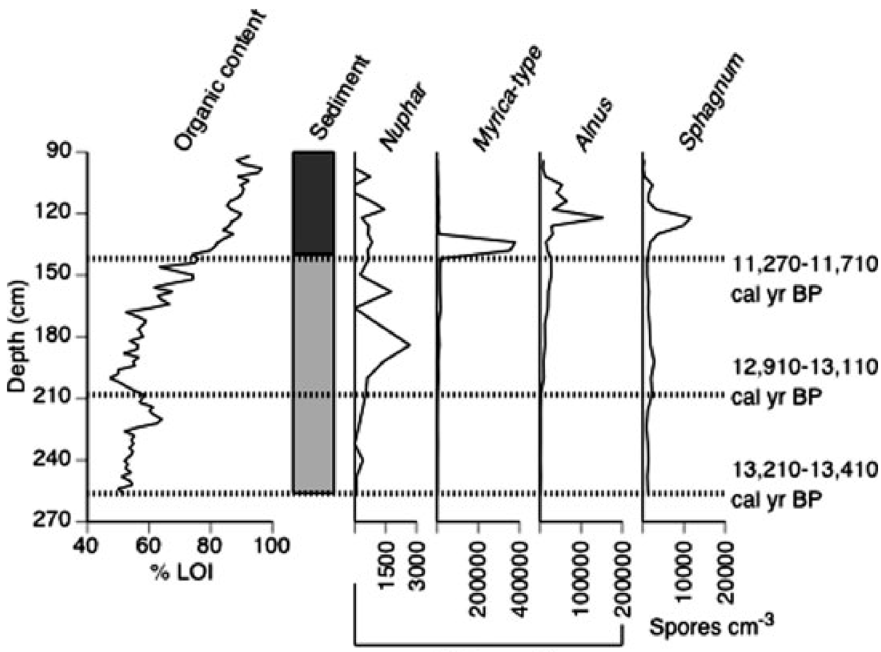

Figure 3 Organic content (percent weight loss-on-ignition; % LOI), sediment characteristics (light grey is lacustrine sediment, dark grey is peat), and pollen and spore concentrations for selected taxa from the Highstead Swamp sediment record. Note changing scale for *x*-axes. Horizontal lines are depths of ^{14}C samples; the 2σ calibrated ^{14}C age ranges are shown

et al., 2002), although some ecological changes may have been underway in advance of the onset of YD cooling (Lindbladh *et al.*, 2007).

The end of the YD cold interval in the Highstead Swamp record is also marked by changes in vegetation seen at other sites. *Picea* pollen percentages decline abruptly at ca. 11 500 cal. a BP, and boreal taxa such as *Abies* are replaced by temperate taxa including *Pinus strobus*, *Tsuga canadensis* and *Quercus* (e.g. Mayle *et al.*, 1993; Shuman *et al.*, 2002; Lindbladh *et al.*, 2007). A comparison of pollen and palaeoclimatic data by Williams *et al.* (2002) indicates that vegetation responded quickly to rising temperatures at the beginning of the Holocene. The peak in *Alnus* pollen percentages at the YD–Holocene boundary in the Highstead Swamp record, however, is not a feature that is normally observed in other pollen records from eastern North America (but see Newby *et al.*, 2000). In fact, the decline of *Alnus* is typically seen as a distinguishing marker of the end of the YD (Mayle *et al.*, 1993). We interpret the increase in *Alnus* abundance, as well as the rise in *Myrica*-type pollen occurring just prior to the *Alnus* peak, as evidence for changes in the composition of the local vegetation in response to a shift in moisture availability and hydrological conditions at the beginning of the Holocene.

Several lines of evidence from the Highstead Swamp record indicate a sequence of hydrological and ecological changes during the transition from the YD to the Holocene. The decline in the abundance of *Nuphar*, an aquatic plant, and shift from lacustrine sediment to peat suggest that the lake that occupied the basin during the Lateglacial interval became a swamp after ca. 11 500 cal. a BP. A similar transition in the sediments of Makepeace Cedar Swamp, located in southeastern Massachusetts, was also interpreted as a shift from lake to swamp at the beginning of the Holocene (Newby *et al.*, 2000). The changes in wetland vegetation at Highstead Swamp are consistent with this interpretation. The wet substrate of the swamp was initially dominated by *Myrica gale*, as evidenced by the high abundance of *Myrica*-type pollen, and subsequent development of the swamp likely allowed *Alnus* and *Sphagnum* to become prevalent. We suspect that the *Alnus* pollen represents the presence of *Alnus incana* subsp. *rugosa*, which can occur with *Sphagnum* in bogs and swamps in eastern North America (e.g. Cronan and DesMeules, 1985).

Taken together, the changes observed in the sedimentary record from Highstead Swamp are consistent with lake-level studies from eastern North America (Lavoie and Richard, 2000; Newby *et al.*, 2000; Shuman *et al.*, 2001), which suggest that water levels declined ca. 11 500 cal. a BP in response to declining effective moisture. Those dry conditions prevailed in New England until ca. 8000 cal. a BP, when the deterioration of the Laurentide Ice Sheet brought a wetter climate to the region (e.g. Shuman *et al.*, 2006).

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