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Human-ecosystem interactions in relation to Holocene environmental change in Port Joli Harbour, southwestern Nova Scotia, Canada

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ABSTRACT

A high-resolution pollen record from Path Lake in Port Joli Harbour, Nova Scotia, Canada, provides a paleoecological perspective on Holocene climate and vegetation variability within the context of local archaeological research. Pollen assemblages in the early Holocene reflect a post-glacial forest dominated by *Pinus*, *Tsuga*, *Betula* and *Quercus*. During this time, a lower frequency of radiocarbon dated cultural material suggests lower human settlement intensity. Shallow water aquatic (*Isoetes*) and wetland (*Alnus*, *Sphagnum*) taxa increased after 3400 cal yr BP in response to a transition towards wetter climatic conditions. Culturally significant periods, where settlement intensity increased in the Maritimes and Maine, coincide with maximum values of reconstructed total annual precipitation, suggesting that environmental conditions may have influenced prehistoric human activity. European settlement, after 350 cal yr BP, was marked by a rise in *Ambrosia*. The impact of anthropogenic fire disturbances on the landscape was evidenced by peak charcoal accumulations after European settlement.

Introduction

Understanding the complex structure of human–ecosystem interactions, both in the past and present, is an important aspect of environmental studies (Briggs et al., 2006). Archaeological and historical records provide evidence of cultural activities, while paleo-environmental records reconstruct past vegetation and climate regimes. The combination of these records allows for a better understanding of how ecosystem structure is related to human land-use, and vice-versa, at a decadal- or century-scale temporal resolution (Briggs et al., 2006, Gajewski et al., 2011). By combining archaeological records with studies of local to regional scale changes in vegetation composition and climate during the mid to late Holocene, inferences can be made regarding cultural development and adaptation of past human populations to environmental changes (Coe and Flannery, 1964).

The paleoecology of coastal ecosystems can be more specifically studied in relation to shell middens, which provide archaeological records of maritime cultures (Graham et al., 2003). Archaeological excavations of shell middens from the Atlantic coast of Nova Scotia indicate the presence of ancient Mi'kmaw occupations between ca. 3000 and 350 cal yr BP (Keenlyside, 1999). This paper uses a paleo-ecological perspective to investigate Holocene vegetation and climate variability, within the context of local archaeological research in Port Joli Harbour, southwestern Nova Scotia.

After local deglaciation, post-glacial climate change began with a warming period (late glacial; 14,000–10,000 cal yr BP), where boreal/woodland forests dominated the landscape (Mott and Stea, 1993; Mayle and Cwynar, 1995). During the late glacial, the Younger Dryas (12,900–11,700 cal yr BP) represented a major reversion to cooler conditions, causing a change in vegetation to shrub and herbaceous tundra (Mayle et al., 1993; Levesque et al., 1994; Walker et al., 2009). Another notable global cooling of 4 °C occurred during the early Holocene '8200 cal yr BP event' (Lennox et al., 2010). Around 3000 cal yr BP, there was a regional transition to relatively wet and cool conditions in Nova Scotia (Railton, 1973; Ogden, 1986; Lennox et al., 2010). Superimposed on broad-scale climate changes during the Holocene were higher frequency variations, the latest of which was a cool period termed the Little Ice Age (LIA), which occurred across North America between 600 and 100 cal yr BP (Wanner et al., 2008).

Relative sea-level changes in Nova Scotia during the Holocene were due to a combination of postglacial isostatic adjustments (Edgecombe et al., 1999), regional crustal subsidence and local sea-level rise (Forbes et al., 2009). Submergence of the coastline and fluctuations in marine productivity associated with rising sea levels during the mid to late Holocene would have had consequences for Mi'kmaw settlements along the coast. The interaction of Mi'kmaw occupations with terrestrial as well as marine ecosystems is an important consideration when developing a detailed environmental history of the region.

Human activities have had profound influences on forest dynamics in eastern North America (Delcourt and Delcourt, 2004; Gajewski et al., 2011). Clear-cutting or controlled burning of forests for agriculture during European settlement in Nova Scotia between 350 and 200 cal yr BP led to major transformations in vegetation distribution and structure (Briggs et al., 2006). The region of Port Mouton, located less than 10 km from Port Joli Harbour, was an encampment of De Monts and Champlain

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around 350 cal yr BP, and a settlement for loyalists after the American Revolution around 170 cal yr BP (Fig. 1; Macgregor, 1832; Dunlop and Scott, 2006). The long history of human occupation extending to the present makes the region surrounding Port Joli Harbour an ideal location for studying human–ecosystem relationships. A high-resolution pollen record of a sediment core from Path Lake (43°52.17′N, 64°55.39′W; Fig. 1) was used to show the evolution of the Acadian Forest Region in southwestern Nova Scotia during the mid- to late-Holocene, at a time when human occupations along the coast were becoming increasingly prominent.

Study site

Path Lake is located approximately 600 m from the northwestern shoreline of Port Joli Harbour, at an elevation of 15 m above present sea level (Fig. 1). This headwater lake is large (21.9 ha), slightly acidic (pH 6.2), and has an extensive littoral zone (Nova Scotia Department of Fisheries, 1995). Path Lake receives minimal inflow from a small spring at its northwest corner, and an outlet channel flows towards the ocean from the eastern side.

The present vegetation of the Atlantic Maritime Provinces is classified as the Acadian Forest Region (AFR; Mayle and Cwynar, 1995). The high abundance of red spruce (*Picea rubens*) is a distinguishing feature of the AFR, as this shade-tolerant species thrives in high moisture conditions (Mosseler et al., 2003). Other associated species include balsam fir (*Abies balsamea*), eastern hemlock (*Tsuga canadensis*), eastern white pine (*Pinus strobus*), yellow birch (*Betula alleghaniensis*), sugar maple (*Acer saccharum*) and American beech (*Fagus grandifolia*) (Mosseler et al., 2003). Port Joli Harbour is further categorized within the AFR as part of the Atlantic Shore Ecoregion, as a forest type described as Acadian–Boreal Coastal. Wetland environments are common along the coast and include fens, raised or flat bogs, and salt marshes (Webb and Marshall, 1999).

Methodology

In July 2013, a 4.16 m long sediment sequence was recovered from Path Lake using a modified Livingstone piston corer. The uppermost sediments were collected in a clear plastic tube. Unconsolidated sediments near the water–sediment interface (7 m deep) were extruded at 0.5–1.0 cm intervals, with individual cross-sections stored in zip-lock bags. Remaining sediments were extruded horizontally and intact in the field, and wrapped in plastic-wrap, aluminum foil and PVC tubing for transport to the University of Ottawa. Cores were stored in a refrigerator at 4 °C.

The magnetic susceptibility of the Path Lake sediment core was measured at 1.0 cm intervals using a Bartington™ MS2C meter and loop sensor. Values within 4 cm of core extremities were excluded from analysis as the sensor averages over several cm.

Determination of organic and carbonate content within the sediment cores was assessed using loss-on-Ignition (Dean, 1974). The dry weight was obtained after heating the subsamples to 105 °C for 12–24 h followed by ignition at 550 °C for 4 h to determine the organic carbon content (Heiri et al., 2001). The carbonate content was obtained after igniting the subsamples at 950 °C for 2 h (Dean, 1974), and resultant values were multiplied by 1.36 to compensate for the molar mass of carbon dioxide and carbonate (Heiri et al., 2001).

Accelerator-mass spectrometry (AMS ^{14}C dating) was used to obtain the ages of six samples at a series of depths in the Path Lake core. Identifiable pieces of organic matter including fibres, wood and charcoal, were picked from sieved sediment. These samples of organic matter were then submitted to the Beta Analytic Dating Laboratory, and resulting ages were calibrated using the IntCal09 calibration curve (Reimer et al., 2009). An age–depth model was fit to the data in the R software package BACON to establish a chronology (Blauuw and Christen, 2011).

Sediment subsamples of 1 cm^3 were extracted for pollen analysis. Non-polliniferous material was removed through chemical treatment, involving 10% hydrochloric acid, 10% potassium hydroxide, hydrofluoric acid, and acetolysis solution. Residual pollen material was preserved and mounted on microscope slides with silicone oil (Faegri et al., 1989). Two *Lycopodium* spore tablets (batch #938934) were added to each sample before processing to enable the calculation of fossil pollen concentration and accumulation rates (Faegri et al., 1989). Pollen grains and spores were counted using a Nikon Eclipse 80i light microscope at 400× magnification, along evenly spaced transects to avoid potential differential sorting during the creation of the slides. Reference material and texts helped with the identification of fossil pollen and spores (Roland and Smith, 1969; McAndrews et al., 1973; Faegri et al., 1989; Moore et al., 1991). An average total pollen sum of 535 was reached for 121 subsamples, excluding all aquatic species.

Micro-charcoal was identified as any black, angular fragments or any opaque fragments where a linear or rectangular wood-like structure was visible (Clark, 1982). Fragments were classified into four categories according to size; 1: $218.75 \leq \times < 437.5\ \mu m^2$, 2: $437.5 \leq \times < 875\ \mu m^2$, 3: $875 \leq \times < 1750\ \mu m^2$ and 4: $\geq 1750\ \mu m^2$ (Whitlock and Larsen, 2002; Paquette and Gajewski, 2013). The total area of charcoal for each

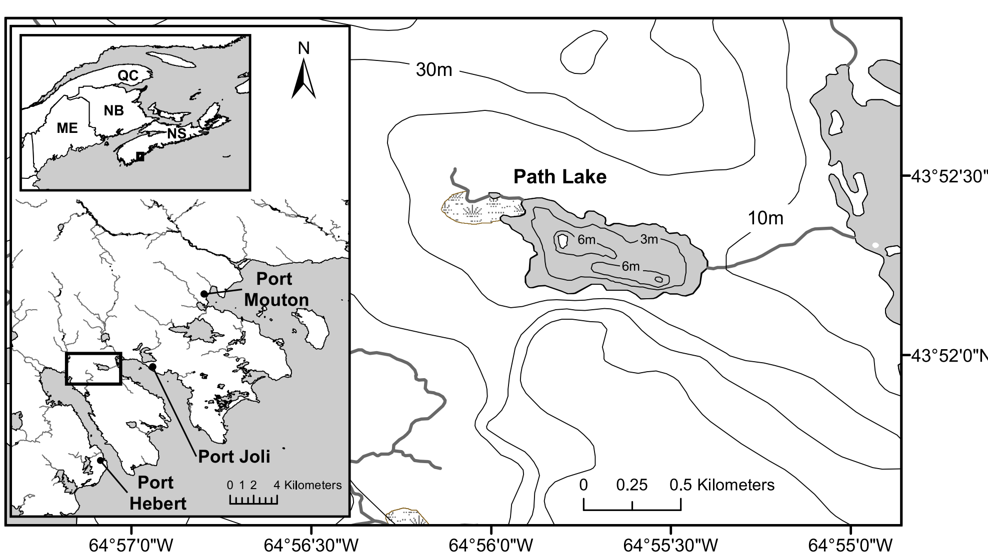

Figure 1. Location of Path Lake in relation to Port Joli Harbour, Southwestern Nova Scotia.