8-1999

Landscape-level control of population dynamics: late-Quaternary paleoecology of beech in upper Michigan

William Petty Rivers

Recommended Citation

Rivers, William Petty, "Landscape-level control of population dynamics: late-Quaternary paleoecology of beech in upper Michigan. " PhD diss., University of Tennessee, 1999.
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To the Graduate Council:

I am submitting herewith a dissertation written by William Petty Rivers entitled "Landscape-level control of population dynamics: late-Quaternary paleoecology of beech in upper Michigan." I have examined the final electronic copy of this dissertation for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Doctor of Philosophy, with a major in Ecology and Evolutionary Biology.

Hazel R. Delcourt, Paul A. Delcourt, Major Professor

We have read this dissertation and recommend its acceptance:

W. Frankling Harris III, Michael A. Huston, Kenneth H. Orvis

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Vice Provost and Dean of the Graduate School

(Original signatures are on file with official student records.)

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Dean of The Graduate School

LANDSCAPE-LEVEL CONTROL OF POPULATION DYNAMICS: LATE-QUATERNARY PALEOECOLOGY OF BEECH IN UPPER MICHIGAN

A Dissertation
Presented for the
Doctor of Philosophy
Degree
University of Tennessee, Knoxville

William Petty Rivers
August 1999

ACKNOWLEDGMENTS

For continual encouragement, advise, and thoughtful comments, I give my sincere thanks to the members of my doctoral committee: Drs. Hazel R. Delcourt, Paul A. Delcourt, W. Franklin Harris, Kenneth H. Orvis, and Michael A. Huston. For generous permission to work within the study area I thank Mr. Morey Allen and the Hiawatha Sportsmen Club. I would also like to thank my coring team, Hazel and Paul Delcourt, Matt Mansfield, and Jeannette Mansfield.

For valuable discussion and access to pre-publication soil maps, I thank Greg Whitney, Steve Ropack, and Craig Outwater of the Mackinac County Soil Survey. I thank David R. Houston for valuable discussion about the effects of beech bark disease. Thanks are extended to Richard Futyma, and Hazel Delcourt for permission to cite unpublished pollen data. This research was supported in part by a grant from the National Science Foundation (No. DEB-9417050).

Numerous people have provided me with additonal help during my time as a doctoral student at the University of Tennessee including Linda McMillan, Pat Cox, Todd and Beth Vincent, Ti Crossman, Kati Ellis, Sam Wallace, Bill Schneider, Bill Painter, Mike Nash, Doug Andreasen, Terry Molnar, Mark Betz, Lisa Kennedy, Sally Horn, Marvin Bennett, Pete Nester, and Bob Tolliver.

I extend my sincerest gratitude to my parents, Anne Marie and Robert Owen Petty, for my life and a childhood complete with a magnificient American beech tree in our backyard. To my daughter Sarah, thank you for sharing with me your perspective on the world and helping me to keep my feet firmly planted on the ground. Finally, I would like to thank my wife, friend, fellow parent, and colleague Rebecca Young Rivers. Her constant emotional and intellectual encouragement have been crucial throughout my doctoral program.

ABSTRACT

In this study I investigated the role lake-effect climate, soil type, and topography played in the late-Quaternary establishment, expansion, and decline of American beech in eastern Upper Michigan. General Land Office surveys and modern soil surveys were used to establish the presettlement distribution of beech on nine soil cover types in an eight township study area in Mackinac County, Michigan. Pollen analysis from small lakes (<10 ha) varying in distance from Lake Michigan (2-15 km) and surrounded by various soil types were used to determine the establishment, expansion, and decline of American beech.

Presettlement beech was positively associated with loamy soils over gravelly till, sandy soils with ortstein, and loamy, sandy soils over gravelly till. An outlying population of beech became established 5790 yr BP near the climatically ameliorated shore of Lake Michigan on fine-textured loamy soils. At a second site also surrounded by fine-textured loamy soils beech pollen did not reach appreciable levels until 5070 yr BP. Between 3000 and 2500 yr BP beech populations increased throughout Upper Michigan at sites on loamy soils, and expanded onto the areally more abundant sandy soils with ortstein.

These results indicate that climate amelioration by Lake Michigan and fine-textured soils were both required for beech establishment at 5790 yr BP in eastern Upper Michigan. Expansion of beech populations around 3000 yr BP onto coarse-textured soils was most likely the result of soil development at the landscape level and a shift to a more mesic climate regionally. Since 2000 yr BP, selected populations of American beech declined in response to habitat loss as lowland mesic sites became more hydric in response to paludification. Other populations collapsed as upland mesic sites became more xeric in response to lowering of water tables due to isostatic rebound and river downcutting. The occurrence of an outlying population of American beech along the ameliorated shores of Lake Michigan during the Hypsithermal interval provides a partial analog for potential refugia under an enhanced Greenhouse climate.

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CHAPTER I

INTRODUCTION

As the Laurentide ice sheet retreated from its maximal advance at the end of the Wisconsinan glacial age, 17 000 radiocarbon years Before Present (yr BP), species began adjusting their geographic ranges in response to a global increase in temperature and increased land area available for colonization across eastern North America (Davis 1976, 1981, 1983, Delcourt and Delcourt 1987, Webb 1988). The postglacial rates and directions of these taxon-specific range adjustments have been studied extensively using paleoecological techniques at subcontinental and regional scales and have been related to late-Quaternary changes in climate and seasonality (Bennett 1985, M. Davis *et al.* 1986, Huntley and Webb 1989, Huntley *et al.* 1989, Woods and Davis 1989). Far fewer studies have focused on the controls of plant species distributions and abundances on a spatial and temporal scale at the landscape level (10^6 – 10^9 square meters, and 10^2 - 10^3 years) (Brubaker 1975, Bernabo 1981, Graumlich and Davis 1993, H. Delcourt and P. Delcourt 1996).

One forest species that has proven especially useful in the investigation of late-Quaternary tree migrations and forest dynamics is American beech (*Fagus grandifolia* Ehrh.), a deciduous, late-successional, mesophytic tree species in the family Fagaceae (all nomenclature follows Gleason and Cronquist [1963]). American beech is widespread today throughout most of eastern North America (Little 1971) (Fig. 1) and is a dominant or co-dominant canopy tree species in 20 forest cover types in eastern North America (Tubbs and Houston 1990). It is most abundant in association with sugar maple (*Acer saccharum*), yellow birch (*Betula lutea*), red spruce (*Picea rubens*), hemlock (*Tsuga canadensis*), and magnolia (*Magnolia spp.*). While beech is a minor commercial

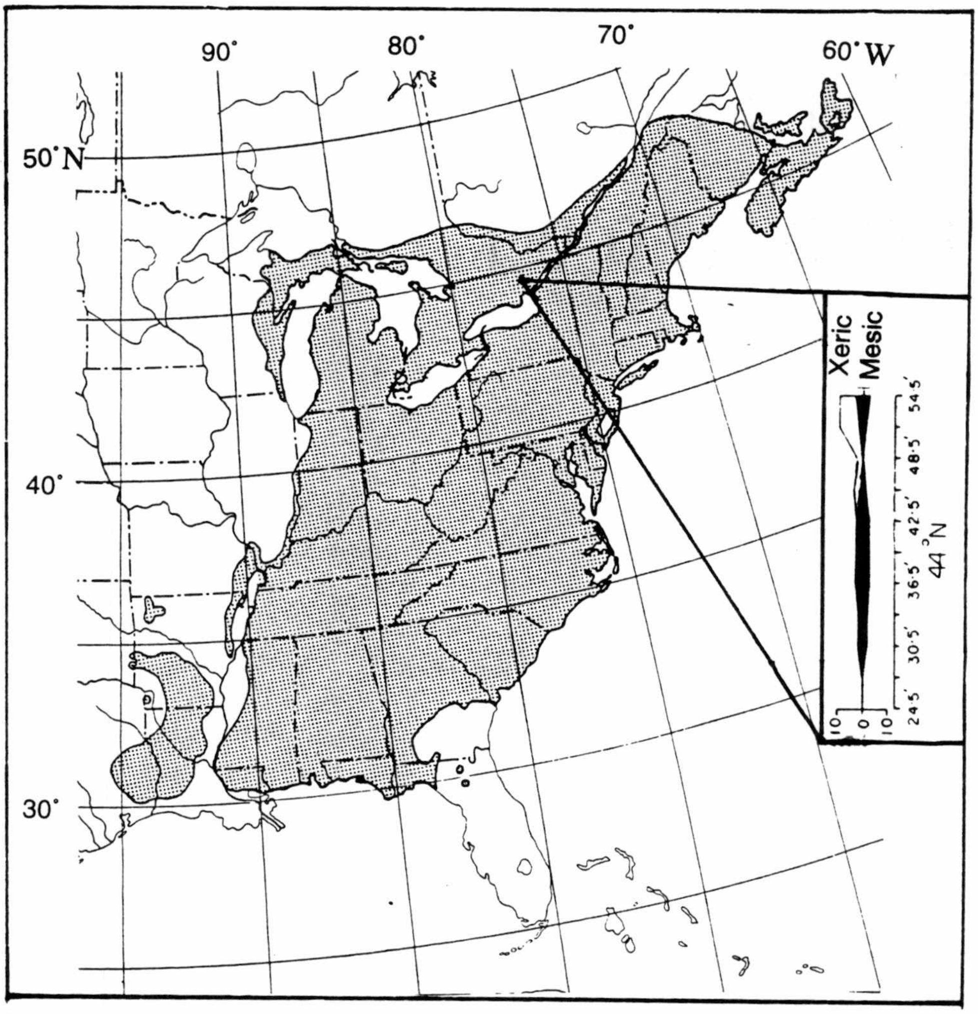


Figure 1. Pre-Columbian distribution map (shaded area) for American beech (*Fagus grandifolia* Ehrh.) (modified from Little 1971). Inset shows the importance value of beech on mesic habitats (black) and xeric habitats (white) near its northern range limit along a transect from 44°24.5'N to 44°54.5'N in southern Ontario (from Beschel *et al.* 1962).

hardwood, growing stock volumes (GSV) in commercial forests commonly reach greater than 5% of extractable timber (Delcourt *et al.* 1984) (Fig. 2). In the deciduous forests of eastern North America beech is most abundant in the Beech-Maple Forest region and the central and eastern portions of the Hemlock-White Pine-Northern Hardwoods region (Braun 1950) (Fig. 2). As a long-lived, canopy species, American beech plays an important role in the forest dynamics where it occurs. Beech mast is eaten by numerous mammals and birds including black bears, foxes, deer, squirrels, ruffed grouse, blue jays, and ducks. In the northern portion of its range beech is the only deciduous nut producer and, therefore, becomes an increasingly important food for wildlife (Tubbs and Houston 1990). Understanding the late-Quaternary controls on the distributional history of American beech is needed to predict its range adjustments due to anthropogenic global warming. American beech is an ideal tree species for the study of past forest invasions and shifts in distribution because 1) as a late-successional, forest-canopy dominant, beech plays an important role in forest dynamics; 2) beech pollen can be readily identified to species (Kapp 1969, McAndrews *et al.* 1973), thus allowing for species-specific reconstruction of its past distribution and abundance; and 3) beech was the last deciduous tree species to successfully invade the already established, closed-canopy forest ecosystem in the eastern half of the Upper Michigan during the last 8000 years, making it an ideal "case-study" to understand where and how tree species will survive significant shifts in their current range limits as a result of global warming.

A. Purpose of Study

The purpose of this study is to examine the shifting landscape-level controls of the population dynamics of American beech in eastern Upper Michigan for the last 8000 years, and to specifically answer the question, what environmental factors have controlled the

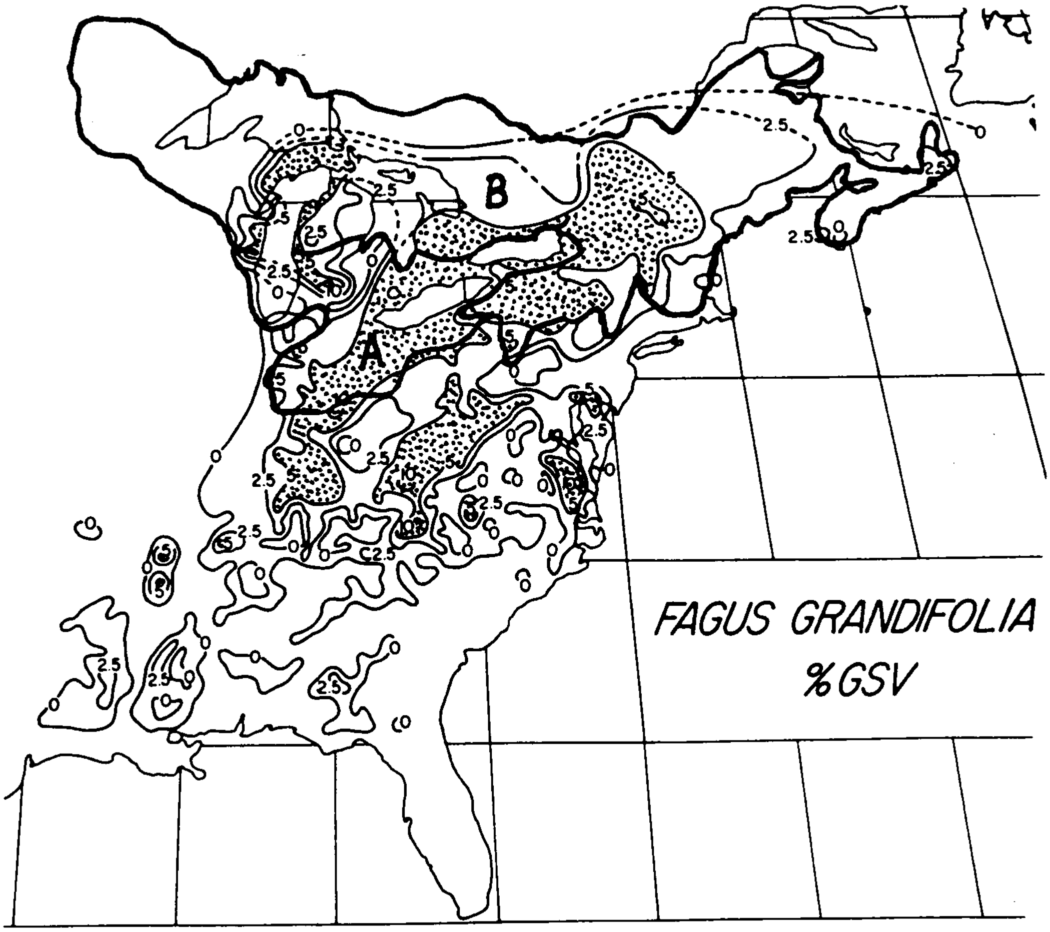


Figure 2. Map of the growing stock volume (% GSV) of American beech (from Delcourt *et al.* 1984) showing the forest regions where American beech is most abundant, the Beech-Maple Forest region (A) and the Hemlock-White Pine Northern Hardwoods region (B) (after Braun 1950). Shading indicates area where beech makes up great than 5% of the GSV.

distribution and abundance of American beech over a time scale of 100 to 8000 years and a spatial scale of 10^6 to 10^9 m^2?

B. Late-Quaternary Patterns of Beech Migration

Based on previous palynological studies, the migration and expansion of American beech onto deglaciated landscapes has typically occurred toward the end of interglacial cycles (Kapp and Gooding 1974, McAndrews 1981). This pattern has been demonstrated on a subcontinental scale (Fig. 3) (Delcourt and Delcourt 1987) as well as at individual sites for a) the current interglacial cycle (McAndrews 1981, Kapp 1977a,b, Davis 1985, M. Davis *et al.* 1986, Bennett 1987, 1987, S. Webb 1983, 1986, 1987, Woods and Davis 1989) and b) a pre-Illinoian interglacial cycle (Kapp and Gooding 1974) (Fig. 4). These data are consistent with the interpretation of a predictable response by American beech to a cyclic environmental or climatic factor. This pattern has also been recognized as having occurred during multiple interglacial cycles for the ecological equivalent of American beech in Europe, European beech (*Fagus sylvatica*) (Birks 1986, Watts 1988).

While a spatial and temporal analysis of changes in the distribution and abundance of American beech is not possible for pre-Wisconsinan landscapes due to a paucity of plant-fossil sites and poor age control, such changes have been reconstructed for eastern North America for the late Wisconsinan and Holocene (Davis 1976, 1981, 1983, Bennett 1985, Delcourt and Delcourt 1987, Dexter *et al.* 1987, and Webb 1988). During the Wisconsinan full-glacial interval (22 000 to 18 000 yr BP) small populations of American beech (based upon fossil pollen preserved in radiometrically-dated, organic-rich, wetland sediments) grew in southern Louisiana (Tunica Bayou [with macrofossil evidence], Jackson and Givens 1994, P. Delcourt and H. Delcourt 1996), Alabama (Goshen Springs, Delcourt 1980), and Florida (Sheeler Lake, Watts and Stuiver 1980; Camel Lake, Watts *et al.* 1992) (Fig. 5a). From these refugial populations beech expanded

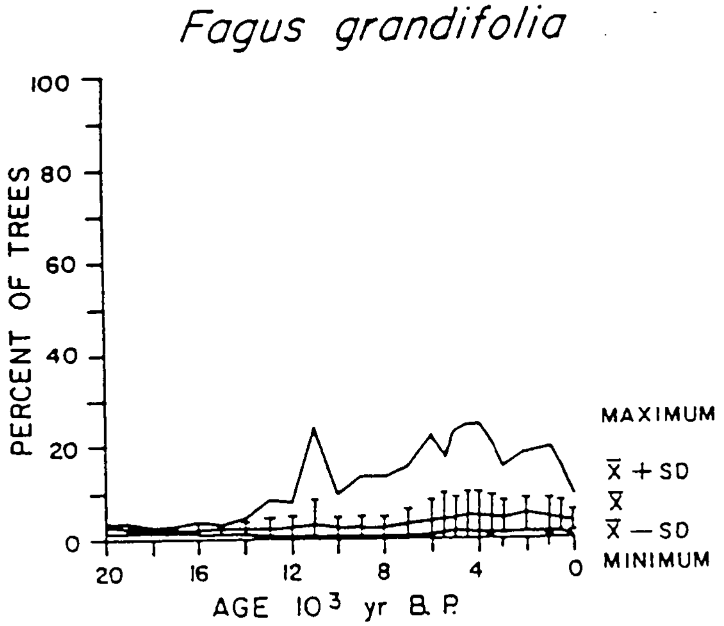


Figure 3. Graph of the changes in paleo-dominance of American beech during the last 20 000 yr BP in eastern North America showing that the maximum dominance for beech occurred 4000 yr BP (from Delcourt and Delcourt 1987). Shown are the maximum, minimum, and mean values of paleo-dominance as well as ± 1 SD of the mean.

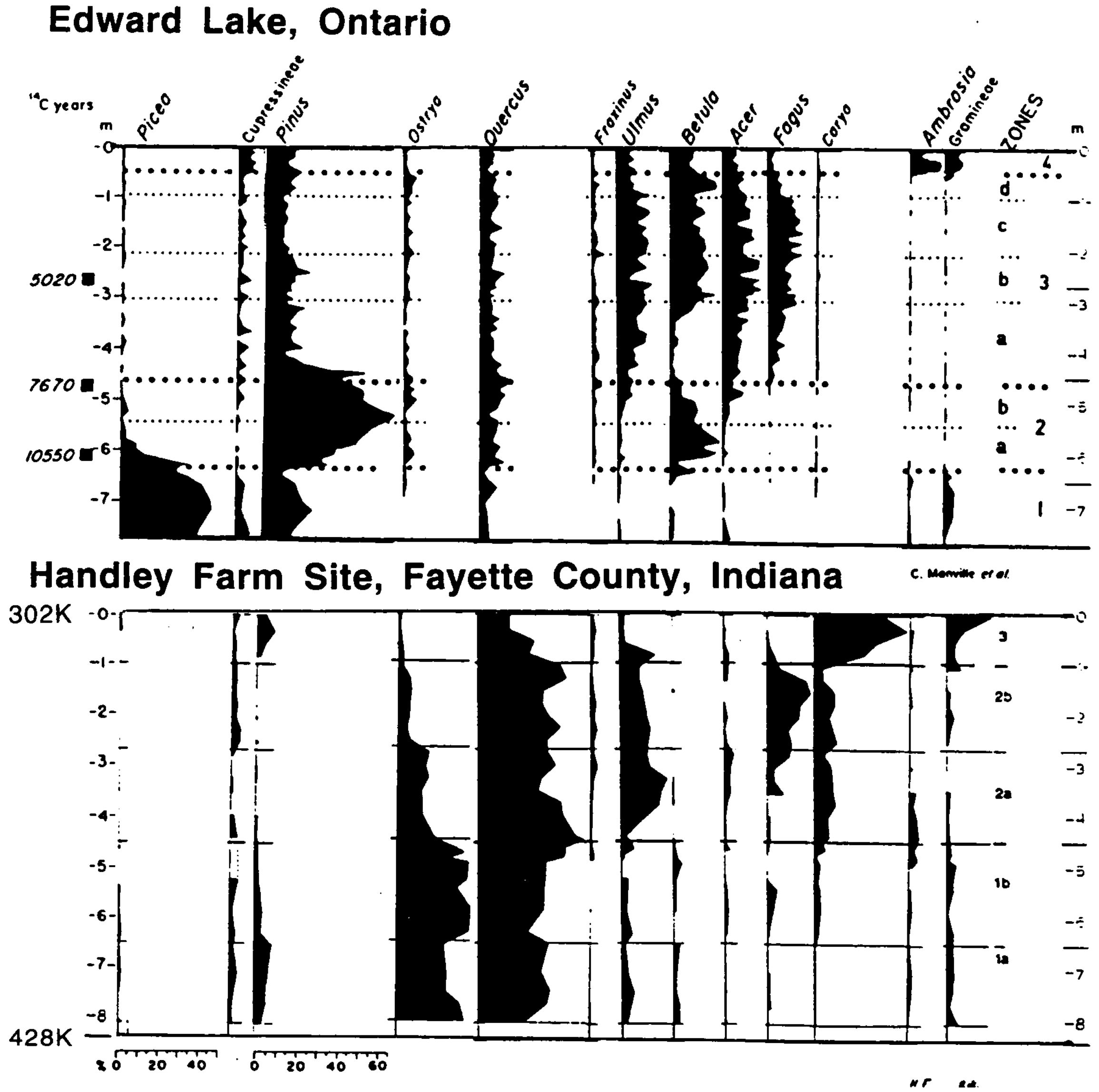


Figure 4. The occurrence of American beech pollen during two Pleistocene interglacial cycles in North America. Data are from Edward Lake (EdL), Ontario, modified from McAndrews (1981) (a Holocene interglacial sequence [10 000 yr BP to present]) and Handley Farm Site (HF), Indiana, modified from Kapp and Gooding (1974) (a pre-Illinoian interglacial sequence ["Yarmouthian"] occurring between *circa* 428 000 and 302 000 yr BP, based on Fullerton [1986]).

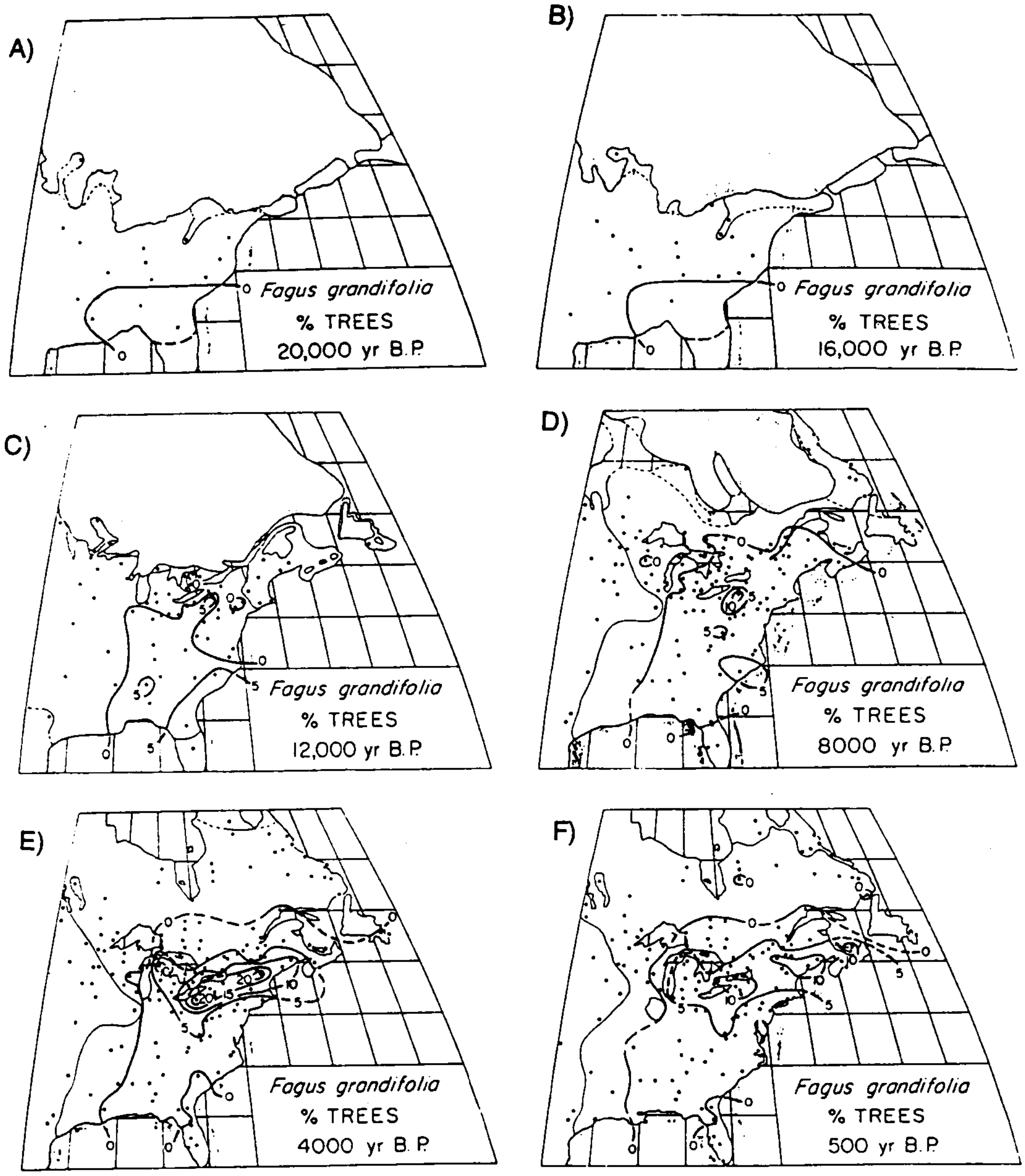


Figure 5. Late-Quaternary paleo-dominance maps for American beech from 20 000 to 500 yr BP (modified from Delcourt and Delcourt 1987).

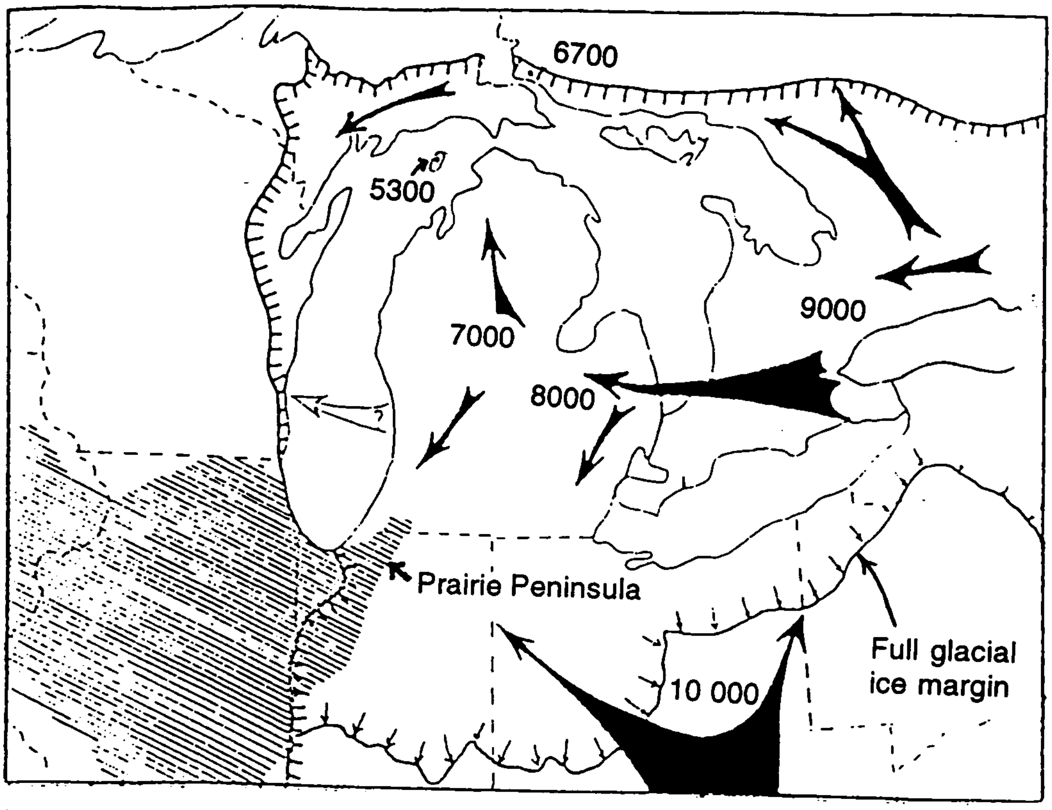
north and east as climate warmed. Beech demonstrated a K-migrational strategy during the late Quaternary, in that its populations were initially small in size and then gradually increased, resulting in the maximum abundance of the species located several hundred kilometers behind the initial migrational front (Delcourt and Delcourt 1987). From 20 000 to 12 000 yr BP, beech migrated northward, but made up less than 10% of the reconstructed forest composition throughout its range (with reconstructions based upon modern pollen-vegetation calibrations using geometric-mean linear regression between % arboreal pollen and % growing stock volume). During the late Pleistocene, the greatest populations of beech occurred in the Southeast from northern Florida to coastal Georgia and South Carolina (Fig. 5a,b,c). Between 12 000 and 8000 yr BP, the population center for beech shifted from the Southeast to the Northeast (Pennsylvania and New York) (Fig. 5c,d). Beech populations expanded to their greatest abundance in the deglaciated portion of North America between 8000 and 4000 yr BP (Fig. 5d,e), some 8000 to 12 000 years after this region became ice free. During this same interval beech population dominance declined to less than 5% of forest composition in the southern portion of its range. Over the past 4000 years, beech spread into the western Great Lakes region (Fig. 5e,f) where it is continuing to spread westward today (M. Davis *et al.* 1986) while simultaneously declining in dominance farther to the north and east (Liu 1990, Russell *et al.* 1993). Calculations of overall mean migration rates of beech for the last 16 000 years range from 169 to 200 m yr^{-1} (based on 1 to 5 different migration tracks) (Davis 1983, Delcourt and Delcourt 1987) with the maximum average rate of 272 m yr^{-1} calculated for the time interval from 12 000 to 10 000 yr BP (Delcourt and Delcourt 1987). These rates are comparable to other species of nut-bearing trees such as *Quercus* and *Carya* (S.Webb 1986, Delcourt and Delcourt 1987) and indicate that beech trees were dispersed by some animal vector at a rate of 6.8 to 8.0 km $generation^{-1}$ (based on a minimum age of reproduction for beech of 40 years) (Johnson and Webb 1989). The now extinct passenger pigeon is a likely candidate as a disperser of beech nuts based on historic observation of their preference for beech nuts and their migratory fly-ways (S. Webb 1986).

Within the Great Lakes region, several researchers have studied the distributional history of American beech (Bailey and Ahearn 1981, Kapp 1977b, Futyma 1982, Webb 1983, M. Davis *et al.* 1986, Woods and Davis 1989). While the paleoecological criteria for determining when beech arrived at a particular site have varied among researchers, a general pattern and timing of beech migration into the Great Lakes region has emerged (for fuller discussion of the debate concerning criteria, see the two sections, BACKGROUND: Determination of Local Taxon Presence Using Palynological Data, and METHODS: Criteria for Determining Time of Beech Establishment). Below I describe this pattern, outlining three significant ecological questions which remain unanswered. I then formulate a set of testable hypotheses.

American beech migrated into the Great Lakes region from the southeast, through Ohio and Pennsylvania, between 12 000 and 8000 yr BP (Fig. 6a). Kapp (1977b) noted that beech apparently migrated northward more rapidly than westward when it reached the Great Lakes because it was effectively blocked by a "filter barrier" imposed by the grassland extension known as the Prairie Peninsula (Benningoff 1964). Beech was present by 9000 yr BP on the northern side of what was then a much shallower Lake Ontario (water levels during this period were 60 to 80 m below modern position) (Anderson and Lewis 1985). Kapp (1977b) hypothesized that beech entered Lower and Upper Michigan at 9000 and 6700 yr BP, respectively, via Ontario, south and north of Lake Huron, which at this time was gradually rising following a much lower water level (known as the Stanley Low Phase) (Eschman and Karrow 1985). Between 8000 and 5000 yr BP beech populations spread throughout Lower Michigan, reaching Beaver Island approximately 5300 yr BP (Kapp *et al.* 1969). Kapp (1977b) hypothesized that beech dispersed across the southern portion of Lake Michigan to reach eastern Wisconsin during this mid-

A)

B)



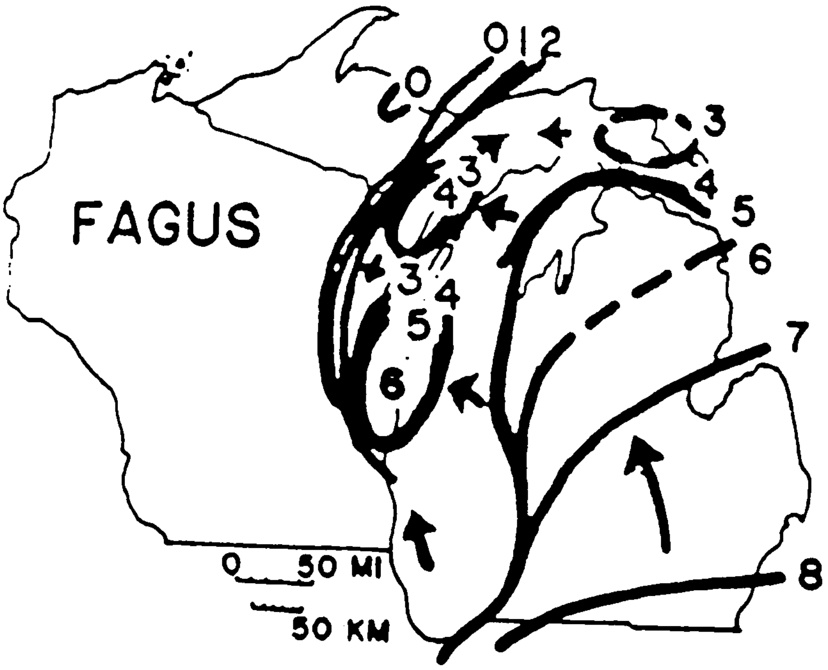


Figure 6. Holocene migration histories of American beech in Great Lakes region based on previously published work, modified from a) Kapp 1977b, and b) M. Davis *et al.* 1986. Figure 6a indicates arrival times in radiocarbon yr BP and 6b in thousands of radiocarbon yr BP.

Holocene period as well. At the time of publication for Kapp's paper (1977), there were no radiometrically dated sites in Upper Michigan or Wisconsin within the modern-day distributional limit of beech with which to test his hypotheses. Preliminary research by R. Futyma (cited in Bailey and Ahearn, 1981) suggested that beech did not reach Upper Michigan until 3000 yr BP, reflecting a potential lag in beech dispersal of 2000 to 3000 years. With the addition of several new sites, M. Davis *et al.* (1986) tested the hypotheses that the migration of beech into Wisconsin and Upper Michigan was limited either by its dispersal ability or by Holocene climate barriers. In their study they demonstrated that American beech became established in southeastern Wisconsin by 6200 yr BP via long distance transport across either a water or southerly prairie barrier of 80 to 120 km (Fig. 6b). Thus, the smaller water distance of 10 to 40 km separating Lower and Upper Michigan across the Straits of Mackinac was judged not sufficient to have limited beech-nut dispersal. Davis *et al.* (1986) concluded that mid-Holocene climate and/or environments must have limited the establishment of beech in Upper Michigan between 5000 and 3000 yr BP. Between 3000 to 2000 yr BP beech populations expanded rapidly throughout Upper Michigan and eastern Wisconsin (Fig. 6b) (M. Davis *et al.* 1986, Woods and Davis 1989). Since that time, some populations of beech have declined in abundance, whereas others have remained the same or increased in forest-canopy dominance. Beech reached its modern range limit in western Upper Michigan and Wisconsin within the last 1000 years (Woods and Davis 1989) (Fig. 6b).

Both Futyma (1982) and Woods and Davis (1989) considered that the apparent delay in beech migration into Upper Michigan may be an artifact of incomplete sampling, although for different reasons. Futyma (1982) suggested that undetected outlying populations of beech may have become established before 3000 yr BP along the mesic shoreline of Lake Michigan, where climate amelioration (warmer winters, cooler summers) would have provided suitable habitat for beech. Woods and Davis (1989) hypothesized that since all of the sites included in their study of eastern Upper Michigan occurred on sandy soils derived from glacial outwash, undetected outlying populations of beech may have become established prior to 3000 yr BP on fine-textured soils. On these more clay-rich (or calcium rich) soils, soil moisture (and nutrients) may not have been limiting to beech colonization.

Woods and Davis (1989) suggested that a regional shift to a more mesic climate around 3000 yr BP allowed beech to expand onto the more extensive, previously unsuitable coarse-grained sandy soils. Alternatively, Franzmeier *et al.* (1963), in a chronosequence study of sandy soils in northern Lower Michigan, found that beech and sugar maple forests were associated with the oldest (most developed) sandy soils. They hypothesized that postglacial development of cemented ortstein layers (accumulations of organo-metalic sesquioxides) in the B horizon of these soils increased the water holding capacity and nutrient supplying power of soil, favoring the Holocene establishment and growth of both sugar maple and beech (Franzmeier *et al.* 1963). Because of the relatively late date of the expansion of these mesic forests (occurring some 7000 years after deglaciation of the area), M. Davis *et al.* (1986) discounted the possible role soil development might have played, arguing that all soil development would have already occurred by the time beech arrived.

Several researchers have documented declines in beech populations over the last 2000 years in the northeastern portion of its range (Bennett 1985, Delcourt and Delcourt 1987, Liu 1990, Russell *et al.* 1993). The decline of beech at many sites has been explained by climatic cooling (Russell *et al.* 1993, Campbell and McAndrews 1993); however, at the landscape level, where beech populations may be increasing and decreasing at different sites within the same area, additional explanations need to be considered. In Upper Michigan at least two explanations for the apparent decline of beech at selected sites are possible. First, beech may have declined in response to increased competition from other mesic tree species such as sugar maple, hemlock, or yellow birch (for example, reciprocal replacement with sugar maple, *sensu* Woods 1979). Second, beech populations may have declined in response to a gradual rise in the water table and increased peat growth resulting in the displacement of beech by more mesic and hydric tree species, such as white cedar (*Thuja occidentalis*), tamarack (*Larix laricina*), and black spruce (*Picea mariana*). Thus, paludification (Ritchie 1987) would have resulted in the decline of beech only at low-lying sites with relatively shallow water tables.

C. Hypotheses To Be Tested

From this general picture of the postglacial history of beech in the Great Lakes region, several questions remain unanswered. First, why might beech have been delayed in reaching eastern Upper Michigan? Or, following the axiom "absence of evidence is not evidence of absence," if beech were not delayed, and instead previously undetected populations had become established, where and on what soil types did these outlying populations first occur? Second, why was beech apparently so late in expanding its populations in Upper Michigan relative to Lower Michigan? When its abundance did increase, and onto what soils did beech populations expand? Finally, what factors have led to the decline of beech at certain sites? To investigate these ecological questions, I have focused on an area in eastern Upper Michigan along Lake Michigan's northern shore (Figs. 7 and 8). Using palynological records from four lakes within the study area, as well as published and unpublished pollen curves from 12 additional lakes in Upper Michigan and eastern Wisconsin, I test the following seven hypotheses:

Concerning the postglacial establishment of American beech in eastern Upper Michigan:

Hypothesis 1a. Beech was significantly delayed in reaching the study area because of some geographic barrier to its dispersal, with no definitive evidence for outlying

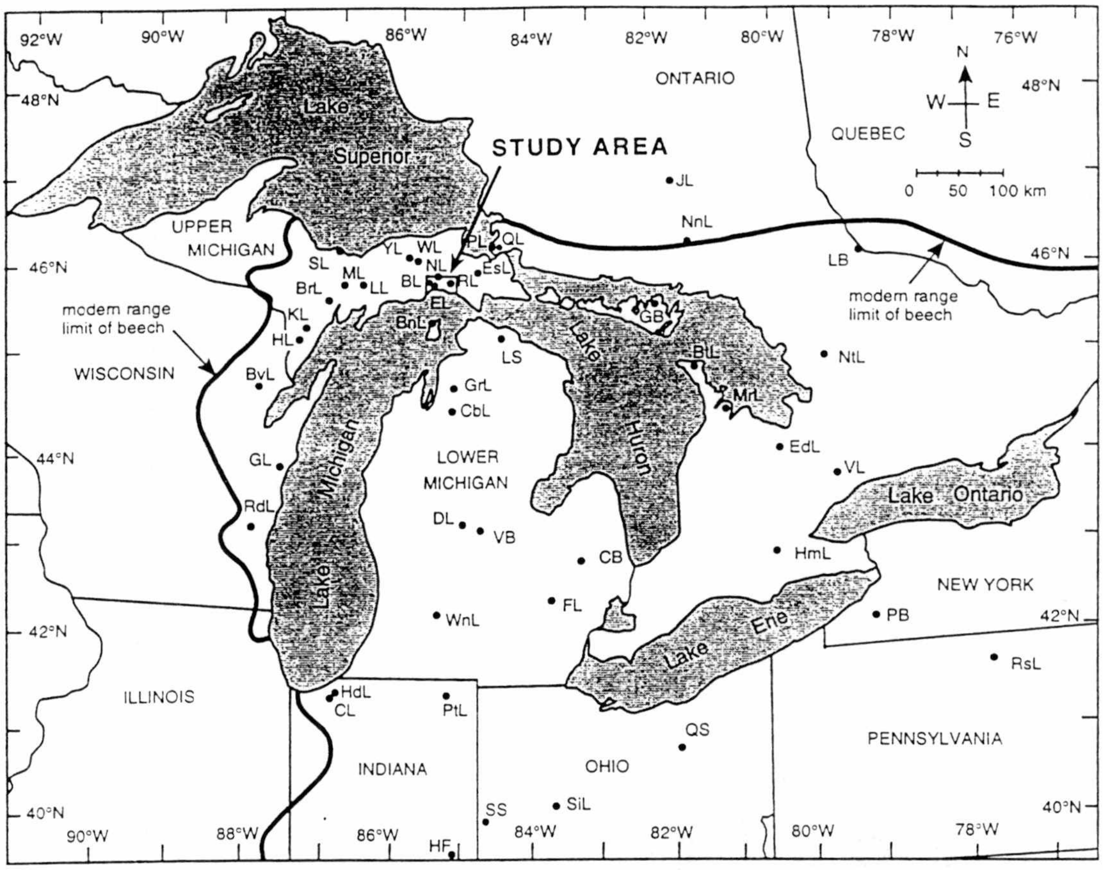


Figure 7. Location of study area in eastern Upper Michigan showing study sites and additional sites used in regional analysis and discussion. Pre-Columbian margin of beech distribution is modified from Little (1971). Sites names: BL, Beaverhouse Lake (this study). BnL. Barney Lake (Kapp *et al.* 1969), BrL, Brampton Lake (Woods and Davis 1989). BtL. Bartley Lake (Bennett 1992). BvL, Beaver Lake (Woods and Davis 1989). CB. Chippewa Bog (Ahearn and Bailey 1980). CbL, Cub Lake (Rasmussen 1982). CL. Clear Lake (Bailey 1972), DL, Demont Lake (Kapp 1977a) , EL. Elbow Lake (Petty 1994). EdL. Edward Lake (McAndrews 1981), EsL, East Soldier Lake (Futyma 1982). FL. Frains Lake (Kerfoot 1974). GB, Greenbush Swamp (Warner *et al.* 1984). GL. Gass Lake (S. Webb 1983, 1987), GrL, Green Lake (Lawrenz 1975), HL. Hoglund Lake (Woods and Davis 1989). HdL, Hudson Lake (Ahearn and Bailey 1980), HmL. Hams Lake (Bennett 1987). JL. Jack Lake (Liu 1990), KL, Kitchner Lake (Woods and Davis 1989), LB, Lac Bastien (Bennett 1987). LL, Lorraine Lake (Woods and Davis 1989). LS. Lake Sixteen (Futyma and Miller 1986). ML, MacDonald Lake (Woods and Davis 1989). MrL, Mary Lake (Bennett 1992). NL. Nelson Lake (H. Delcourt. unpublished data). NnL. Nina Lake (Liu 1990). NtL. Nutt Lake (Bennett 1987), PB. Protection Bog (Miller 1973). PL. Prince Lake (Saarnisto 1974), PtL. Pretty Lake (Williams 1974). QL, Quadrangle Lake (Terasmae 1967), QS. Quillin Site (Shane 1987), RL. Ryerse Lake (Futyma 1982). RdL. Radtke Lake (Webb 1983, 1987). RsL, Rose Lake (Cotter and Crowl 1981). SL. Spirit Lake (Woods and Davis 1989). SiL. Silver Lake (Ogden 1966). SS. Stotzel-Leis Site (Shane 1987). VB. Vestaburg Bog (Gilliam *et al.* 1967) . VL. Van Nostrand Lake (McAndrews 1970. 1976). WL, Wolverine Lake (Futyma 1982). WnL, Wintergreen Lake (Manny *et al.* 1978). YL. Young Lake (Woods and Davis 1989). See Appendix A for location. elevation. area. and additional information for each study site.

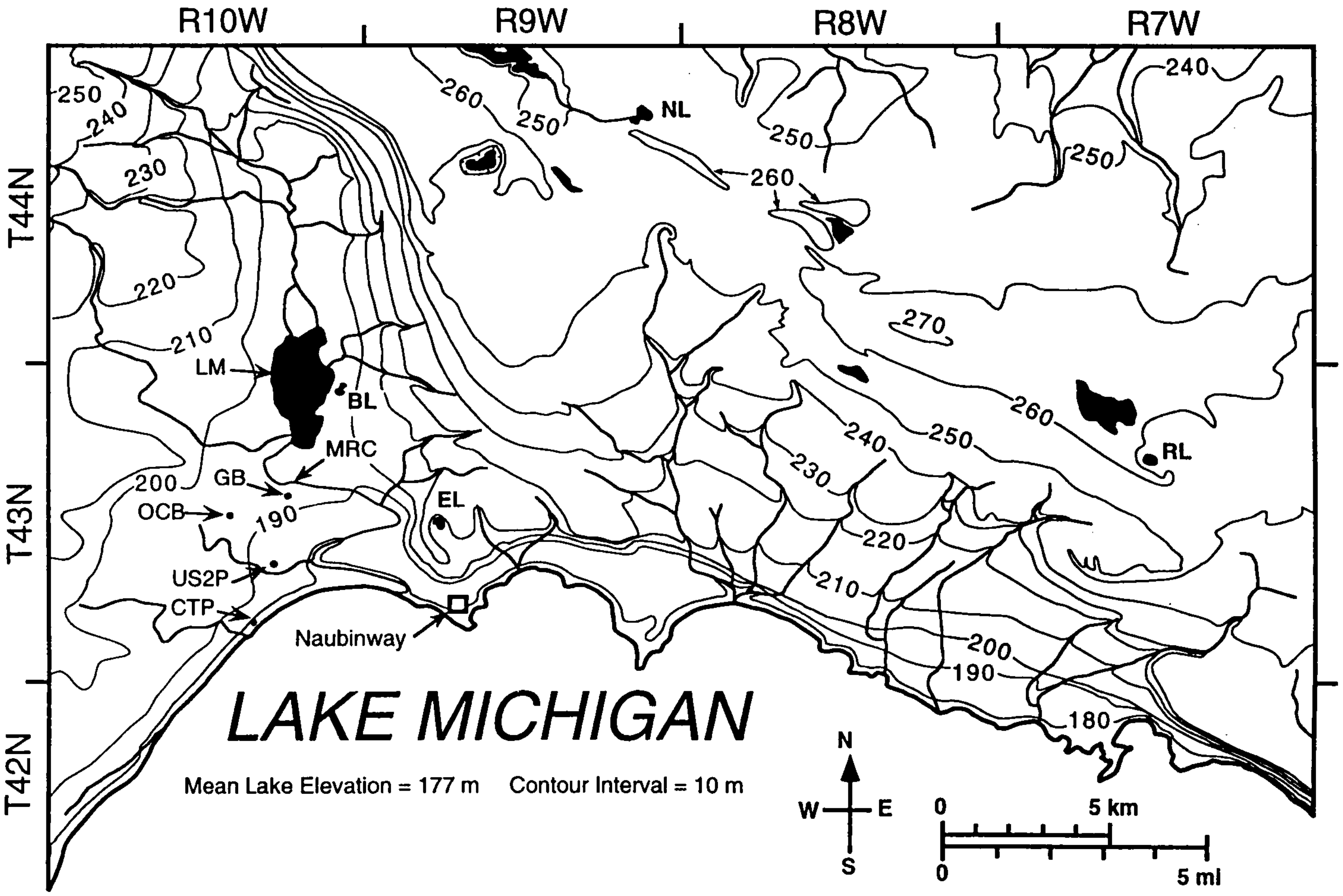


Figure 8. Detailed map of local study area in eastern Upper Michigan. Map shows drainage and topographic relief of the study area and the location of four lake sites used in analysis of local beech arrival, expansion and decline: BL, Beaverhouse Lake (this study); EL, Elbow Lake (Petty 1994); NL, Nelson Lake (H. Delcourt, unpublished; Nester 1999); and RL, Ryerse Lake (Futyma 1982). Additional sites discussed in text include: MRC, Millicoquins River Cut; GB, Greylock Bog; OCB, O'Neil Creek Bog; US2P, US2 Pond; and CTP, Carnegie Trail Pond. Other inland lakes are shown as black silhouettes

populations in eastern Upper Michigan prior to 3000 yr BP. (delayed establishment hypothesis).

Hypothesis 1b. Outlying populations of beech first became established prior to 3000 yr BP along the climatically ameliorated shores of Lake Michigan (lake-effect hypothesis).

Hypothesis 1c. Outlying populations of beech first became established prior to 3000 yr BP on fine-textured, calcareous soils where moisture and nutrient availability would not have been limiting to beech colonization (fine-textured calcareous soils hypothesis).

Concerning the expansion of American beech populations between 3000 and 2000 yr BP:

Hypothesis 2a. Beech populations expanded onto previously unsuitable upland coarse-textured sandy soils as climate regionally became cooler and more moist (coarse-textured soils hypothesis).

Hypothesis 2b. Beech populations expanded preferentially onto coarse-textured sandy soils with pedogenic ortstein layers (ortstein hypothesis).

Concerning the local decline of American beech at selected sites during the last 2000 yr BP:

Hypothesis 3a. Beech populations declined in response to competition from other mesic tree species (interspecific competition hypothesis).

Hypothesis 3b. Beech populations declined in response to loss of appropriate habitat with paludification of formerly mesic sites (paludification hypothesis).

CHAPTER II

BACKGROUND

A. Geologic Setting

Eastern Upper Michigan lies between Lake Superior to the north, Lake Michigan to the south, and Lake Huron to the east. The bedrock underlying the southern half of Upper Michigan is predominantly Middle Silurian dolomite, which forms the northwestern extension of the Niagara Escarpment (Fig. 9) (Hough 1958, Dorr and Eschman 1970). Several bedrock formations, including Silurian carbonates and shales, dip gently (8.5 m km^{-1}) to the south, forming the outermost concentric "rings" exposed in the Michigan structural basin (Fig. 9) (Hough 1958). Within the study area, the Manistique Member and the Burnt Bluff Formations of the Middle Silurian dolomite form upland knolls along the "height of land", the west-to-east drainage divide for surface waters in streams flowing south to Lake Michigan. These bedrock outcrops occur within a landscape dominated by Quaternary age deposits (Vanlier and Deutsch 1958, Farrand *et al.* 1984) (Fig. 10).

The Quaternary history of the upper Great Lakes region has been dominated by episodes of glaciation. Less-resistant Devonian shales that underlie much of Lake Michigan were deeply scoured by glacial flow during successive ice ages (Thwaites and Bertrand 1957). The ice sheet of the most recent glaciation, the Wisconsinan, reached as far south as central Illinois and southern Indiana (Dreimanis 1977; Mayewski *et al.* 1981). The retreat of the Laurentide Ice Sheet began around 17 000 yr BP (Dreimanis 1977, Clayton and Moran 1982) and marked a fundamental shift from glacial to interglacial climate. The retreating glacier and subsequent proglacial lakes laid down unconsolidated morainal, outwash, and lake-plain deposits of varying thicknesses which form a heterogeneous patchwork of late Quaternary surfaces across the Great Lakes region and

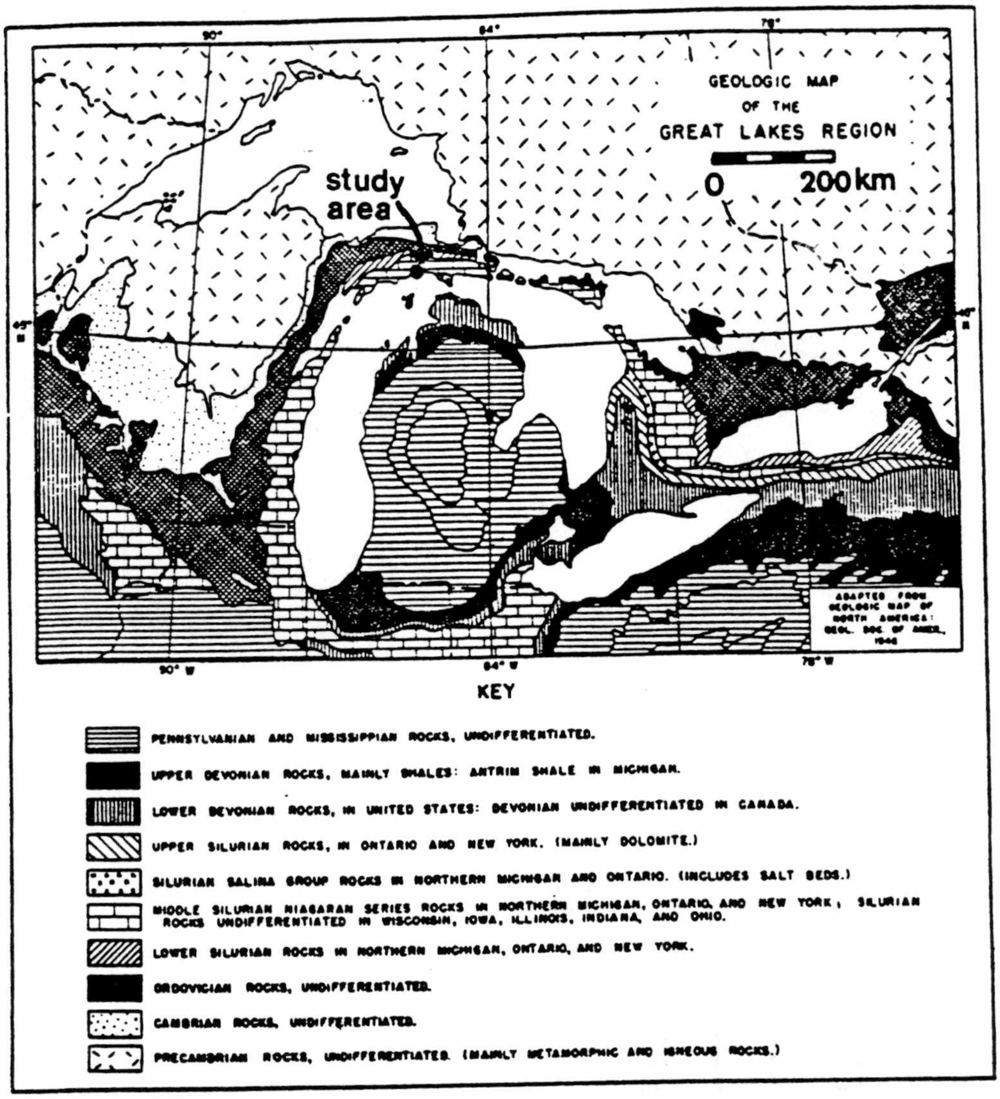


Figure 9. Bedrock geology of Great Lakes region (modified from Hough 1958). Location of study area is indicated by the block dot. The middle-Silurian age carbonate bedrock forms the Niagara Escarpment, the west-to-east oriented upland interfluve and drainage divide for surface waters flowing southward through the study area.

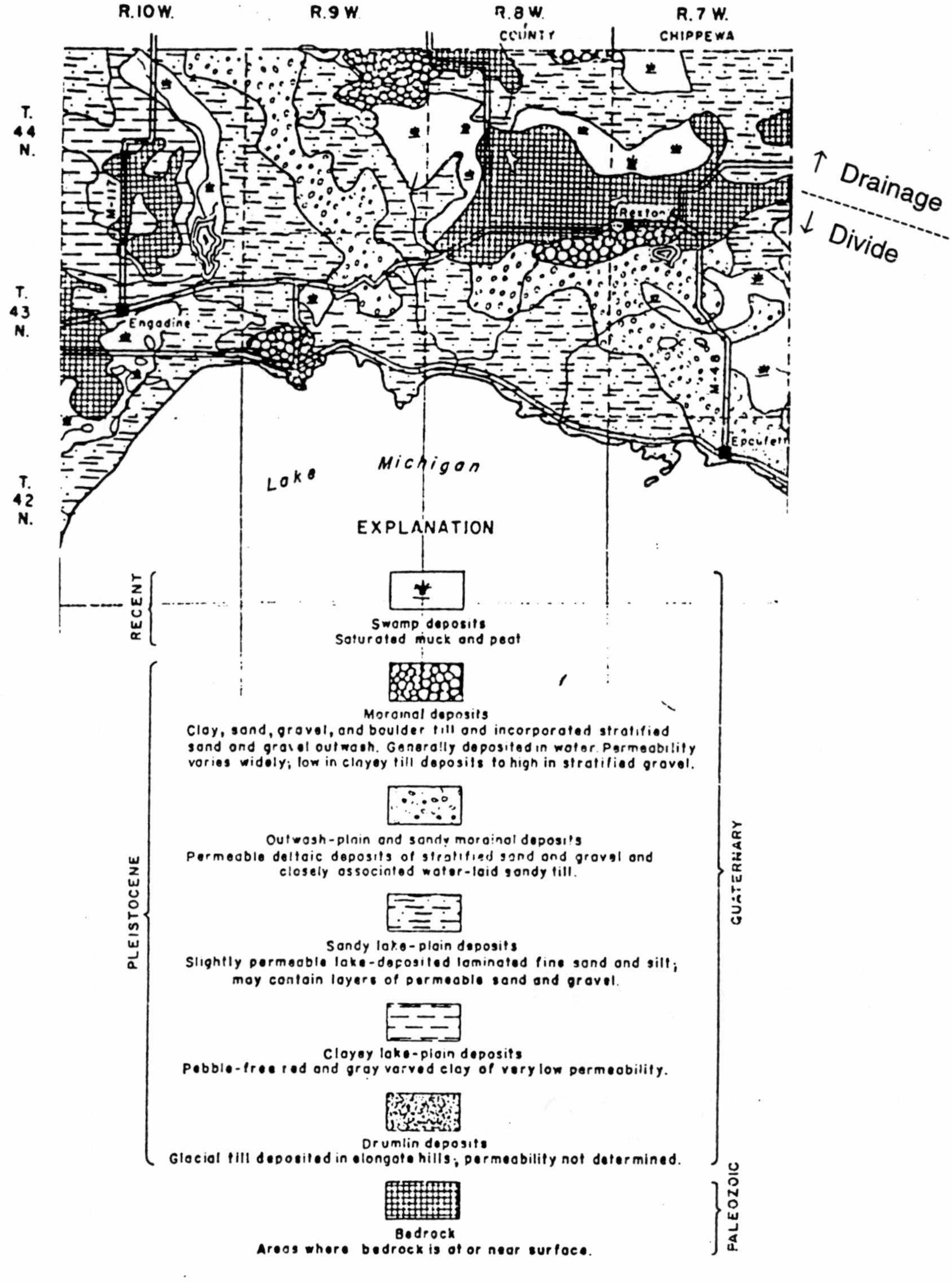


Figure 10. Surface geology of the study area (modified from Vanlier and Deutsch 1958).

within the study area (Fig. 10). Because Upper Michigan was almost completely submerged below the early Great Lakes (Larsen 1987), understanding their history and how they reworked these deposits is required as a context for any late-Quaternary study of landscape and vegetation history.

During and after deglaciation the Great Lakes fluctuated in response to changes in drainage outlets, climate, and isostatic rebound (due to removal of the weight of glacial ice) (Andrews, 1970; Clark and Persoage, 1970; Larsen 1987, Clark *et al.*, 1990, Petty *et al.* 1996). By 11 000 yr BP, after a series of brief retreats and readvances, the Laurentide Ice Sheet had retreated to the northern portion of what is today the Upper Peninsula of Michigan (Fig. 11a,b). The great lake at this time, Glacial Lake Algonquin, covered most of the Upper Peninsula leaving an archipelago of islands formed on the highest portions of glacial moraines (Futyma, 1981). With further retreat of the ice sheet, the North Bay outlet was exposed farther to the northeast, resulting in the partial draining of Glacial Lake Algonquin. During the subsequent interval called the Chippewa Low stage, between 10 300 yr BP and 8000 yr BP (Fig. 11c), the lake surface reached a lower limit of 102.1 m (335 ft) below the modern lake shores (Hough, 1958)

During the Chippewa Low, Lake Michigan and Lake Huron were separated with drainage from Lake Michigan into Lake Huron via the now submerged Mackinac River through the Straits of Mackinac. Rapid rebound of the deglaciated North Bay outlet resulted in a transgression in the Michigan and Huron basins. By 8300 yr BP the level of Lake Michigan had risen to 152.4 m (500 ft) above modern sea level (a.s.l.) (Chrzastowski *et al.,* 1991), and by 8100 yr BP, lakes Huron and Michigan were once again joined, as the North Bay outlet continued to rebound and limit eastward drainage from the central Great Lakes (Larsen, 1987). This transgression resulted in a series of highstands beginning around 6900 yr BP (Petty *et al.* 1996). A second highstand at 5400 yr BP has been identified within the study area and is associated with a rise in local water tables (Petty

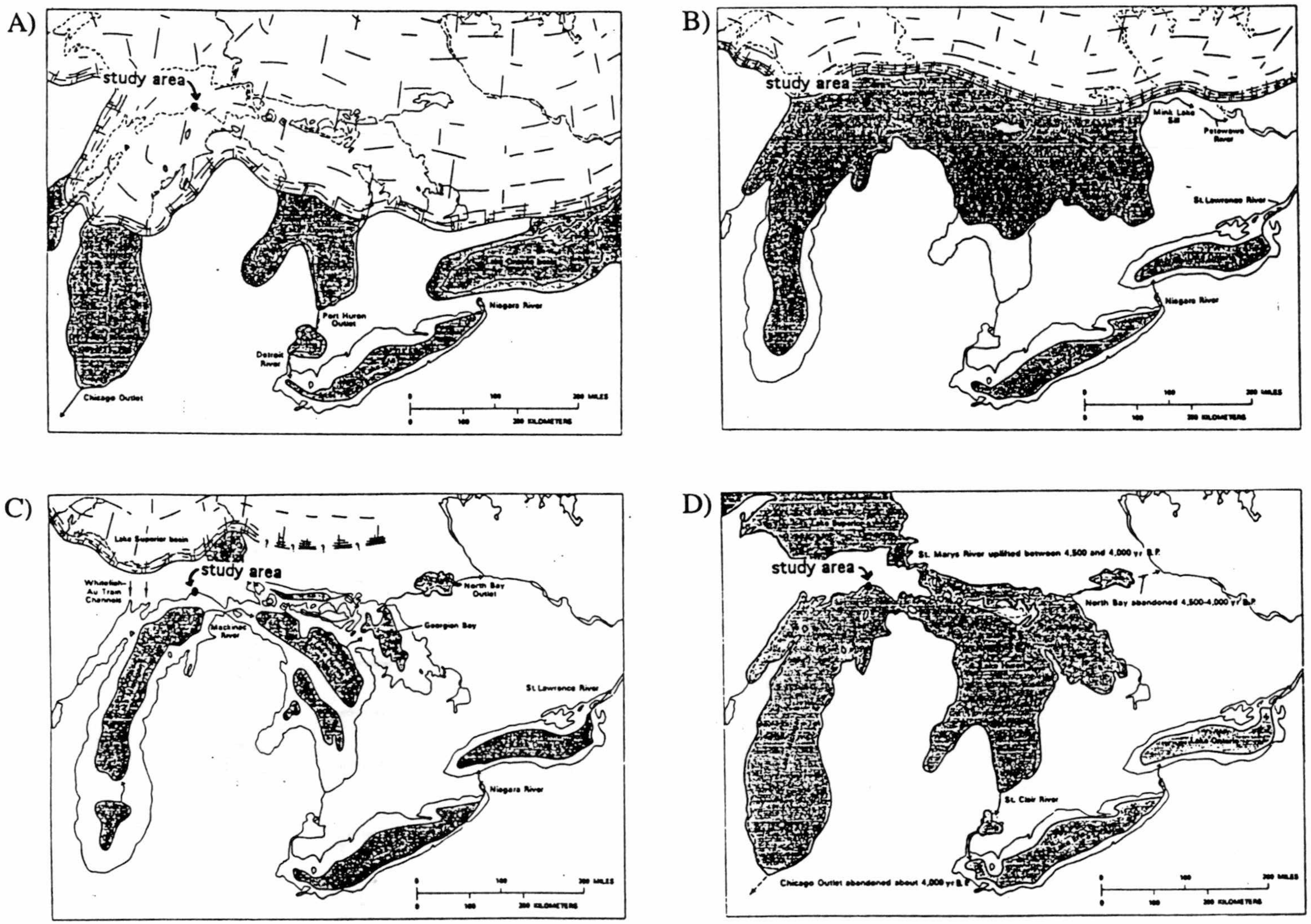


Figure 11. Geographic extent of late-Pleistocene and Holocene lakes in the Great Lakes basin (modified from Larsen 1987). Location of study area is marked with the black dot. The time intervals shown are A) 11 800 yr BP, B) 11 200 to 11 000 yr BP, C) 10 300 to 8000 yr BP, and D) 5400 to 4000 yr BP.

et al. 1996). Thus, there may have been relatively brief sub-regional mesic intervals during the longer Hypsithermal dry period. During the Nipissing I high stand (5400 yr BP), three outlets were temporarily in use simultaneously: North Bay, Chicago, and Port Huron (Lewis, 1969) (Fig. 11d). Between 4500 and 4000 yr BP, the North Bay outlet was abandoned due to continued rebound. By 3800 yr BP the Chicago outlet was also abandoned when the primary outlet shifted to the southern end of Lake Huron, as downcutting of the Port Huron outlet through glacial till concentrated drainage into the St. Clair River and into the Lake Erie - Lake Ontario - St. Lawrence Valley. This downcutting of the Port Huron outlet established the temporary stable level referred to as the Algoma stage in Lakes Michigan and Huron. Modern Lake Michigan began when the Port Huron outlet again was down-cut to just above its modern level by 2500 yr BP (Hansel *et al.*, 1985). During post-Algoma and historic times, Lake Michigan water level has fluctuated ± 1.5 m about its present elevation of 176.4 m (578.7 ft) (Fig. 12) (Larsen 1987; Fraser *et al.* 1990).

Past shorelines within the study area are shown in Figure 12. Lineations south of Lake Millecoquins identify occurrence of numerous beach ridges and swales formed over the past 5400 yr BP. The climatic control of Holocene lake levels was investigated by Fraser *et al.* (1990) who stated that, "It is apparent that during high lake levels, weather patterns are produced that result in 1) cooler average temperatures, especially during the early summer, and 2) significantly greater precipitation during the spring and early summer." These climate conditions result in decreased evaporation and increased runoff which together lead to higher lake levels. Studies of beach ridges formed over the past 6000 years along the southern and northern shores of Lake Michigan have identified cyclic fluctuations in lake level with frequencies of 35 and 150 years in the south (Thompson 1992) and 70 years in the north (Delcourt *et al.* 1996). The 70-year cycle correlates with a global temperature oscillation (Schlesinger and Ramankutty 1994, Delcourt *et al.* 1996).

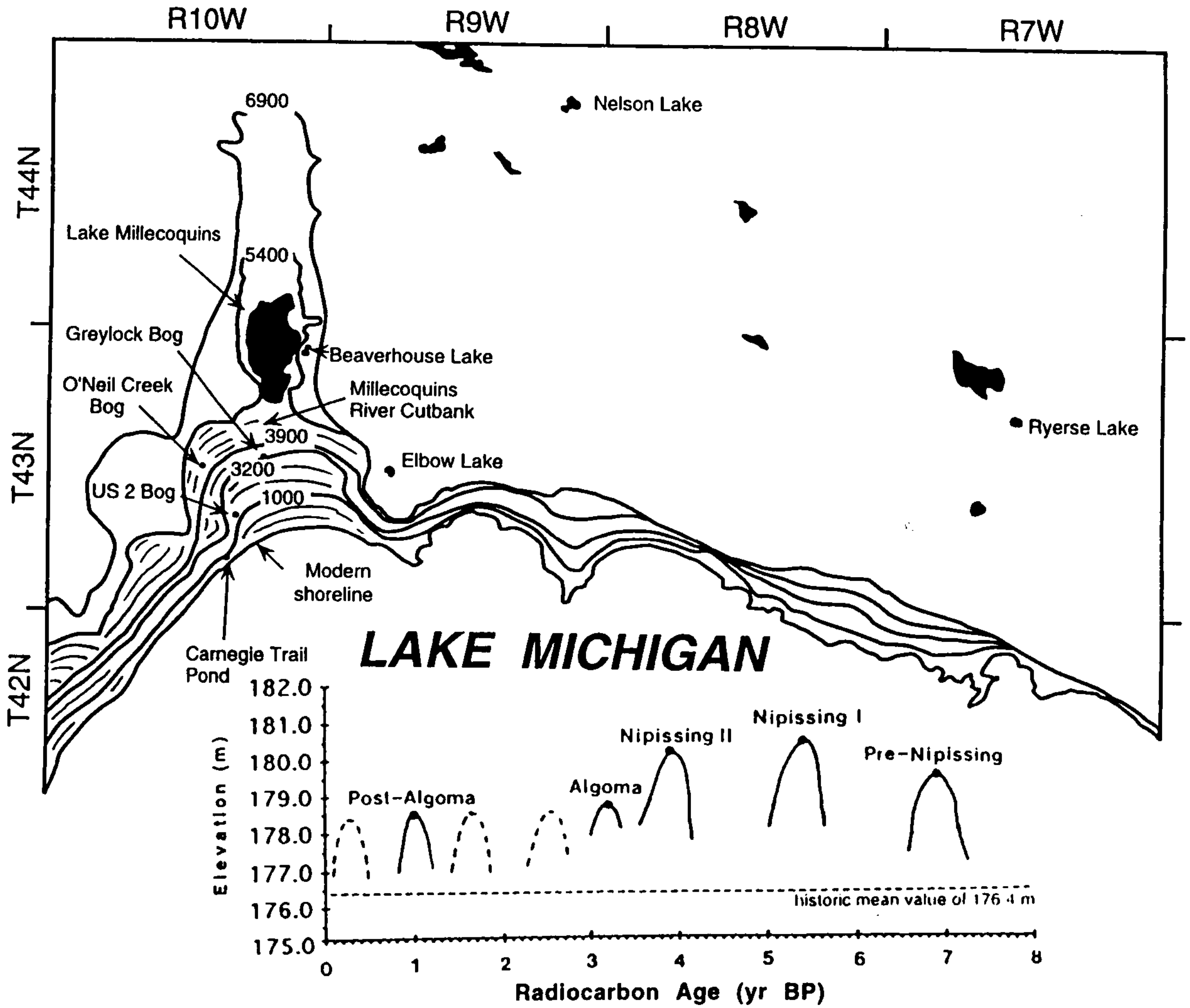


Figure 12. Paleoshorelines and Lake Michigan water levels within the study area for the past 6900 years (after Petty *et al.* 1996) shown in map and graph view. Shown are 5 identified highstands at 6900, 5400, 3900, 3200, and 1000 yr BP in map view along with 3 additional hypothesized highstands (dotted curves) at 2500, 1600, and 200 yr BP in graph view. Labeled sites are those included in this study.

Isostatic rebound of the region resulted in greater than 60 m of uplift within the study area between 10 000 and 8000 yr BP (Fig. 13). The uplift over the past 8000 years has been at a slower but consistent rate of 22.6 cm per century and has resulted in 18 m of uplift within the study area (Petty *et al.* 1996). This uplift has resulted in the formation of 75 sets of beach ridges and swales south of Lake Millecoquins and the gradual downcutting of the Millecoquins River (Fig. 12). This combination of geologic uplift and long-term fluctuations in the water level of Lake Michigan has changed the distance each study site has been from the Lake Michigan shoreline over time (Fig. 12). This variation in distance from Lake Michigan has caused variation in the lake-effect climate surrounding the sites and the degree to which this climate has shaped the vegetation.

B. Climate

Modern climate

Three dominant factors control the climate of the Great Lakes region. In hierarchical order, these factors are latitude, annual succession in the relative dominance and duration of three main airmasses, and the mesoscale feedbacks on climate from the Great Lakes themselves (Eichenlaub 1979, Eichenlaub *et al.* 1990). The Great Lakes are located between 41° and 49° N latitude, resulting in a large variation in the amount of incoming solar radiation during the year due to changes to the tilt of the earth's axis. For Sault St. Marie, Michigan (located 50 km east of the study area at a latitude of 46°23'N), average daily incoming solar radiation varies annually from 2.5 kilojoules m^{-2} (at winter solstice when the solar altitude is 20° above the horizon) to 25 x 10^3 kilojoules m^{-2} (at summer solstice when solar altitude reaches 67° above the horizon) (Eichenlaub *et al.* 1990). This variation is the driving force behind an annual fluctuation in the mean daily air temperature from –10°C to 18°C at the Sault St. Marie station.

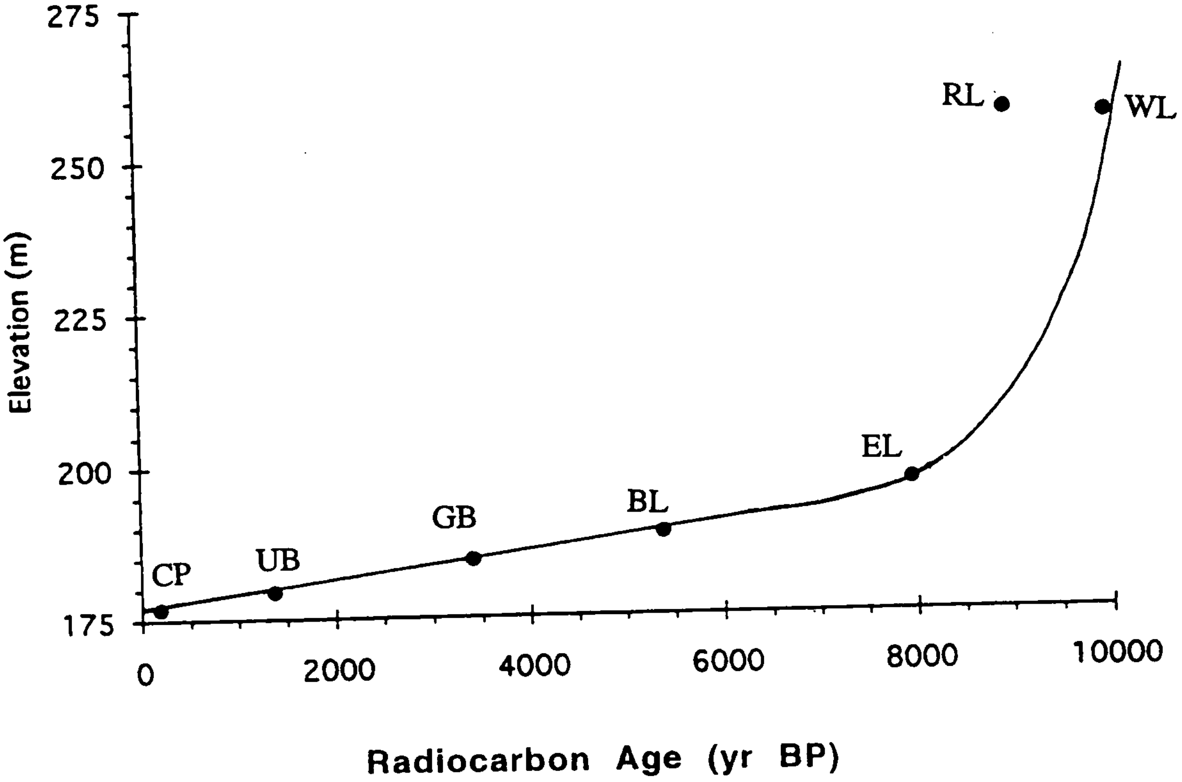


Figure 13. Curve of isostatic rebound (uplift of land surface) within the study area for the past 10 000 years (modified from Petty *et al.* 1996). Site abbreviations correspond to sites shown in Figures 7 and 8 and are BL (Beaverhouse Lake), CP (Carnegie Trail Pond), EL (Elbow Lake), GB (Greylock Bog), NL (Nelson Lake), RL (Ryerse Lake), and UB (US 2 Pond).

Superimposed on this annual variation in insolation is the influence of three airmass regimes on the climate of the Great Lakes and specifically, Upper Michigan (Eichenlaub 1979) (Fig. 14). The three regimes are a highly modified maritime Polar (mP) originating in the North Pacific Ocean; a continental Polar (cP) source of cold, dry air forming in northern Canada, and a maritime Tropical (mT) source of warm, humid air from the Gulf of Mexico (from Eichenlaub 1979). The relative dominance of each of these airmasses corresponds primarily with their modal position relative to the jet stream. The predictable relationship between ridges and troughs in the jet stream, the flow of airmasses, and the resultant "down wind" climate for a region is described as "teleconnection" (Eichenlaub 1979) (Fig. 15). When the Pacific/North American (PNA) teleconnection is in strongly zonal mode there is an enhanced westerly air flow (typically in the summer). The Maritime Polar airmasses from the Northern Pacific Ocean influence the weather most during these times although by the time they reach the Great Lakes region they have lost most of their maritime moisture crossing the Rocky Mountains. Periods of enhanced zonal flow bring what is considered normal or average temperatures and moderate precipitation (mostly convective in origin) (Eichenlaub 1979). When the PNA teleconnection is in a strongly meridional phase (with a north-south axis of airmass flow, typically but not exclusively in winter), weather is dominanted by continental Polar and maritime Tropical airmasses. These phases are characterized by greater extremes in precipitation and temperature (Eichenlaub 1979). Precipitation during the meridional phases comes mainly from the Gulf of Mexico and from the Great Lakes themselves (summer and winter). In some coastal areas, up to 85% of the wintertime precipitation is due to lake effect snowfall (Norton and Bolsenga 1993) and 16% of the summer rain is internally generated by the Great Lakes (Gat *et al.* 1994, Rodionov 1994).

For the historic period AD 1931-1961, the average annual temperature in northern Lower Michigan was 17.6 °C (Bernabo 1981). The growing season for eastern Upper

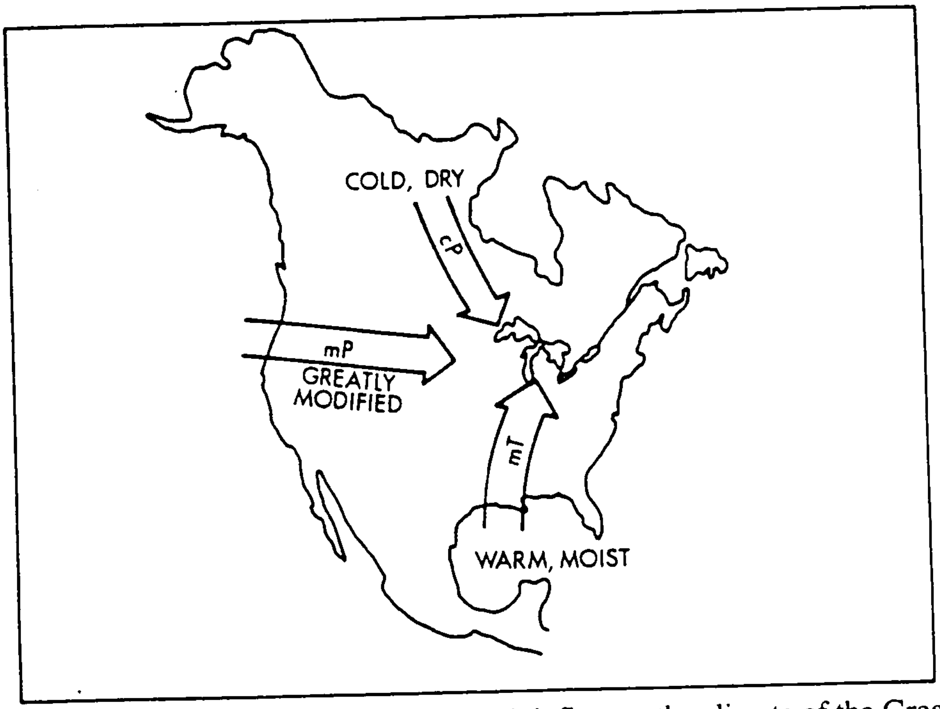
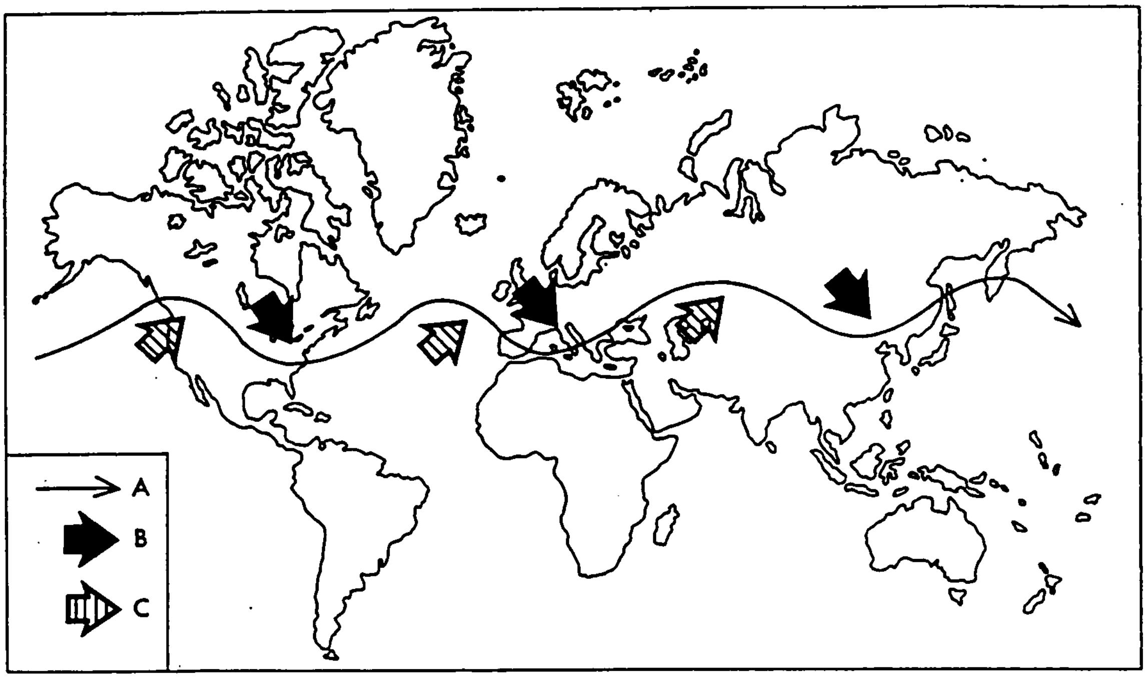


Figure 14. Three main air mass regimes which influence the climate of the Great Lakes region. The three regimes are a highly modified maritime Polar (mP) originating in the North Pacific Ocean, a continental Polar (cP) source of cold, dry air forming in northern Canada, and a maritime Tropical (mT) source of warm, humid air from the Gulf of Mexico (from Eichenlaub 1979).



A. The jet stream **B.** Areas located beneath upper air troughs—colder than normal **C.** Areas located beneath upper air ridges—warmer than normal

Figure 15. Teleconnections and the Jet Stream (from Eichenlaub 1979).

Michigan averages 130 days from the last occurrence of frost in the spring to the first occurrence of frost in the fall (range equals 90 to 160 days) (Eichenlaub *et al.* 1990). Eastern Upper Michigan receives an average of 79 cm of precipitation per year (evenly distributed throughout the year in the form of snow and rain) (Barnes and Wagner 1981). For the period of record (since AD 1891), extreme minimum temperatures across eastern Upper Michigan have ranged between -28°C and -46°C, while extreme maximum temperatures have ranged between 34°C and 39°C (Eichenlaub 1990). The shores of Lakes Michigan and Superior are the areas that have experienced the greatest wintertime snowfall, and the highest minimum and lowest maximum temperatures due to the thermal buffering effects of these lakes.

The influence of the Great Lakes on the climate of the surrounding land is the third main factor which controls the climate of the Great Lakes region. These "lake effects" occur because the higher specific heat of water (relative to land) means that water takes longer than land to warm up in the summer and longer to cool down in the winter. This differential heat transfer to the atmosphere from water versus that from land results in increased precipitation (snow, rain, fog drip), decreased daily and annual range in temperature, and increased breezes from the water surface towards the land in the summer. In general terms, lake effect reduces the continentality of the land surrounding the Great Lakes (Kopec 1965) (Fig. 16). Continentality is a measure of the degree to which an area is influenced by a large body of land, resulting in greater variability of temperature and precipitation then that associated with maritime climates (Conrad 1946). This effect can be quantified by studying regional meteorological data (see **Lake effect** below).

Paleoclimate

Early- to mid-Holocene climate change in the upper Midwest has been documented by proxy climatic evidence from fossil-pollen assemblages preserved in lake and bog

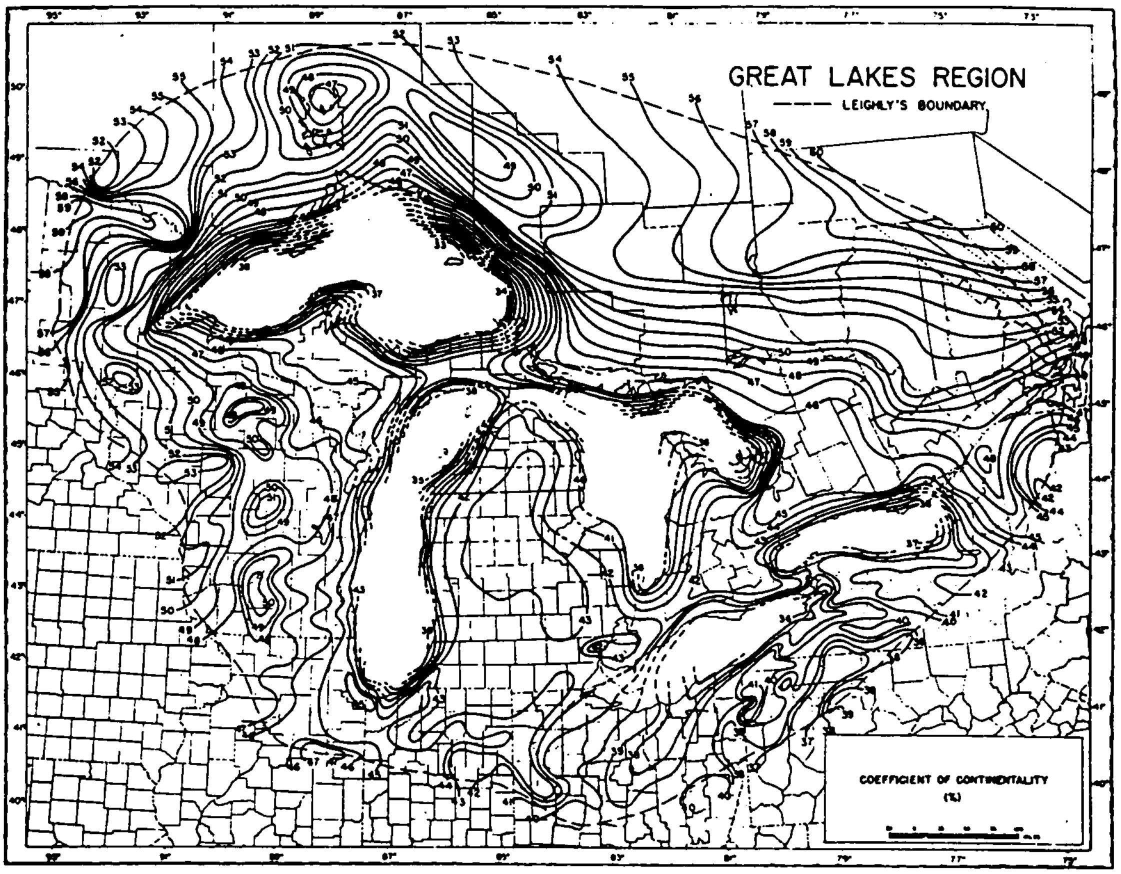


Figure 16. Isoplethic patterns of continentality coefficient at 1% interval for the Great Lakes Region (from Kopec 1965).

sediments (Davis 1967, Wright 1976, Futyma 1982, Bartlein *et al.* 1984), stable-isotope chemistry of sediments (Dean *et al.* 1984, Winkler *et al.* 1986, and Nester 1999), and geomorphology of stream deposits (Knox 1985).

During the period following deglaciation of the Upper Peninsula of Michigan, from 8000 to 3000 yr BP, the climate of this area shifted from a moist cold climate characteristic of areas close to the retreating glacial border, to a warmer, drier climate (Fig. 17) (summarized by Winkler *et al.* 1986). This "Hypsithermal" interval has been documented throughout the north-central United States, and is characterized by an eastern expansion of prairie (Wright, 1976) and a lowering of lake levels (Winkler *et al.*, 1986). However, within this mid-Holocene period, in southeastern Wisconsin, Knox (1985) identified a peak in the frequency of stream floods that occurred around 5500 yr BP. Knox (1985) suggested that periods of increased climate variability could result in such increases in flood frequency. Within the study area, a Lake Michigan highstand around 5400 yr BP caused the rise of local water tables (Petty *et al.* 1996). By 3500 yr BP, regional climate had become cooler and more mesic as interpreted from bog expansion (Futyma, 1982) and lake-level rise (Brugam and Johnson 1997) in the Upper Peninsula of Michigan and northern Lower Michigan (Futyma and Miller 1986) and from decreased fire frequency in southern Wisconsin (Winkler *et al.*, 1986). Within the study area, Nester (1999) shows a decrease in temperature, increase in precipitation, and a 1.4 m rise in water table between 3000 and 2800, based on stable isotopes of $\delta^{18}O$ and $\delta^{13}C$, and lithologic transitions of lacustrine sediments from marl to gyttja at Nelson Lake (NL, Fig. 8).

Climate for northern Lower Michigan for the past 2700 radiocarbon years was reconstructed by Bernabo (1981) based on the fossil-pollen record from Marion Lake, Charlevoix Co., Michigan. The results from his study showed a 1.3°C range in growing-season temperature over the past 2700 years. A warm period extended from 2700 yr BP to 1600 yr BP, followed by a relatively brief cooler interval from 1600 yr BP to

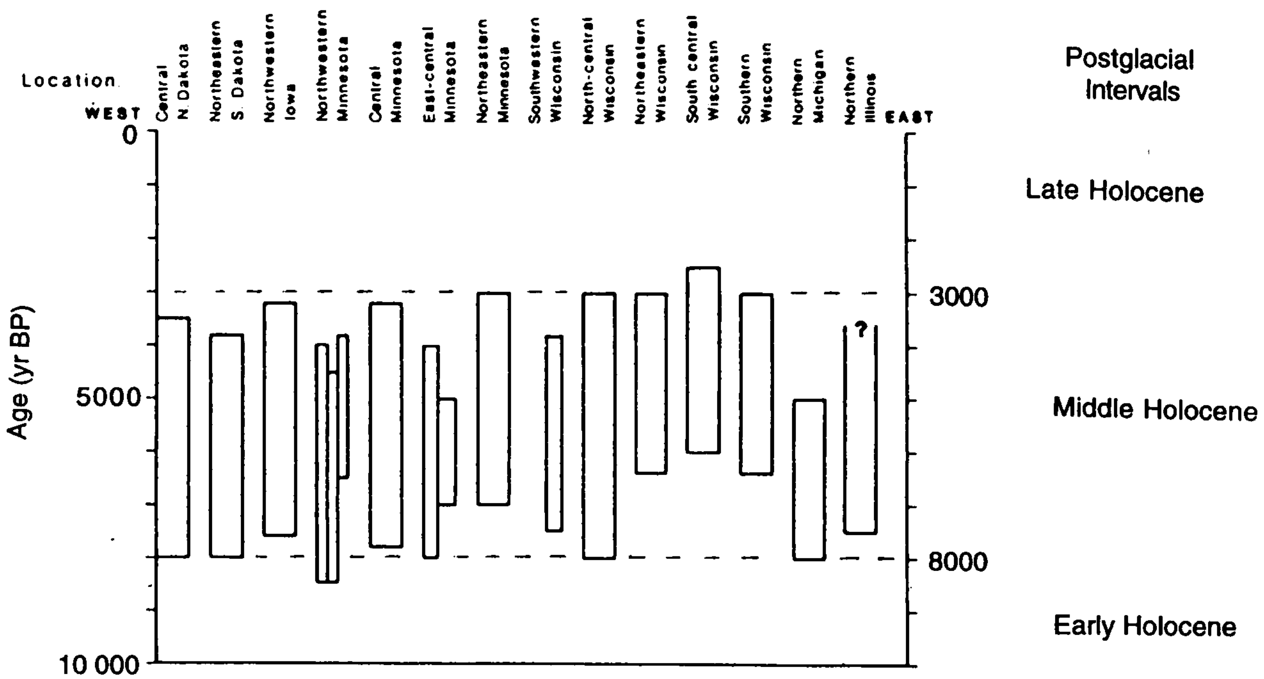


Figure 17. Occurrence of Hypsithermal interval in Upper Midwest (modified from Winkler *et al.* 1986). Dashed lines between 8000 and 3000 yr BP are based on the intervals from the two closest areas to the study area (northeastern Wisconsin and Upper Michigan). See Winkler *et al.* (1986) for list of references used to make this figure.

1300 yr BP. A "Medieval" warm period occurred from 1300 yr BP to 800 yr BP which was the last time temperatures approximated those of today. The Little Ice Age is well-represented by a cooling trend beginning around 800 yr BP with average growing season temperatures reaching a minimum of 16.6°C by 240 yr BP, 1°C below the AD 1931-1961 average of 17.6°C. By 140 yr BP temperatures had risen to within 0.5°C of the AD 1931-1961 average. This historic warming trend has continued to the present (Bernabo 1981).

Seasonality of solar radiation

Cyclic variation in Earth-Sun orbital parameters, which affect the amount and seasonality of solar radiation reaching the earth's atmosphere, has been correlated with the glacial-interglacial cycles of the Quaternary (Imbrie and Imbrie 1979). Kutzback and Guetter (1986) have plotted for 45° N latitude the Northern Hemisphere changes in summer and winter solar radiation input along with glacial ice-volume for the past 18 000 years (Fig. 18). During the maximal extent of the Laurentide Ice Sheet (circa 17 000 yr BP) the seasonal contrast between winter and summer solar radiation was close to that of today, with relatively mild winters and cool summers. Climatic conditions of warm and moist winters and cool summers favor glacial expansion. Seasonality of solar radiation since that time increased to maximum contrast around 9000 yr BP (that is, cold winters, hot summers, and variable temperatures during springs and falls) and then gradually declined until today. When seasonality of temperature is heightened, winters become too cold for the needed snowfall to feed the continental ice sheets and warmer summer temperatures cause increased melting of glaciers at their southern margin.

This pattern of heightened seasonality between 12 000 and 9000 yr BP, followed by a gradual reduction in seasonality to the present, has been related to the interglacial distributions and abundances of several taxa (O. Davis 1984, O. Davis *et al.* 1986, Huntley

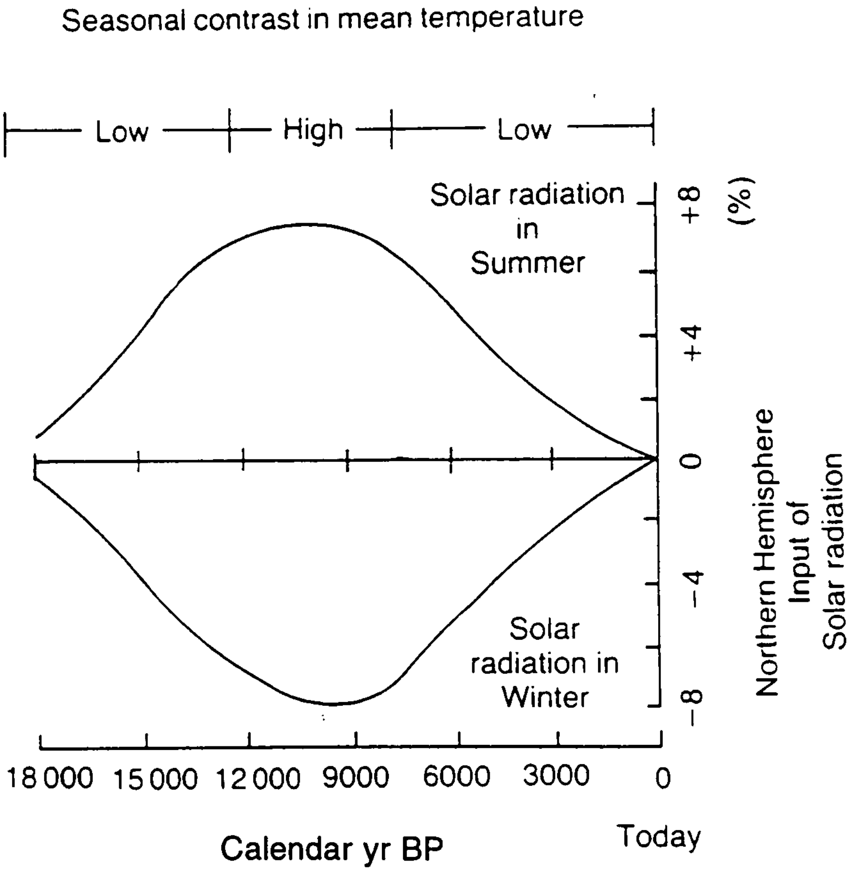


Figure. 18. Changes in solar insolation for the past 18 000 calendar years (modified from Kutzbach and Guetter 1986).

and Webb 1989, Delcourt and Delcourt 1994) including American and European beech (*Fagus sylvatica* L.) (Huntley *et al.* 1989). For beech, Huntley *et al.* (1989) explain the late glacial expansion of both species based upon their autecological requirements, their lower tolerances of both cold winters and warm summers as compared with other taxa such as *Quercus*, *Pinus*, and *Tilia*.

For 45° N latitude the timing of within-month maximum radiation (expressed as a percentage of the total annual change in solar insolation during the late Quaternary) has progressed over the past 18 000 calendar years from an April maximum (16 000 to 14 000 yr BP) to July (12 000 to 8000 yr BP) to October (6000 to 2000 yr BP) to January (2000 yr BP to present) (Fig. 19). That is to say that insolation for the month of April was greatest between 16 000 and 14 000 yr BP. This progression of within-month thermal maxima played an important role in the post-glacial expansions of thermophilic species at increasing elevations, with lower elevation species expanding during the early Holocene, and higher elevation species expanding during the middle Holocene (O. Davis *et al.* 1986). In a similar fashion, the timing of within-month thermal minima has progressed from October (18 000 to 12 000 yr BP) to January (12 000 to 8000 yr BP) to April (6000 to 2000 yr BP) to July (2000 yr BP to present). The relevance of this to the current study is that for mesic, cool-loving species, the timing of thermal minima, rather than thermal maxima, may have played an important role in the Holocene expansion of mesic taxa such as American beech within the Great Lakes region. For example, if water stress were reduced during critical times of the year due to the occurrence of thermal minima this would tend to favor the growth of mesic taxa.

Disturbance regimes

Within the context of today's climate, several forms of weather-related disturbance affect Michigan landscapes, including wind storms (downbusts and tornadoes), fire, ice and

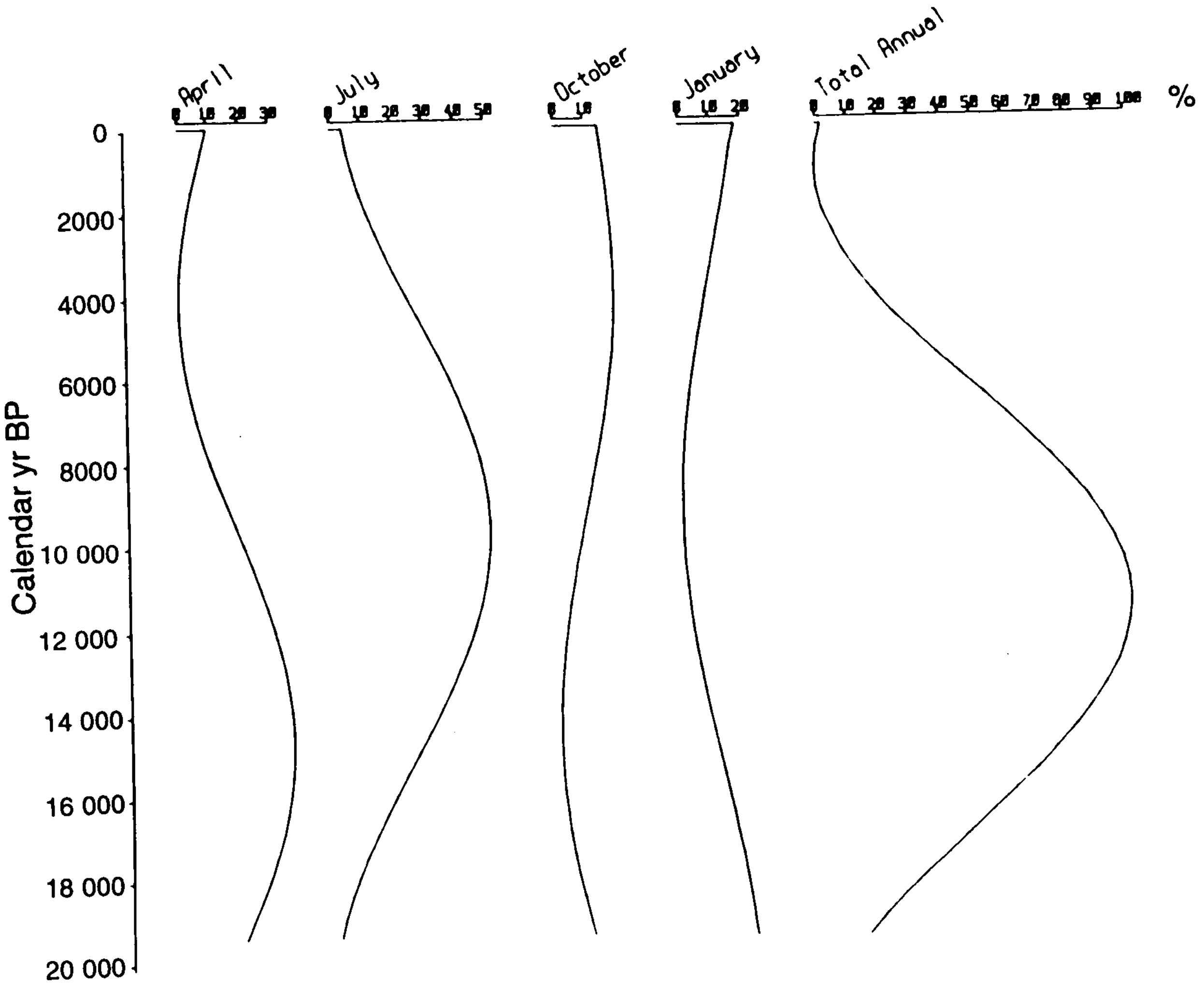


Figure 19. Changes in solar insolation for the past 20 000 years for April, July, October, and January expressed as a percent of (modified from O. Davis *et al.* 1986).

hail storms. For the period from AD 1948 to 1977, the average number of thunderstorms per year has varied from greater than 50 in southwestern Lower Michigan, to less than 40 in northern Lower Michigan and along the shores of Upper Michigan (Eichenlaub *et al.* 1990). High winds and tornadoes also follow a south-to-north decrease in frequency. Recurrence intervals of catastrophic windstorms within any given 6x6 mile area vary from a minimum of 153 years in southwestern Michigan to a maximum of 918 years (or longer) in northern and Upper Michigan (Eichenlaub *et al.* 1990). Of particular interest to forest ecologists and forest managers is that there has been an increase in tornado frequencies over the past 40 years nationwide and in the state of Michigan (Eichenlaub *et al.* 1990), perhaps as a response to global warming as more energy is transferred through the atmosphere. An increase in size and frequency of treefall gaps resulting from these tornadoes could shift the competitive balance toward canopy species better able as saplings to take advantage of the increased light levels. Of significance for my research are the results of a long-term study of the beech-maple forest of Warren Woods in southeastern Lower Michigan by Poulson and Platt (1982, 1996). They have concluded that an increase in the density of treefalls, from 0.16 trees per acre (for the period from AD 1949 to 1974) to 1.64 trees per acre (for the period from AD 1975 to 1995), has caused an observed increase in sugar maple saplings and poles and a simultaneous decrease in the number of saplings and poles of American beech. This increase in sugar maple is likely due to its ability to grow faster than American beech in large gaps whereas American beech has faster lateral growth into smaller gaps (Poulson and Platt 1996).

Past disturbance regimes for windfalls (treefalls, windthrows, blowdowns, downbursts) and fire for Michigan forests have been reconstucted based on tree ring analysis (Frelich and Lorimer 1991), presettlement land surveys (Whitney 1986), and charcoal preserved in lake sediments (Nester 1999). For hemlock-white pine-northern hardwoods forests, Whitney (1986) estimated a recurrence interval for windthrows of 1220 years and for fires of 1389 years. For the same forest type in western Upper Michigan, Frelich and Lorimer (1991) estimated a recurrence interval of 1273 years for surface/ground fires and 4545 years for canopy killing fires. For windfalls due to "downbursts" Frelich and Lorimer (1991) estimated recurrence intervals from 1183 to 1920 years depending on their methods.

For the presettlement forests within the study area, Delcourt and Delcourt (unpublished data) estimated the recurrence intervals of windfalls and fire based upon the GLO surveys. For sugar maple–fir-beech-yellow birch forests, windfalls have an estimated recurrence interval of 787 years. The recurrence interval for fire is 37 years within the white pine-white birch-aspen forests, 34 years for jack pine-aspen forests, and 27 years for red pine. Due to the lack of identified fire damaged areas in other forest types estimates of recurrence intervals was not possible.

Changes in the fire disturbance regime surrounding Nelson Lake (Fig. 8) have been studied by Nester (1999) based on charcoal data for the last 7000 years. A decrease in the charcoal accumulation rate indicated that fire frequency decreased in the mixed conifer-northern hardwood forest after 3000 yr BP, possibly due to the development of an extensive peatland southwest of Nelson Lake which would have created a fire break.

Little is known about the long-term frequency, distribution, and recurrence interval of severe ice and hail storms in Upper Michigan. Ice and hail storms would likely affect large areas but with relatively minor damage to trees (mostly leaf and small branch damage).

Lake effect

On a regional scale, seasonality of climate is greatly influenced by latitude and proximity to large bodies of water. With increased latitude, north or south of the equator, the annual range of temperature increases. Likewise, seasonality of temperature (along with other climate variables) increases with increased distance from large bodies of water, whether oceans or large freshwater lakes (Eichenlaub 1979). The mesoscale influence of the Great Lakes in central North America has been extensively documented (Eichenlaub 1979, Eichenlaub *et al.* 1990, Phillips and McCulloch 1972), and is characterized by a wide range of climate conditions collectively referred to as "lake effects." Lake effects include increased cloudiness and fogs, cooler summer temperatures, warmer winter temperatures, increased precipitation in summer (including summer fog drip), and increased snowfall amounts in winter. All of these climate phenomena are a direct or indirect result of a) the greater specific heat of water versus land resulting in land-water temperature gradients diurnally and seasonally, and b) evaporation of water from the lake surface which is then transported over land as water vapor (and potential precipitation) by prevailing winds. The monthly progression of mean temperature exhibits reduced thermal amplitude and a much lower range in temperature for water versus land (Fig. 20). There is also a delay over Lake Superior in water reaching its thermal maximum until September (Eichenlaub 1979).

For eastern Upper Michigan, several lake effects of Lake Michigan and Lake Superior can be easily quantified by examining climatological changes along a transect (A-A') across the peninsula, trending NW from the study area (Figs. 21, 22). The variation in extreme minimum temperatures recorded between AD 1891 and 1987 illustrates the ameliorating effects of both Lakes Michigan and Superior. Within the first 20 km inland from Lake Michigan, there is typically a 6.6°C (12° F) difference in recorded extremes of winter temperature (Fig. 21). The dotted line on this figure marks the -41°C cold-hardiness threshold of mortality for American beech when individuals are exposed to frigid winter extremes (Burke *et al.* 1975) (see discussion of Beech Autecology, below). Within the first 20 km of the Lake Michigan shore the average growing season decreases by 20 days (Fig. 23) and snowfall increases by 60 cm (Fig. 24) (Eichenlaub *et al.* 1990).

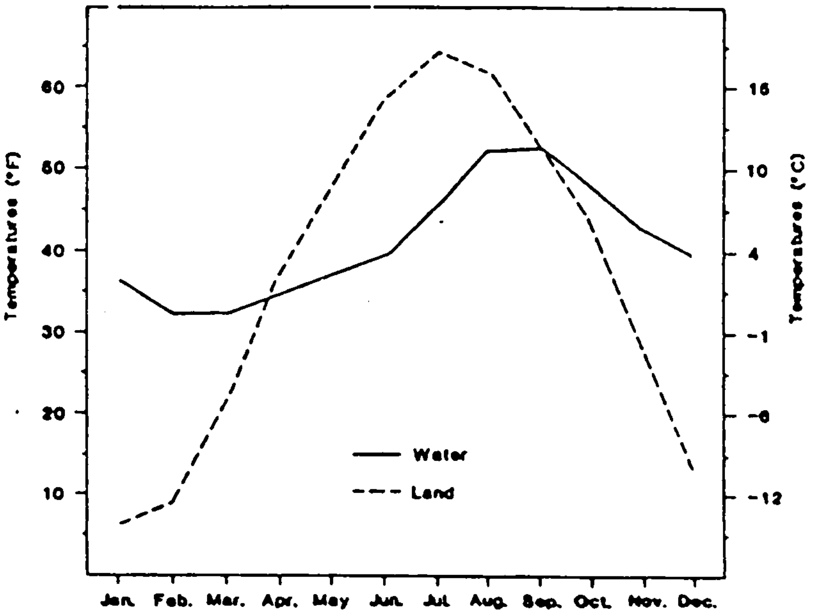


Figure 20. Mean monthly values of temperature for Lake Superior (water surface) and bordering uplands (land surface) (modified from Eichenlaub 1979).

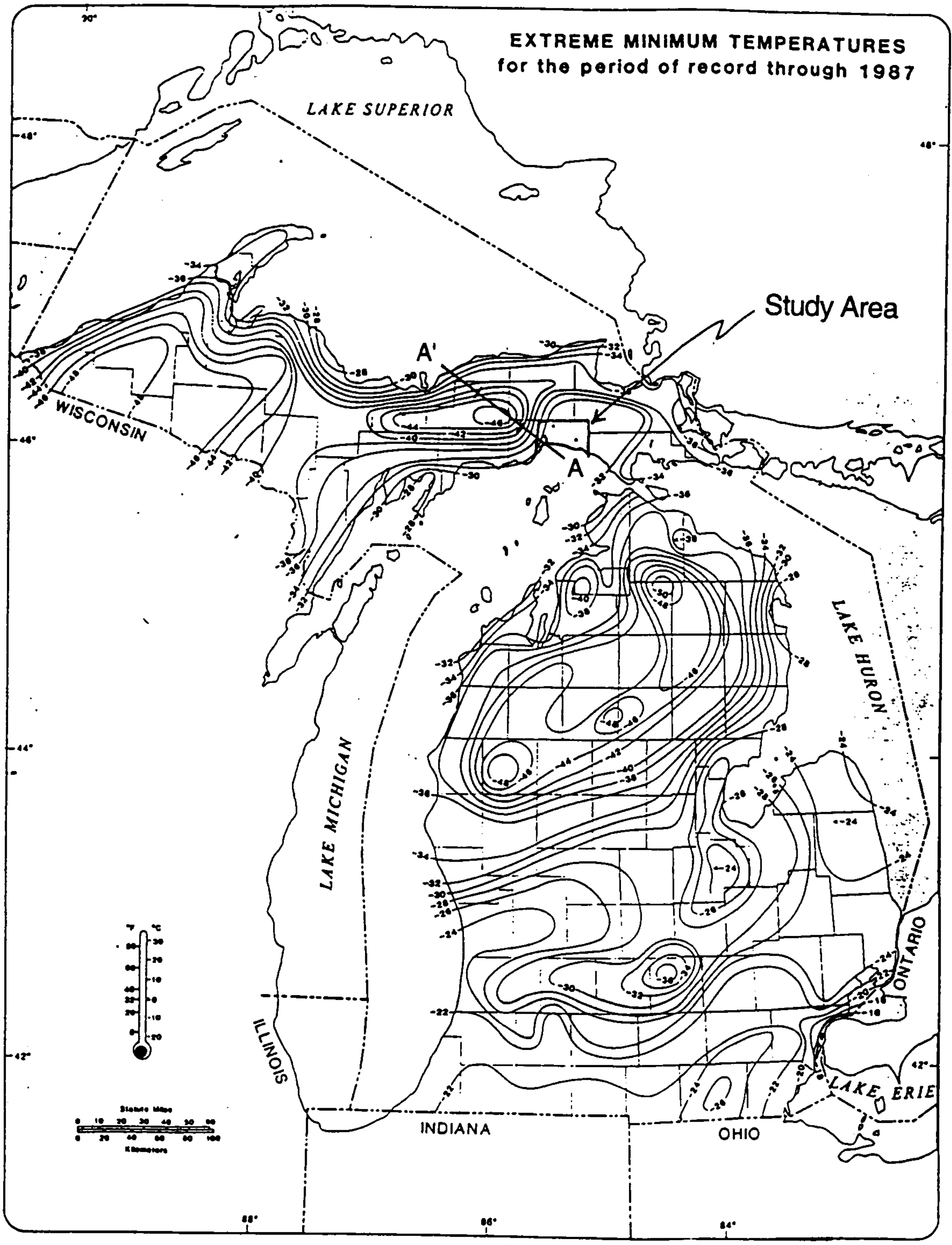


Figure 21. Map of the distribution of extreme minimum temperatures for Michigan from A.D. 1891 to 1987 (modified from Eichenlaub *et al.* 1990).

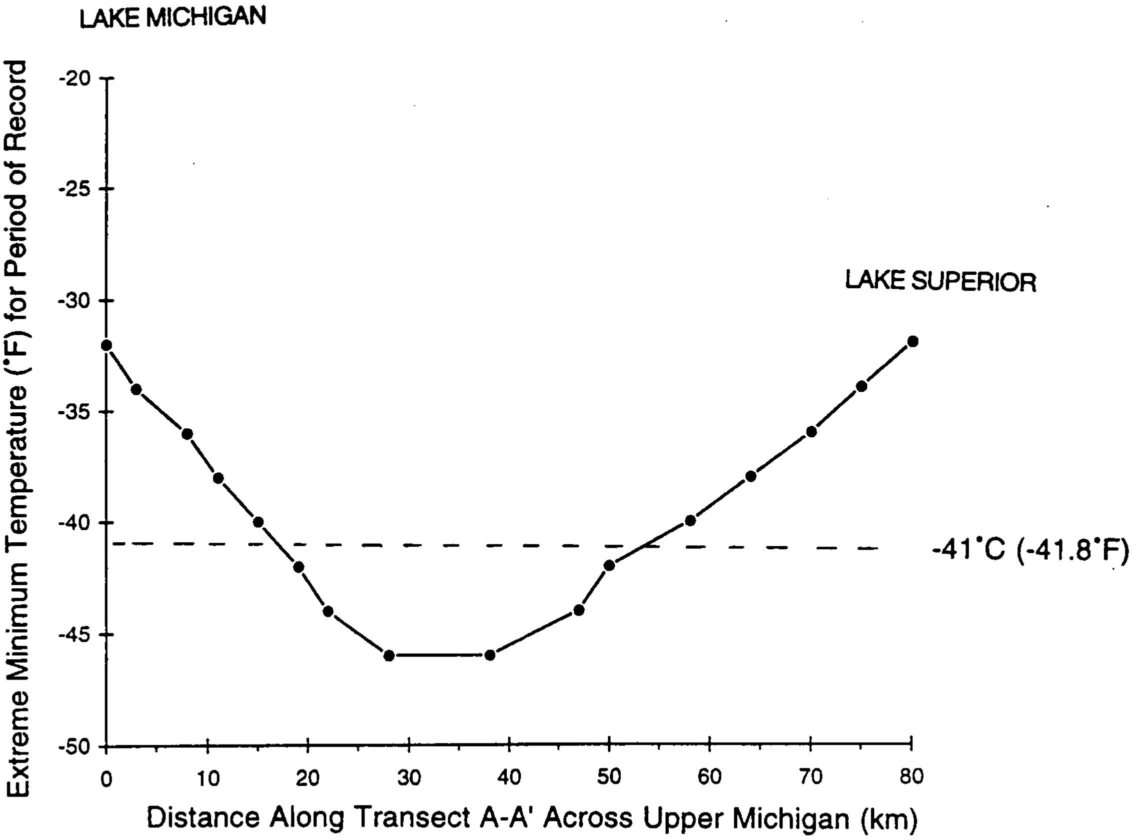


Figure. 22. Gradient in extreme minimum temperature (°F) across Upper Michigan along a transect from Lake Michigan to Lake Superior (A-A' of Fig. 21) (from Eichenlaub *et al.* 1990).

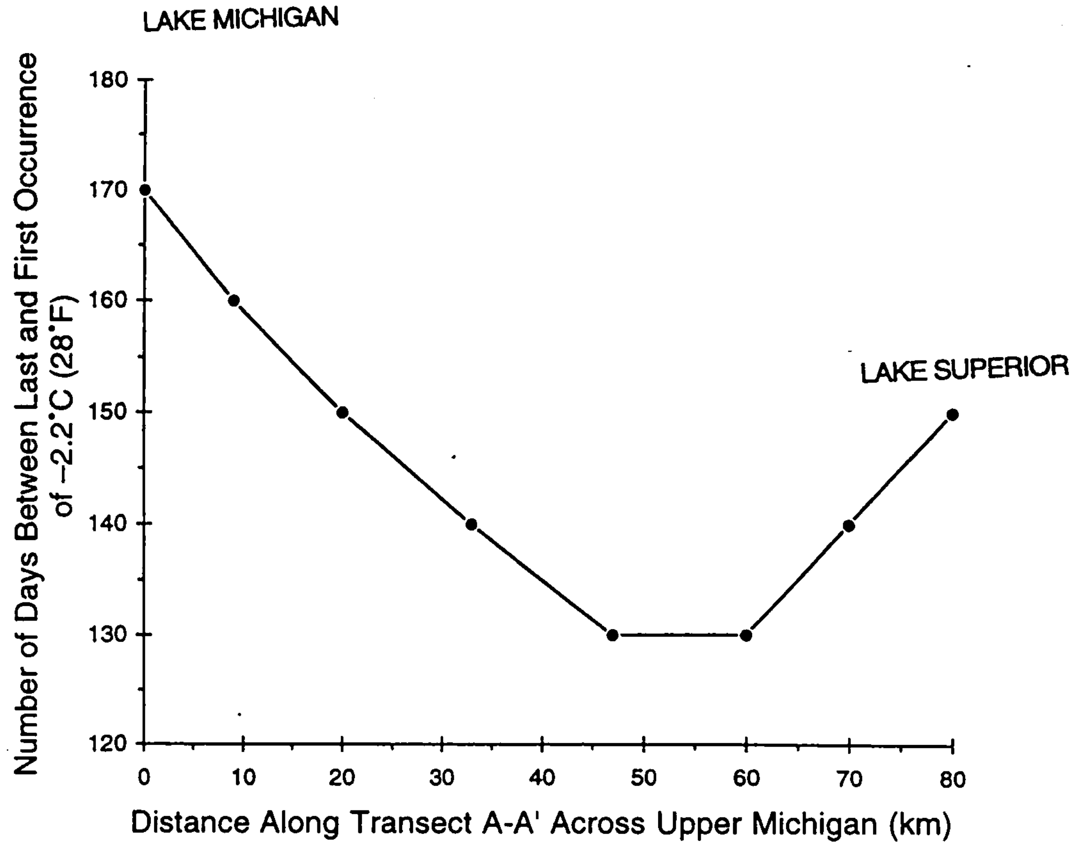


Figure. 23. Gradient in the number of days between the last and first occurrence of 28˚F across Upper Michigan along a transect (A-A' of Fig. 20) (from Eichenlaub *et al.* 1990).

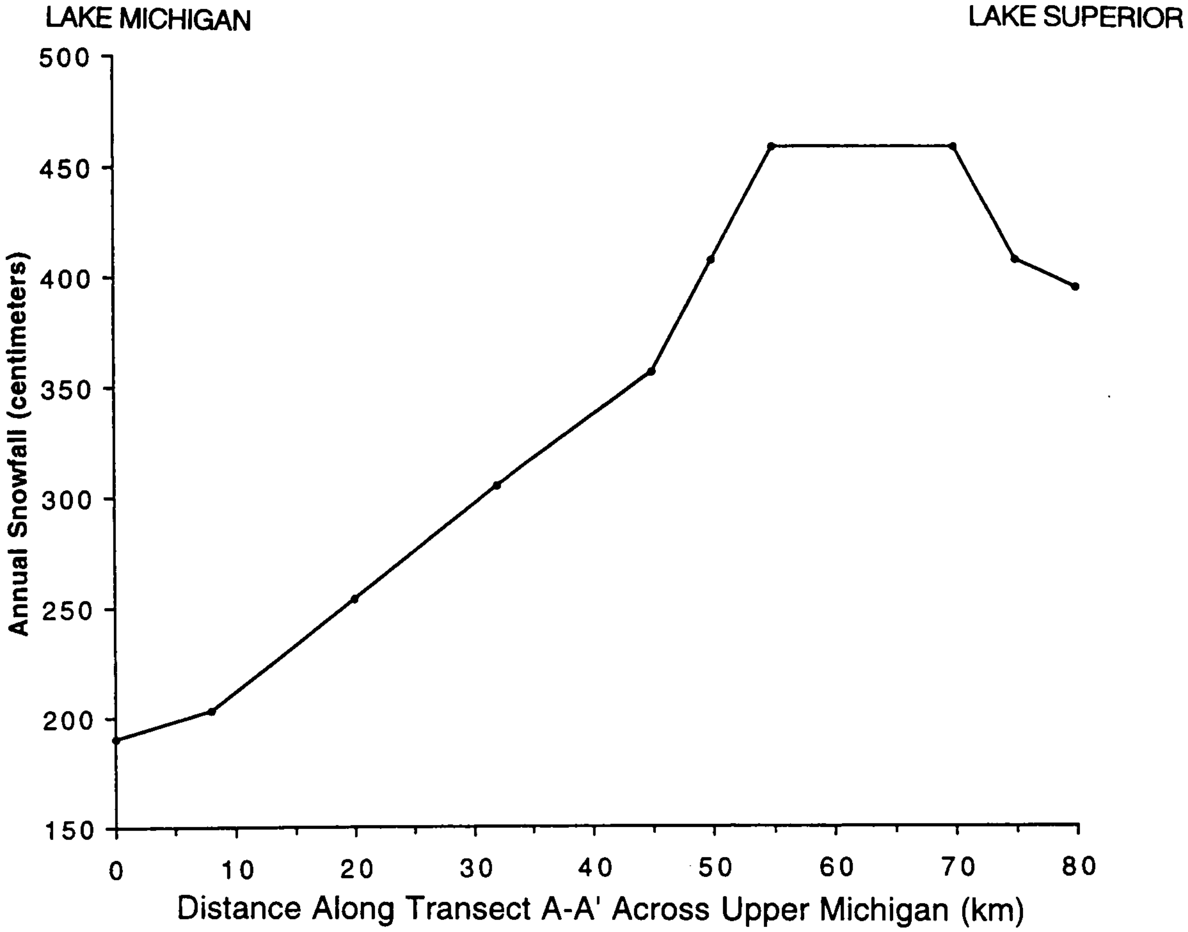


Figure. 24. Gradient in the amount of winter snowfall across Upper Michigan along a transect A-A’ (Fig. 20) (from Eichenlaub *et al.* 1990).

The importance of lake effects on vegetation has been suggested by modern studies of conifer tree distributions on islands of northern Lake Michigan (Harman and Plough 1986) and coastal Maine (R. Davis 1966), as well as in the paleoecological literature (Lewis and Anderson 1989). This latter study suggests that periodic pulses of cold melt water from proglacial Lake Agassiz, an expansive proglacial lake which formed as the Laurentide Ice Sheet retreated from what is now Minnesota, resulted in shifts in vegetation toward more cool-loving trees such as spruce (*Picea*) and fir (*Abies*) along the shores of the Great Lakes.

C. Soils

Soils of Upper Michigan

The soils of Upper Michigan were mapped originally by Veatch *et al.* (1923, 1927, 1929) and Veatch (1953) and more recently by Whitney (1992, 1995). The soil types of eastern Upper Michigan are closely tied to the underlying parent material (Farrand *et al.* 1984). Soils formed from lacustrine deposits are mostly acidic sands with very little clay or silt, either excessively drained on the upland outwash plains and dunes or poorly drained in the lowlands between beach ridges. Soils formed from ground moraine deposits are typically pH-neutral to calcareous sandy loams or loams and tend to be stony (Albert 1995). Situated along the topographic crest of the Niagara Escarpment, bedrock outcrops have shallow calcareous soils with moderate to poor drainage of surface water. Soils within the study area belong to a diversity of soil orders, primarily, Alfisols, Histosols, and Entisols, with fewer Orthods and Aquods. Within the western half of the study area, H. Delcourt and P. Delcourt (1996) mapped 9 major groups of soils based on modern soil surveys by Whitney (1995) according to soil texture and water holding capacity.

Sandy soils with ortstein layers (Orthods) were of special interest in the present study due to my Hypothesis 2b that their late-Holocene formation may have contributed to the expansion of beech 3000 to 2000 yr BP. Within Mackinac County, these soils occur on over 28 000 hectares and have been described as the "best expressed" ortstein anywhere in the country (G. Whitney, unpublished report), prompting Whitney's submission of a formal proposal to change the requirements for their placement into the Ortstein family of Spodosols. Ortstein increases the cation exchange capacity (CEC) and water holding capacity of the soil (Franzmeier and Whiteside 1963b), and thus may have led to a late-Holocene vegetationl shift in dominance from pine to northern hardwoods (Franzmeier *et al.* 1963). The CEC of sandy soils with ortstein is increased over that of sandy soils without ortstein by the accumulation of organic matter and exchangable bases in the B horizon of soils with ortstein (Franzmeier and Whiteside 1963b).

Theories of ortstein development

Many researchers have studied the development of ortstein layers in the B horizons of sandy soils (Franzmeier and Whiteside 1963 a,b, Franzmeier *et al.* 1963, Karavayeva 1968, Messenger *et al.* 1972, Messenger 1975, DeConinck 1980, Nichols *et al.*1990, Ugolini *et al.* 1990, Schaetzl and Isard 1990, 1991, Mokma and Vance 1989, Barrett and Schaetzl 1992). Ortstein forms in coarse-textured material (medium quartz sand) as a result of podzolization, the translocation of sesquioxides in a soil profile (Boul *et al.* 1989). In the case of ortstein, iron and aluminum oxides leach from the A and O horizons to the B horizon where they precipitate. The generally accepted paradigm identifies three main causal agents in ortstein development: precipitation, disturbance regime, and vegetation. Precipitation in the form of rain and snow is critical for ortstein formation since water translocates the organo-metalic complexes between the soil horizons, causing the cementation of sand particles into an indurated layer. Ortstein is distinct from fragipans which are low in organic material and form as a result of clay particles becoming aligned and cemented in loamy soils (Franzmeier *et al.* 1989). Times of variable rainfall cause fluctuations in ground water tables which also may be involved in the translocation process (Nichols *et al.* 1990). A second significant function of precipitation in the formation of ortstein is when snowfall occurs early in the winter (typically before January) and is quite heavy (greater than 1.5 m annually) (Schaetzl and Isard 1991, 1996). When heavy snow storms occur early in the winter, the underlying soils do not freeze beneath the insulating mantle of snow, resulting in increased infiltration through the soil of spring meltwater (Schaetzl and Isard 1996). Based on the results of Franzmeier and Whiteside (1963b), Muhs (1984) proposed that a threshold of iron and aluminum ion accumulation (between 0.2 and 0.4% extractable iron and aluminum oxide) may be neccessary for the accumulation of organic material in the B horizon to take place. With greater movement of water through the soil profile, the translocation of Fe and Al increases as does the leaching of organic acids from the litter.

A second important causal agent in ortstein development is low disturbance of the soil profile (Mokma and Vance 1989). Here two forms of disturbance appear to be most influential: fire, and biotic activity of soil organisms. Low fire frequency promotes the accumulation of organic litter which is the source of the organic acids that bind with Fe^{++} and Al^{++} ions and cause cementation to take place. The recurrence interval needed for sufficient litter buildup is not known. Low biotic activity by soil organisms promotes podzolization and thus ortstein formation by slowing the decay rate of raw forest litter, and thereby also increasing the amount of litter available over time for leaching (Buol *et al.* 1989).

Vegetation is the third main factor involved in ortstein development (Hole 1975, Cruickshank and Cruickshank 1981, Ugolini *et al.* 1990) as litter from vegetation is the source of the organic acids which bind with iron and aluminum ions. Vegetation can dramatically influence soil development, and in the case of Spodosols, conifer trees and heath shrubs, with their highly acidic leaf litter which is very slow to decay, promote podzolization (Damman 1971, Hole 1975). Under conifers, fulvic acid, leached from the acidic leaf litter, is the main organic acid involved in the cementation process of ortstein horizons (Ugolini *et al.* 1990).

In summary, sandy soils that are most likely to develop ortstein layers in the B horizon are those which have a) a fluctuating water table at some time during the year, b) early snowfall prior to soil frost, c) deep snowpack resulting in large amount of spring thaw infiltration, d) low disturbance rates by fire and soil organisms, and e) coniferous or heath vegetation which supplies fulvic acids needed to bind with iron and aluminum.

D. Vegetation

Presettlement forest types

Upper Michigan is within the Mixed-Conifer, Northern-Hardwood Forest region of eastern North America (Braun, 1950; Chase and Pfeifer, 1966; Rowe *et al.* 1977). Presettlement vegetation maps for the Upper Peninsula (Stearns 1987) show four basic forest types: (1) boreal forest and conifer swamp; (2) pine forest and barrens; (3) northern mesic hardwood forest, and (4) wet mesic forest. These forest types were mapped largely from compiled soils maps (Veatch 1953) and, thus, reflect the complex mosaic pattern of the substrate they occupy. Finer-scale resolution based solely on General Land Office Survey records (*circa* AD 1840-49) shows that the presettlement forests within the western half of the study area were highly variable over short distances (H. Delcourt and P. Delcourt 1996) (Fig. 25). Forests of presettlement time graded from stands mainly of sugar maple (*Acer saccharum*), elm (*Ulmus* spp.), ironwood (*Ostrya virginiana*), and beech west of Millecoquins Lake, to white pine (*Pinus strobus*), white birch (*Betula papyrifera*), and aspen (*Populus* spp.) southwest of Millecoquins Lake. In the northeast sector the forest was composed primarily of jack pine (*Pinus banksiana*) and hemlock (*Tsuga canadensis*) (not necessarily in the same stands) along with sugar maple, fir (*Abies*

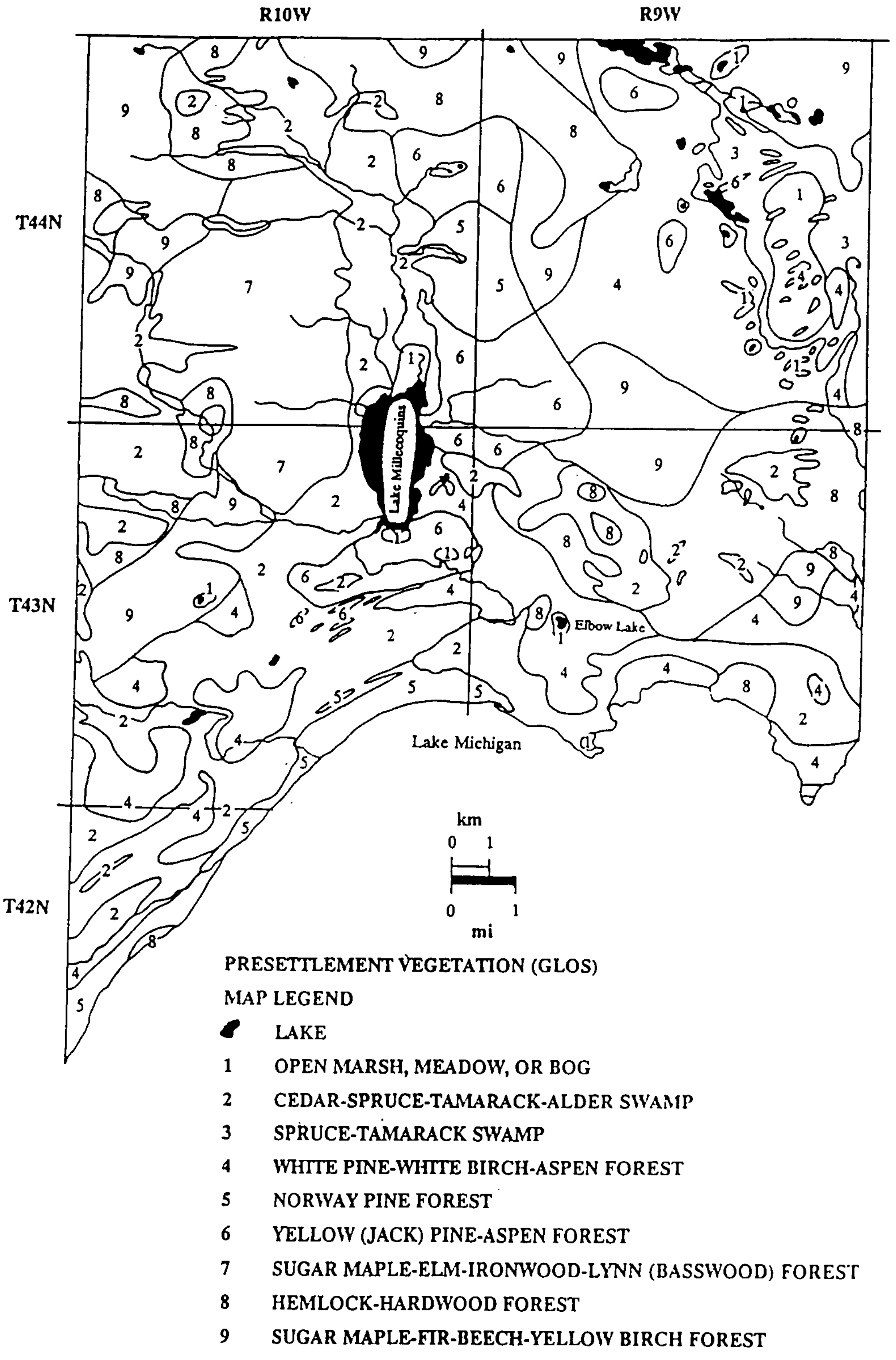


Figure 25. Presettlement vegetation map for western half of study area (from H. Delcourt and P. Delcourt 1996).

balsamea), beech, and yellow birch. Swamps of cedar (*Thuja occidentalis*), spruce (*Picea* spp.), tamarack (*Larix laricina*), and alder (*Alnus* spp.) (mainly along streams draining southward into Lake Millecoquins and on Algoma and post-Algoma surfaces (Fig. 12), beach-ridge and swale topography) also were common in this area. Surrounding Elbow Lake, the forest was dominated by white pine, white birch, and aspen, with a hemlock-hardwood stand to the northwest of the lake. In the beach-ridge complex west of Elbow Lake and south of Millecoquins Lake (Fig. 8) the presettlement forest was composed largely of cedar, spruce, and tamarack, with red pine (*Pinus resinosa*) along the coast. Within the study area groupings of forest taxa are strongly associated with particular soil types and drainages. For example, pine-hardwood forest taxa (white pine, white birch, aspen) are associated with acidic, well drained, upland sands of glacial outwash and lake plains, and mesic hardwood forest taxa (sugar maple, elm, ironwood, and basswood) are associated with basic, loamy clay till. Cedar-spruce-tamarack-alder swamp taxa are found on poorly drained, acidic, mucky-peat soils (Delcourt and Delcourt 1996).

Holocene vegetation history

The paleoecology of the Upper Peninsula and surrounding areas has been studied by many researchers (Potzger 1954, Brubaker 1975, Bernabo 1981, Futyma 1981, 1982, Warner *et al.* 1984, M. Davis 1987, Madsen 1987, Woods and Davis 1989, Petty 1994, H. Delcourt and P. Delcourt 1996, Delcourt *et al.* 1996, Petty *et al.* 1996, Nester 1999). These studies provide a paleoecological framework for this research. Brubaker (1975), using a "paired basin" strategy, contrasted the development of vegetation on three different substrates (Yellow Dog Plains outwash, Michigamme Highlands outwash, and Michigamme Highlands till) in the north central portion of the Upper Peninsula. She found that during the early Holocene (10 000 - 8000 yr BP), all three substrate types were dominated by jack pine. However, during the dry climate of the mid-Holocene (8000-

5000 yr BP) forests on Michigamme outwash deposits were dominated by white pine, while forests on the till were largely composed of deciduous hardwoods. Throughout the Holocene, the Yellow Dog Plains supported a forest of jack pine. By 3000 yr BP, the climate had become more mesic and the pollen records from the two Michigamme substrates were indistinguishable, demonstrating that different substrates (till vs. outwash) can support similar or different forest types depending on climate regime (dry vs. wet) (Brubaker, 1975).

In a study of Holocene paleoecology of lake and peatland sites in the eastern Upper Peninsula of Michigan, Futyma (1982) documented a sequence of vegetation change for Ryerse Lake (21 km east of Elbow Lake) (Fig. 8) starting with boreal forest dominated by jack and/or red pine (*Pinus banksiana, P. resinosa*) from 9500 yr BP to 7800 yr BP. White pine (*Pinus strobus*) became dominant around 7800 yr BP and then declined around 4900 yr BP when deciduous forest dominated by birch (*Betula*) expanded into the region. In the mesic forests around Ryerse Lake, hemlock arrived between 5700 and 5000 yr BP, followed by American beech between 3500 and 2700 yr BP.

E. Ecology of American Beech

American beech is a long lived (200-400 years), deciduous, shade-tolerant, late-successional tree species that occurs in mesic forests of eastern North America (Tubbs and Houston 1990). Its Pre-Columbian native range (Fig. 1) is from western Texas east to northern Florida, north to Nova Scotia, and west to the eastern half of Upper Michigan, eastern Wisconsin and Illinois (Little 1971). American beech is thought to be limited along its western range border by precipitation (annual precipitation = 580 mm) (Tubbs and Houston 1990) and to the north by temperature (average annual minimum temperature = -41 °C) (Burke *et al.* 1975). Denton and Barnes (1987a,b) showed that in Michigan beech is associated with low continentality and low heat sums prior to the last spring freeze (where heat sums were calculated analogously to growing-degree days using a base temperature of 7.2° C).

American beech is associated with a large number of tree species throughout its extensive range. In the Southeast beech is found in forests along with southern magnolia (*Magnolia grandiflora*) (Braun 1950). Beech is a major component of three forest cover types: Sugar Maple-Beech-Yellow Birch, Red Spruce-Sugar Maple-Beech, and Beech-Sugar Maple. In the Upper Peninsula of Michigan beech has been shown to be associated most strongly with sugar maple, hemlock, and yellow birch (Braun 1950, H. Delcourt and P. Delcourt 1996). Data from Woods (1981) show that American beech becomes increasingly co-dominant with hemlock, rather than sugar maple, toward the northern portion of its range in Upper Michigan.

American beech occurs on soils in the orders Alfisols, Oxisols, and Spodisols (Tubbs and Houston 1990), with pH values ranging from 4.1 to 6.0. Beech occurs with greater abundance on increasingly coarse-textured soils on drier sites in the northern portion of its range (Fig. 1 inset) (Beschel *et al.* 1962). This shift in edaphic preference by American beech toward coarser-textured soils has been observed by many researchers (Westveld 1933, Maycock 1963, Lambert and Maycock 1968, Leak 1978, Woods 1981, Whitney 1986). One important question is, how long has this relationship been established? As beech immigrated into areas toward its northern range limit, did it immediately become established on coaser-textured soils, or did it move on to these soils only after some environmental factor changed?

Within the distributional limit of American beech, three varieties, gray, red, and white, have been described (Camp 1950). White beech occurs primarily in the southeastern United States and is now thought to correlate with the now recognized variety of beech, *Fagus grandifolia* var. *caroliniana* (Loud.) Fern. & Rehd. (Elias 1971). Red beech occurs at lower elevations northward along the Appalachian Mountains. At higher elevations in the Great Smoky Moutain National Park, gray beech is found in "beech gaps" as high as 1829 m (6000 ft). In the upper midwest, beech populations are thought to be a mixture of red and gray beech. The inter- and intra-stand genetic variability of two stands in West Virginia and Maine has been studied by Houston and Houston (1994). They found that genetic heterozygosity was generally higher in the more northern stand. No study to date has been published that looks at how beech varies genetically thoughout its range, or what if any adaptive differences may exist among different varieties or races.

Beech flowers, which are quite susceptible to spring frost, bloom in late April and early May when leaves are about one third grown (Tubbs and Houston 1990). Beech produces large seeds (3.5 grams) which are animal-dispersed (S. Webb 1986, Johnson and Webb 1989). Large mast years vary in frequency from every 2 to 8 years. Blue jays (*Cyanocitta cristata*) have been observed transporting beech nuts up to 4 km in Wisconsin (Johnson and Adkisson 1985) and they preferentially cache beech nuts at the base of pine and hemlock trees (D. R. Houston, personal communication). This behavior might favor the establishment of beech seedlings since germination and survival is greater on mor humus than mull humus soil (Tubbs and Houston 1990). American beech produces root sprouts (Held 1983), but sprouts typically die when the adjacent mother tree dies (Poulson and Platt 1982, 1996).

Due to its extreme shade-tolerance beech can remain in the understory for many decades. Beech has diffuse porous wood anatomy (with initiation of cambial growth not occurring until leaves are fully expanded (Friesner 1942)). Under ideal conditions beech can reach a height of 37 m (120 ft) but average 18 to 24 m (60 to 80 ft) (Tubbs and Houston 1990).

Due to its shallow roots and thin bark, beech is very fire intolerant (Tubbs and Houston 1990). It is favored by small rather than large gaps in the canopy (Poulson and Pratt 1996). Lateral growth of beech branches is greater than for co-occurring sugar maple. Modern beech populations have been greatly affected by the beech bark disease which was introduced from Europe in AD1890 (Houston and Valentine 1988). Since its introduction, beech bark disease has spread inland and now affects trees as far west as Ohio and as far south as the Great Smoky Mountain National Park of Tennessee and North Carolina (Fig. 26). Beech bark disease begins when the introduced scale insect (*Cryptococcus fagisuga* Lind.) feeds on the thin living bark of beech. The wounds caused by the scale insect are then infected by several species of fungi of the genus *Nectria* Fries (Houston 1994). Beech populations typically experience greater than 75% mortality within four to five years of initial infestation and infection (Houston 1997).

Because American beech is one of the most shade tolerant canopy tree species in the eastern deciduous forest, it can outcompete many species. Beech is considered a small-gap specialist whose growth is slower than less shade-tolerant species (including sugar maple) in large gaps and clear cuts (Tubbs and Houston 1990). Woods (1979) describes a process of reciprocal replacement between beech and sugar maple in Warren Woods, Michigan, in which each species has greater seedling mortality beneath conspecifics. An alternative hypothesis, based on 20 years of data from the same forest, has been proposed by Poulson and Pratt (1996), suggesting that American beech and sugar maple are differentially able to take advantage of small and large gaps in the forest canopy. American beech is capable of greater lateral growth making it able to fill in small gaps, while sugar maple is capable of greater vertical extension resulting in its being able to more quickly reach the canopy in larger gaps. Thus, in a forest where multiple sized gaps routinely form, American beech and sugar maple can maintain their codominance. One factor which favors beech is the lack of deer browsing it suffers in comparison with its codominants, sugar maple, yellow birch, and hemlock (Tubbs and Houston 1990).

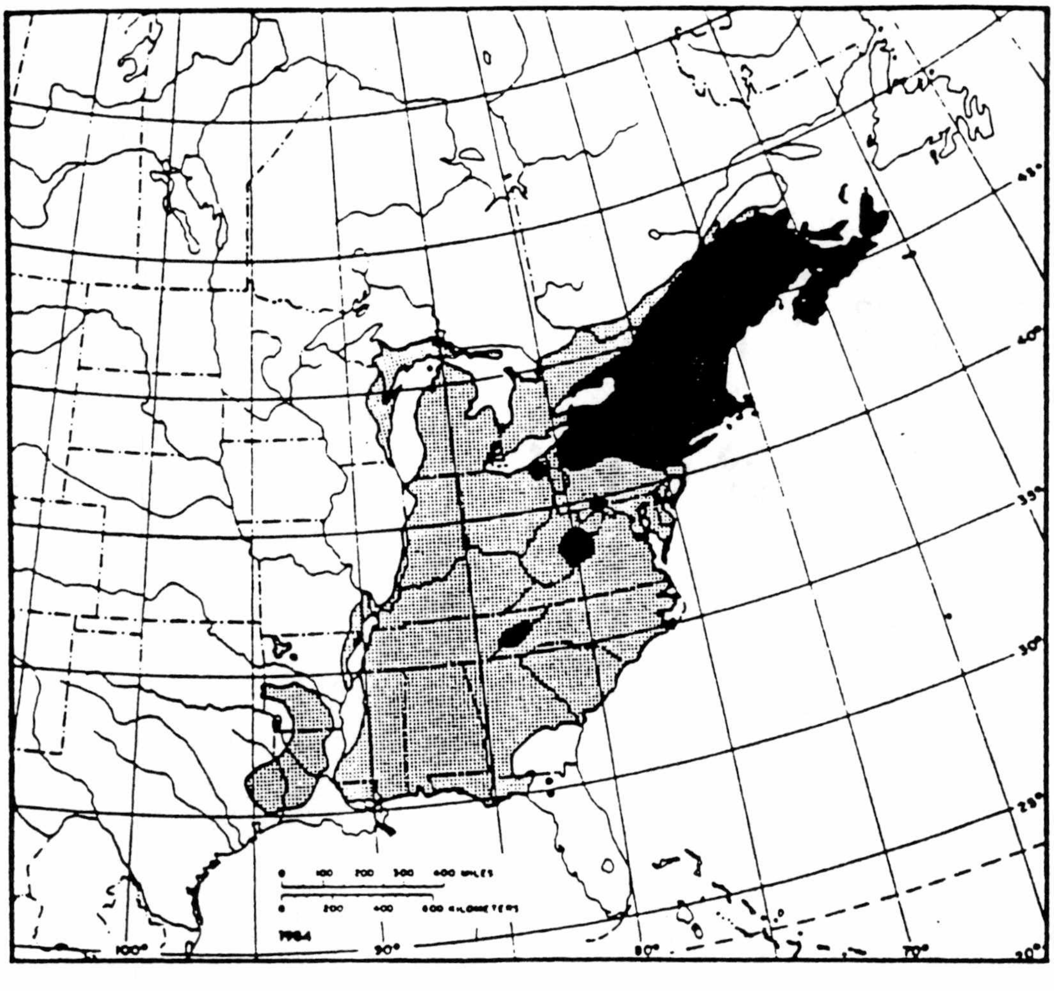


Figure. 26. Distribution of beech scale (black shading) superimposed on the modern distribution of American beech in eastern North America (from Houston 1997).

F. Determination of Local Taxon Presence Using Palynological Data

At the core of using palynological data in paleoecology research is understanding the relationship, for any given taxon, between the abundance of its pollen deposited at a given site and its abundance in the surrounding vegetation. Because of the central position this pollen-vegetation relationship holds, numerous paleoecologists have conducted research to quantify it precisely (Davis 1963, Delcourt *et al.* 1983, Bradshaw and Webb 1985, Prentice 1985, Prentice *et al.* 1986, Schwartz 1989, Jackson 1990, Davis *et al.* 1991). The pollen-vegetation relationship is a function of many factors, including source area (a function of lake size), pollen production, and pollen dispersal.

The first key variable in determining this relationship is the size of the site in which the pollen was deposited. Jacobson and Bradshaw (1981) presented a model relating the lake area to source area, in which sites with smaller diameters receive an increased proportion of pollen from local sources (Fig. 27). More recently, it has been demonstrated that this relationship is somewhat over-simplified (Jackson 1990) and that even very small lake sites (<0.5 ha) have a larger source area than previously modeled. He found that the largest portion of beech pollen deposited into very small (<0.5 ha) lakes originates from between 500 and 1000 meters away from the lake (Jackson 1990). While this result does not agree with the Jacobson and Bradshaw model for very small sites, it does not negate the idea that larger lakes still have a more regional source area.

Two additional key variables in establishing the relationship between pollen and vegetation are (1) the amount of pollen produced by a taxon; and (2) how far that pollen is transported. Pine trees produce copious amounts of pollen that is dispersed over large areas, while sugar maple trees produce relatively small amounts of pollen that is not dispersed very far. The influence of these two variables can be illustrated and assessed by applying regression techniques to data sets of modern pollen abundance of a taxon at a site and some measure of that taxon's abundance in the surrounding forest (Fig. 28).

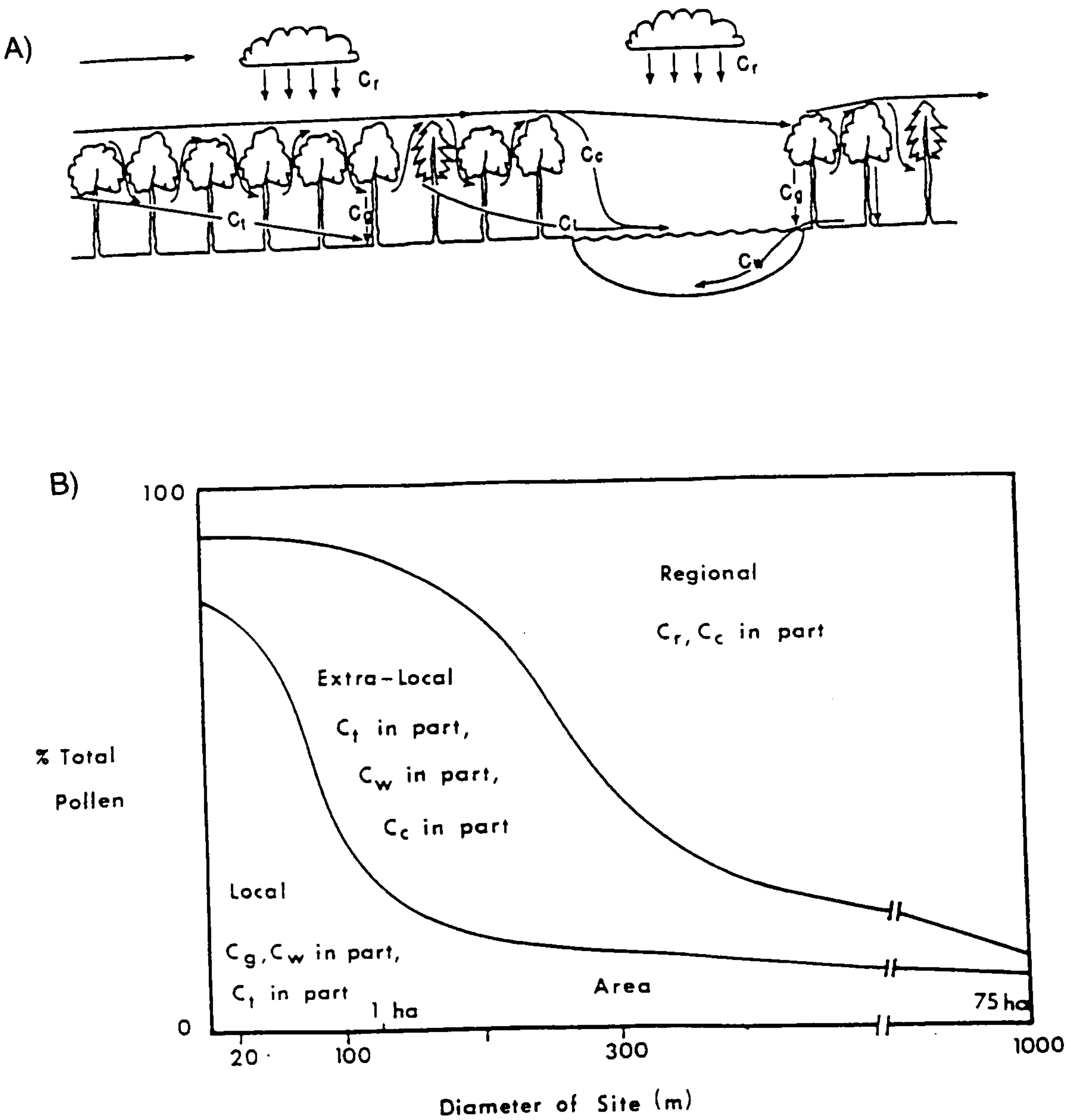


Figure 27. Diagram illustrating A) various sources of pollen deposited to a small lake, and B) model of pollen source area for sites of varying diameters (from Jacobson and Bradshaw) Abreviations correspond to five components of pollen transport: rain (Cr), canopy (Cc), trunk space (Ct), gravity (Cg), and water (Cw).

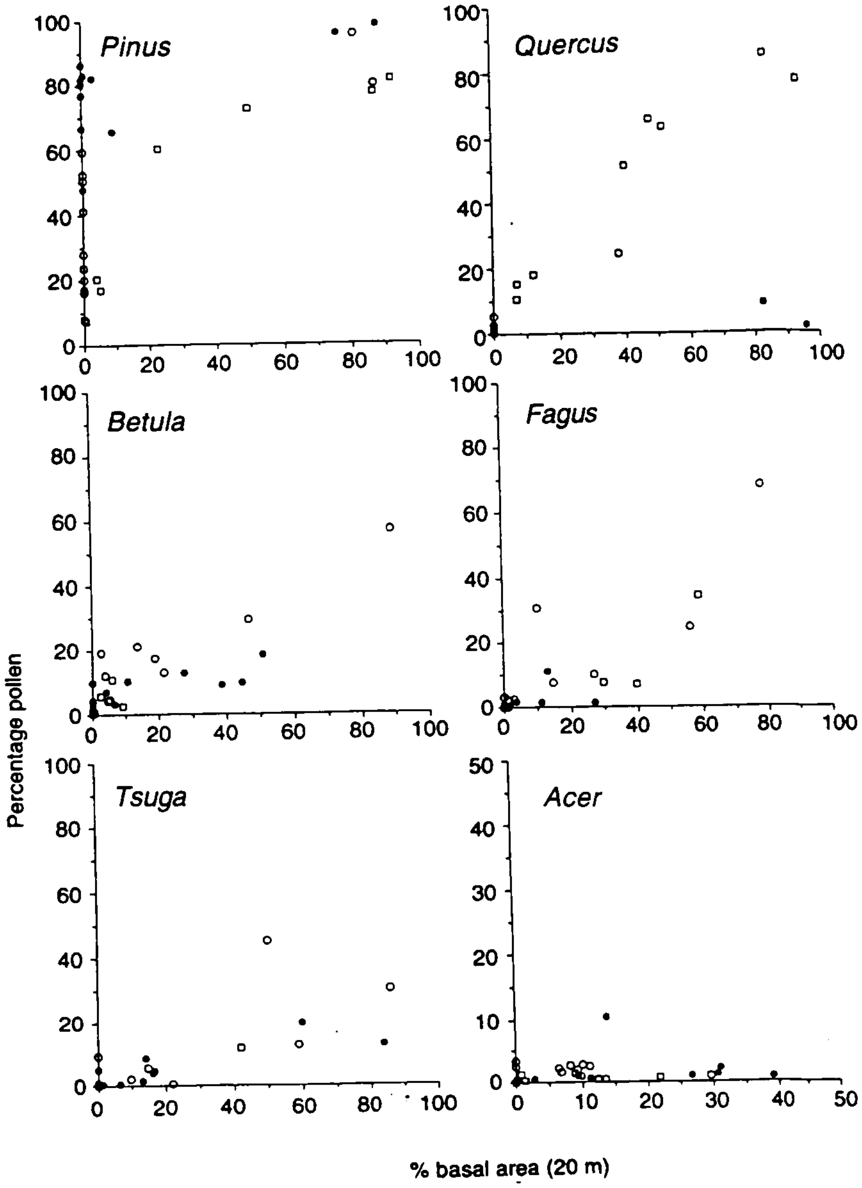


Figure 28. Example of scatter plots from New York, Massachusettes, and Rhode Island showing the relationship between pollen percentages and tree basal area percentages within a 20 m radius of each site for *Pinus, Quercus, Betula, Fagus, Tsuga, and Acer* (modified from Jackson and Wong 1994). Symbols correspond to central Adirondack sites (○), eastern Adirondack sites (●), and southern New England sites (□).

Regression analysis has consistently shown significant positive relationships between pollen and vegetation (Fig. 28, Table 1). These regression models yield three readily interpretable variables. These variables are a) the correlation coefficient (a measure of the overall scatter of the data, b) the slope (a measure of whether a taxon is over- (slope >1.0) , under- (slope < 1.0), or equally-represented (slope = 1.0) in the pollen record relative to the surrounding vegetation, and c) the y-intercept (a measure of the amount of pollen originating outside of the sample radius). If the y-intercept >> 0 then a larger portion of the taxon in question originated beyond the range of vegetation sampling (e.g. Pine). Conversely, a negative y-intercept means that a fair number of trees of a taxon need to be present in the surrounding vegetation before it can be statistically relied on to appear in the fossil record (e.g. maple). For beech, y-intercepts have been reported that are both negative (-2.29) (Delcourt and Delcourt 1987) and positive (2.68) (Jackson 1990), with the majority of estimates and, more importantly, estimates based on data from Michigan and Wisconsin, being close to zero (-0.07 to 0.85) (Bradshaw and Webb 1985, Schwartz 1989). Table 1 summarizes values for these three variables for *Fagus grandifolia* from various studies. Variation in the values of these parameters is a function of 1) different methods used to obtain values, 2) individual errors associated with each method, 3) site specific variation in co-taxa in assemblage, climate, and topography, and 3) sample size.

From this background information, one can begin to discuss the various ways in which pollen abundance of a taxon can be used to determine the local presence of that taxon in the surrounding vegetation. There are three alternative criteria which can be used for establishing the arrival of a taxon to an area based on pollen percentages in a depth/time profile (Fig. 29). It is assumed that a taxon is present within a defined radius of a site when: (A) there begins a continuous presence of pollen of the taxon, (B) a minimum threshold percent is reached indicating local presence (based on the modern relationship between vegetation and pollen deposition), or (C) there occurs a marked increase in

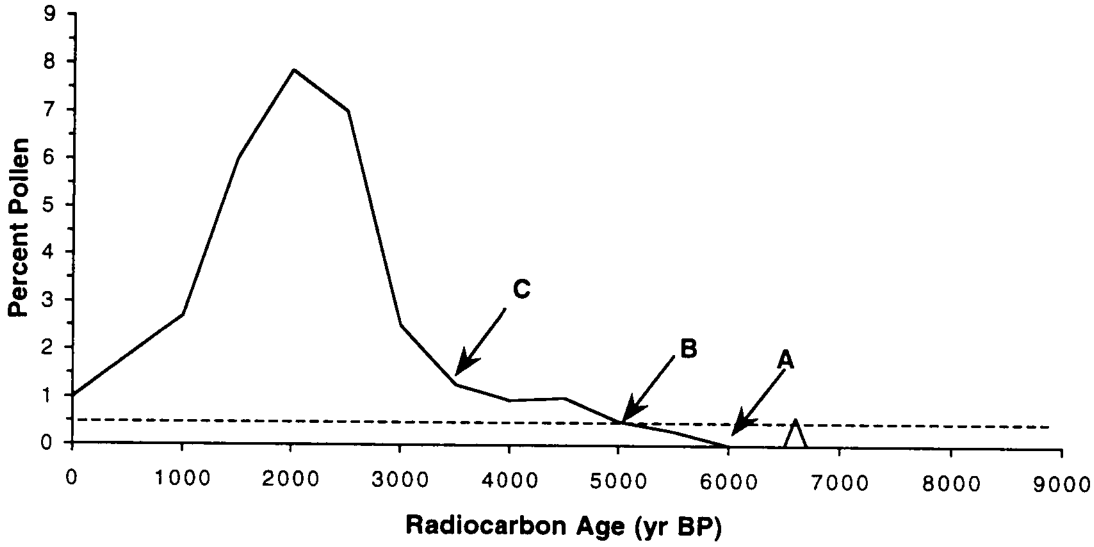


Figure 29. Graphical illustration of three alternative criteria for establishing the arrival of a taxon into an area based on pollen percentages. Shown is a hypothetical pollen curve for a taxon. For each of the three criteria, it is assumed that a taxon is present within a defined radius of a site when: (A) there begins a continuous presence of pollen of the taxon, (B) a minimum threshold percent is reached indicating local presence (based on the modern relationship between vegetation and pollen deposition), and (C) there occurs a marked increase in deposition rate of pollen from the taxon. Note the occurrence in this example of a pollen percentage at 6700 yr BP which rises above the indicated threshold. The continuity of percentages from one level to the next may also be a prerequisite for recognizing the local presence of a taxon (modified after MacDonald 1993).

deposition rate of pollen from the taxon. Note the occurrence in this theoretical example (Fig. 29) of a pollen percentage at 6700 yr BP which rises above the indicated threshold of 0.5%. The continuity of percentages from one stratigraphic level to the next (temporally consecutive) level may also be a prerequisite for recognizing the local presence of a taxon.

Table 1. Values of correlation coefficients, slope, and y-intercepts from regression of American beech pollen abundance and American beech tree abundance.

Correlation Coefficient	Slope	Y- Intercept	Reference
0.94**	0.43	1.42	Jackson (1990) (1000m)
0.85**	0.6	-0.24	Jackson and Wong (1994)
0.81**	0.42	1.99	Jackson (1990) (500m)
0.736**	0.281	0.001	Schwartz (1989)
0.73**	0.52	2.68	Jackson (1990) (100m)
0.27**	1.81	-2.29	Delcourt and Delcourt (1987)

** P<0.01

Davis *et al.* (1986, 1991) used the critical value of 0.5% TTP (total terrestrial pollen) as a threshold to indicate the local (within 20 km) presence of American beech. This value is based upon the inflection point observed in the relationship between presettlement pollen and presettlement trees along the western range limit of American beech in Wisconsin (Fig. 30). One caveat of this method is that it does not systematically deal with pollen records in which beech pollen is not continuously present or only sporadically reaches the 0.5% TTP threshold.

In addition to establishing criteria for local (within 20 km) presence of beech, Davis *et al.* (1986) enumerated the strict criteria for identifying, in the fossil pollen record, the

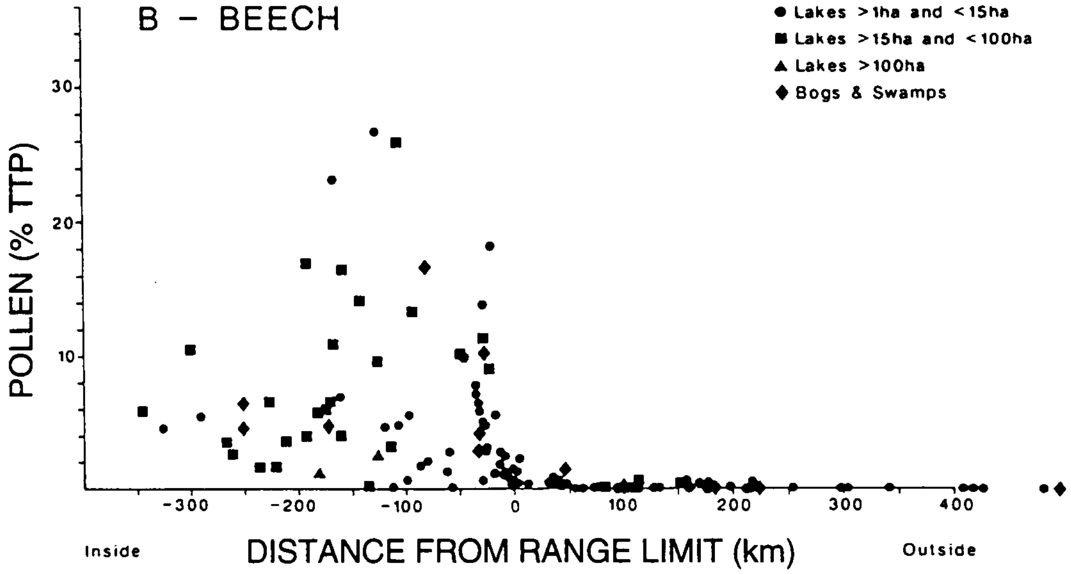


Figure 30. Graph of presettlement beech pollen percentages (% of Total Terrestrial Pollen) from sites of known distance (in km) from the pre-settlement range limit of beech as determined by General Land Office surveys (from Davis *et al.* 1991).

existence of small outlying populations of beech beyond its range limit. Needed would be large pollen counts, consistent occurrence of beech pollen in a series of consecutive samples, and the absence (or below threshold levels) of beech pollen at nearby sites (within 20 km distance).

CHAPTER III

METHODS

A. Criteria for Determining Time of Beech Establishment

In order to test my seven hypotheses concerning the arrival, expansion, and decline of American beech in Upper Michigan, it is first important to clearly establish the criteria for when these events occurred, as recorded within a fossil-pollen stratigraphy. As mentioned in the previous section, Davis *et al.* (1986, 1991), and Woods and Davis (1989) used the criteria of 0.5% TTP except in cases where they believed that a site was beyond the range of long distance transport of beech pollen and there was lower than 0.5% beech pollen at nearby sites. In these circumstances it appears that they marked the arrival of beech at the stratigraphic level where beech pollen starts being continuously recorded (Woods and Davis 1989). They also used the criterion of "nearly continuous" beech pollen presence. One method of avoiding this ambiguity is to set a threshold percentage for a running average of beech pollen percentages, thereby allowing for the periodic absence of beech pollen at a level only if the percentages on either side of this absence are large enough to raise the running average above the threshold. This method has the advantage of incorporating the information present above and below the stratigraphic level in question while remaining an objective criterion which can be compared readily with the records from other sites.

For the purpose of this study I used the following criteria for determining beech arrival, expansion, and decline. I marked **beech arrival** at the stratigraphic level where: 1) the running average of beech pollen percent across three levels was continuous; and 2) greater than or equal to 0.5% TTP (total terrestrial pollen). For all sediment cores this running average spanned between 100 to 800 years and 3 to 20 cm. I marked **beech**

expansion at the stratigraphic level where: 1) the running average percent increases by greater than or equal to 25% (or two or more successive rises which total greater than or equal to 25%), and 2) the running average percent was greater than or equal to 2.0% TTP. The magnitude of beech expansion was determined by subtracting the percent of beech pollen at the level prior to the time of expansion from the maximum beech pollen percent prior to a decline. In determining whether beech declined at a site I did not include declines since European disturbance (AD 1880, 70 yr BP [before the baseline of AD 1950). I identified the occurrence of a **beech decline** as a drop of greater than or equal to 25% (or two or more successive drops which total greater than or equal to 25%) in the running average of beech pollen percent following an expansion. The magnitude of a decline was calculated by subtracting the minimum, pre-Columbian beech pollen percentage after a decline from the beech pollen percentage at the level prior to the decline. I selected greater than or equal to 25% as the criterion for the expansion or decline of American beech populations around a site because it objectively identifies the occurrence of a consistently visible inflection point or sustained decline within the pollen record of beech at several sites. Appendix L contains all of the raw data used in these determinations for the four sites within the study area (Elbow Lake, Nelson Lake, Ryerse Lake, and Beaverhouse Lake).

B. Modern Association Between Beech and Soil Types

In order to establish the modern association between American beech and soil types, 9 soil types were defined based on the modern soil survey of Mackinac County, Michigan (Whitney 1995) (modified from H. Delcourt and P. Delcourt 1996). General Land Office survey records from 1840-41 (Township Surveys) and 1849-50 (Section Surveys) were obtained for the study area from microfilm copies through the Mackinac County Courthouse. These surveys document the vegetation and landscape features on a 1 square mile grid corresponding to 36 sections within each 12 townships. These surveys were used to map the presettlement presence or absence of beech at 2432 statistically independent sample points within the 74,550 hectare study area. Sample points correspond to 311 section corners (4 samples each for 1244 samples) and 594 quarter section corners (2 samples each for 1188 samples). A Chi-squared test of association (Sokal and Rohlf 1981) between presettlement beech and nine soil cover types was performed for the entire 12 township study area. This makes the assumption that no appreciable soil development has occurred during the time between the early-historic GLO survey and the soil survey of AD 1995 (144 years). The resulting X^2 statistic from this test measures the degree to which the observed frequency of beech trees on a given soil type is statistically different from that expected based on the overall abundance of both.

C. Dating of Ortstein Development

For the purpose of this study the timing of ortstein development is important in order to relate its development to the history of American beech within the study area (Hypothesis 2b). Petty *et al.* (1996) used radiocarbon dates of organic matter stratigraphically below (Millecoquins River Cutbank, location: NW 1/4 NE1/4 sec.14, T43N R10W, Fig. 8) and above (O'Neil Creek Bog, location: SE1/4 SE1/4 SW1/4 sec. 15, T43N R10W, Fig. 8) ortstein layers to bracket ortstein formation between 6900 and 3200 yr BP. In this study, I reexamine and reinterprete the evidence for the timing of ortstein development within the study area and incorporate information about the minimum time required for ortstein to develop in nascent soils of Upper Michigan (e.g. parent material such as quartz sand recently deposited by wind or water).

D. Criteria for Site Selection

Local study area

Fossil pollen analysis of lake sediments was chosen as an appropriate method to use in order to test the seven hypotheses posed in the Introduction. Lake sites were selected based on the following criteria. The lakes had to be: 1) small (<10 ha) in order to maximize the proportion of pollen deposited from local sources (Jacobson and Bradshaw 1981); 2) closely spaced to each other (<25 km) in order to facilitate the positive identification of any outlying populations; 3) at varying distances from the shore of Lake Michigan (0-15 km), in order to test for the influence of Lake Michigan in ameliorating climatic extremes; and 4) surrounded by soil types differing in texture and parent material, in order to test for the influence of soil type. Within the study area four small lake sites were chosen for paleoecological study (Fig. 8): (1) Elbow Lake, on loamy soil 2.3 km from the present shore of Lake Michigan (analyzed by Petty 1994); (2) Beaverhouse Lake, on sandy soil without ortstein 5.3 km from the shore (this study); (3) Ryerse Lake, on sandy soil with ortstein 7.7 km from the shore (analyzed by Futyma 1982); and (4) Nelson Lake, on loamy soil 14 km from the shore of Lake Michigan (fossil pollen analyzed by Hazel Delcourt and fossil charcoal analyzed by Peter Nester [Nester 1999]) (Fig. 8).

Regional study area

The arrival, expansion, and decline of American beech at 12 sites from Upper Michigan and Wisconsin (Fig. 7) were analyzed for a regional comparison. The criteria I used in selecting these sites were that each site: 1) be within the historic distributional range of American beech (Little 1971); 2) have a published pollen curve for American beech; 3) have a radiocarbon dated chronology, 4) be of sufficient length as to record the arrival of American beech at that site; and 5) be in a county in which detailed, contemporary soil surveys were available. Using the same categorizations as the study area, the dominant soil type surrounding each site (>50% total soil area within 2 km) was determined by the soil surveys of the counties in which each site occurs. In determining the arrival, expansion, and decline of beech at these sites, I used the same criteria as described above. Finally, 29 additional sites from Lower Michigan, Indiana, Ohio, Pennsylvania, New York, and Ontario (Fig. 7, Appendix A) were selected to aid in the testing of hypotheses 1a concerning beech delay in reaching Upper Michigan and to investigate migrational pathways. Table 2 summerizes the sites used to explicitely test each hypothesis.

E. Site Descriptions and Field Methods

For a complete description of Elbow Lake, Nelson Lake, and Ryerse Lake see references listed in Appendix A. The following descriptions of field and laboratory methods refer to Beaverhouse Lake and three supplemental sites within the study area which comprised the field sampling component of this thesis. Beaverhouse Lake is a small (4 ha) lake located just east of Lake Millecoquins (Fig. 8). A sediment core from the deepest portion of Beaverhouse Lake was collected using a Klein coring device (a soft-sediment coring device developed by Steve Klein, Abysmal Samples, Inc., Seattle, Washington) and a modified Livingston square-rod piston coring device (for lower, consolidated sediments) (Wright, 1967). Three additional lowland sites, all > 2 km from modern beech populations, were studied to test the dispersal range of beech pollen: Greylock Bog (unofficial name, location: SW 1/4 NE1/4 SE 1/4 sec. 14, T43N R10W), US 2 Bog (unofficial name, location: NW1/4 SE 1/4 SW1/4 sec. 23, T43N R10W), and Carnegie Trail Pond (unofficial name, location: SE1/4 SE1/4 SE1/4 sec. 27, T43N R10W). These sites are all located in the lake plain south of Lake Millecoquins (Fig. 8). Sediment cores were collected at these sites using a Russian peat sampler.

Table 2. Summary of sites used to test each hypothesis.

Hypothesis	Description	Sites/Data used to test each hypothesis	Comments
H1a	Delayed establishment hypothesis	Elbow Lake, Nelson Lake, regional sites along most direct migration routes from Pennsylvania to Lower Michigan to Wisconsin and Upper Michigan	This hypothesis is tested by first testing to see if previously undetected beech populations occurred in Upper Michigan during the mid-Holocene, and second by comparing rates of beech migration into Upper Michigan with those prior to reaching Upper Michigan.
H1b	Lake-effect hypothesis	Elbow Lake and Nelson Lake	These two lakes are on the same soil type but at different distances from Lake Michigan.
H1c	Fine-textured, calcareous soils hypothesis	Ryerse Lake and Nelson Lake Beaverhouse Lake and Elbow Lake	These two pairings group sites which were approximately the same distance from Lake Michigan at time of beech arrival but are on different soil types (sand vs. loam).
H2a	Coarse-textured soils hypothesis	GLO Survey and Soil Types, Beaverhouse Lake, Ryerse Lake, East Soldier Lake, Wolverine Lake, Brampton Lake, and Spirit Lake	This hypothesis is tested by first looking at the pre-settlement distribution of beech trees relative to coarse-textured sandy soils and then examining the fossil pollen record from sites surrounded by coarse-textured soils
H2b	Ortstein hypothesis	Beaverhouse Lake and Ryerse Lake Wolverine Lake and Young Lake,	By comparing the pollen records from these pairs of sites surrounded by sandy soils with and without ortstein, I test the importance of ortstein to beech expansion.
H3a	Interspecific Competition hypothesis	Elbow Lake, Kitchner Lake, US 2 Pond	These sites are those which record a decline in American beech for which there are complete pollen records available to compare mesic and hydric tree taxa.
H3b	Paludification hypothesis	Elbow Lake, Nelson Lake, Kitchner Lake	Same as H3a

F. Laboratory Techniques

Radiocarbon dating

The sediment cores were sampled for radiocarbon dates after the cores were transported to the laboratory. Samples were taken at lithologic changes in each sediment core or at intervals spaced between lithologic changes. Percent organic material was determined by loss-on-ignition analysis (Dean, 1974). Core segments with sufficient organic matter for dating (approximately 10 cm in length, 200 cm^3) were removed from the core, sampled for pollen at 2.5 cm intervals, and radiocarbon dated by Beta Analytic, Inc., Coral Gables, Florida. All dates were corrected by ^{13}C analysis. All dates are presented in corrected, radiocarbon years before present (yr BP), unless otherwise noted (Appendix C).

Pollen analysis

Sediment accumulation rates were calculated based on radiocarbon dates. Volumetric sediment samples (0.25 cc - 1 cc) were removed from the segments used for radiocarbon dating at 2.5 cm intervals. The remainder of the core was sampled at depth intervals corresponding to approximately 100 yr intervals (every 2 to 11 cm). All sediment samples were treated using a palynomorph extraction procedure modified from that of Faegri and Iversen (1975) (see Appendix B). Slides were prepared by placing a drop of concentrated pollen residue on a slide and adding a drop of silicone oil for dilution to a concentration suitable for counting. A minimum of 500 total terrestrial pollen (TTP) grains were counted per level. Pollen percentages were calcuated based on this total terrestrial pollen (TTP) sum.

Palynomorphs were counted at a magnification of 400x using a Leitz Laborlux 12 microscope. A magnification of 1000x was used to resolve finer features when necessary.

Taxonomy of plant taxa follows Gleason and Cronquist (1963). Pollen and spore identification was based on the keys of McAndrews *et al.* (1973) and Kapp (1969). For identification of species within the genus *Acer*, the taxonomic key of Helmich (1963) was used.

G. Ordination of Pollen Spectra

In order to investigate changes in vegetation through time, and objectively identify zones within the pollen diagram, the ordination program PC-ORD (McCune 1987) was used to perform Detrended Correspondence Analysis (DCA) (Gauch 1982) on the samples from the lake sediment core from Beaverhouse Lake. Pollen percentages were first analyzed at 1000 year intervals, and then at finer intervals of 500 yr, 200 yr, and 100 yr. Beta diversity was used as an objective measure of vegetation change between levels. For comparison, four (4.0) standard-deviation units of Beta diversity represent a total (100%) changeover in species composition (Gauch 1982), in this case, corresponding to vertically-adjacent stratigraphic samples of arboreal fossil-pollen spectra. As positioned in ordination space along DCA Axis 1, the ordination scores for these samples quantify the magnitude of composition change. When pairs of samples are compared, these values are expressed in terms of Beta diversity relative to increments of radiocarbon time between the samples. The high peaks in Beta diversity were used to divide the pollen diagram into informal assemblage zones to facilitate discussion. Analysis at varying time intervals provided a sensitivity test of DCA to resolve temporal changes in vegetation (Petty 1994).

CHAPTER IV

RESULTS

A. Modern Association Between Beech and Soil Types

The distributions of the nine soil cover types and presettlement beech within the study area are shown in Figures 31 and 32. There were a total of 272 beech trees present at 2432 sample points. The results of the chi-squared test of association between beech and each soil type is presented in Table 3 and Figure 33. Significant positive associations exist between beech and three of the nine soil types. In increasing order of significance, these three soil types are: (1) calcareous, silty to fine sandy loam (type 4, moderately-drained soil); (2) acidic to pH-neutral loamy sand over gravelly till (type 3, well-drained soil); and (3) acidic fine to medium sand with ortstein (type 2, well-drained soil). These three soil types account for 77.9 % of all beech trees present (13.2, 12.5, and 52.2 % respectively). Significant negative associations exist between beech and the remaining 6 soil types. These are: (1) acidic fine to medium sands without ortstein (type 1, well-drained); (2) calcareous silty to fine sandy loam over shallow clay (type 5, moderately-drained soil); (3) calcareous clay to clayey loam (type 6, moderately-drained soil); (4) calcareous to pH-neutral gravelly loam (type 7, poorly-drained soil); (5) poorly-drained, acidic peats and mucks with overlying ortstein in places (type 8, poorly drained); and (6) acidic sands and mucky peats (type 9, poorly-drained soil, sometimes over ortstein). It should be noted that when coarse-textured sandy soils are combined (soil types 1 and 2) the association with beech is still highly significant (X^2= 58.4, $p<0.001$) (see Hypothesis 2a). In contrast, when moderately-drained, fine-textured, calcareous soils are grouped together (Soil Types 4-7), the association with beech is not statistically significant at $p=0.05$ (X^2=-3.26). This result is surprising given that beech generally occurs on finer textured, calcareous soils

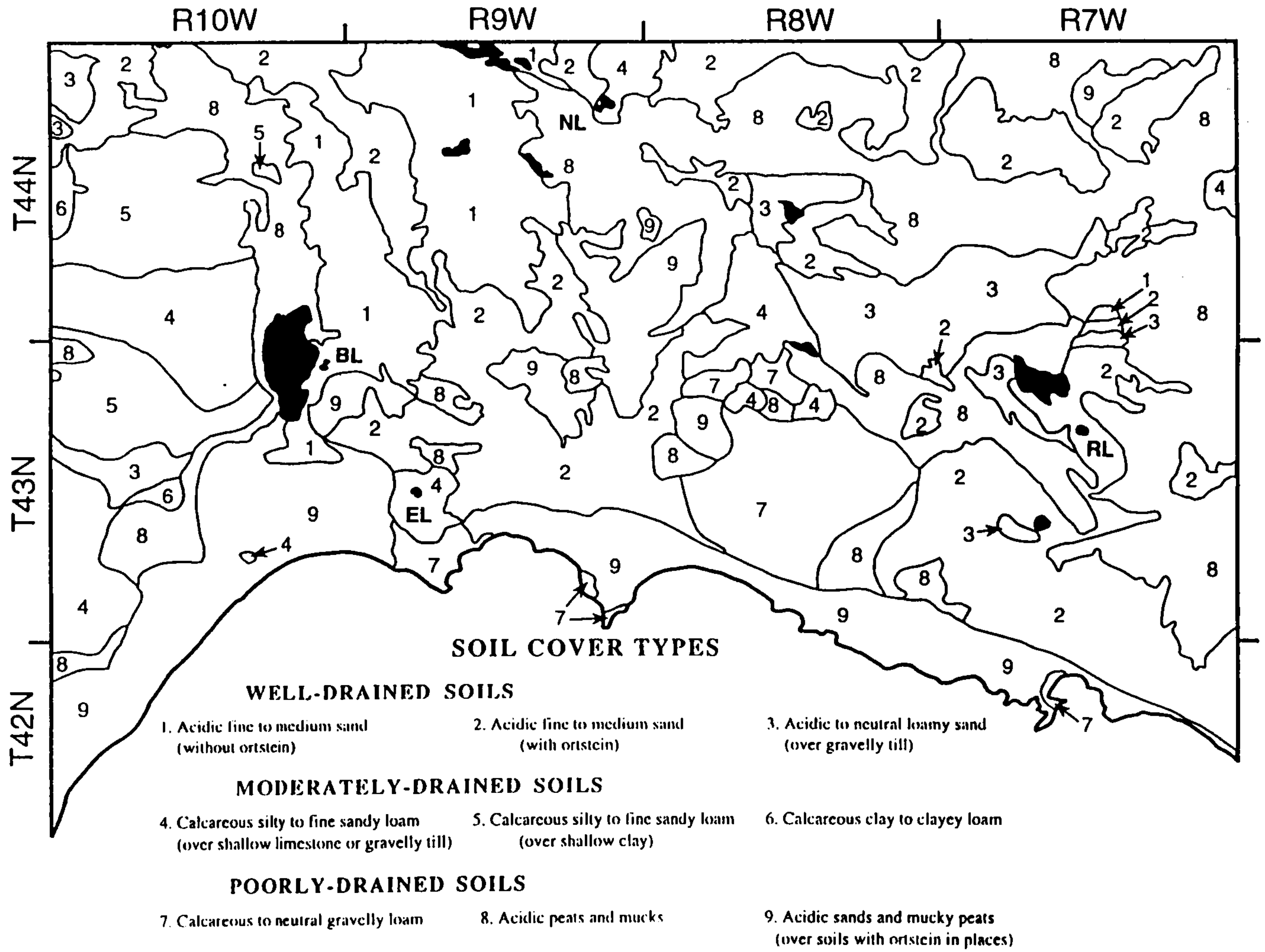


Figure 31. Distribution of nine soil cover types within the study area based on soil survey maps of Whitney (1992). Inland lakes shown as black silhouettes (modified from H. Delcourt and P. Delcourt 1996 and expanded eastward to include area surrounding Ryerse Lake).

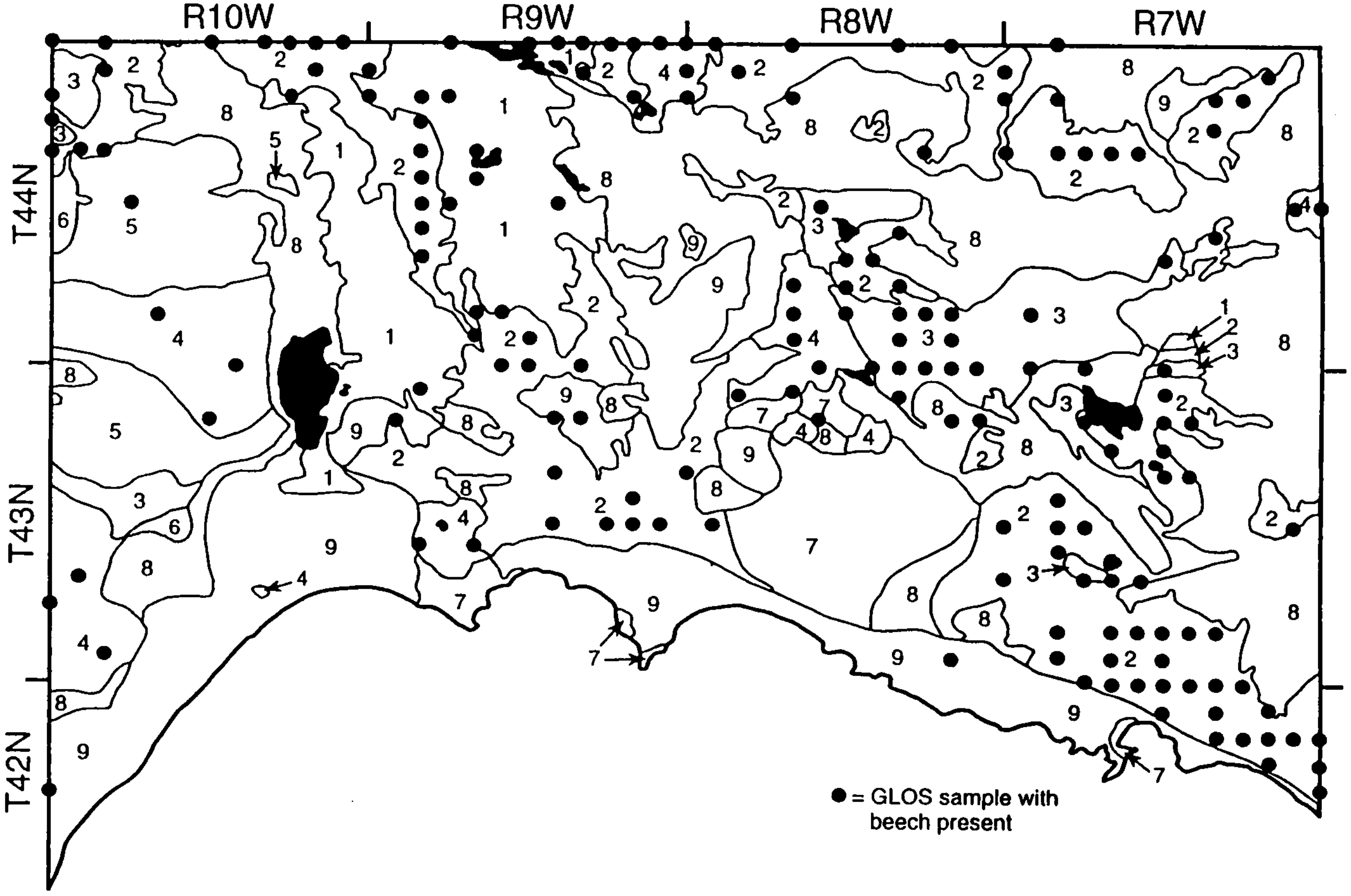


Figure 32. Presettlement distribution of beech based on General Land Office surveys and the distribution of soil types based on modern soil survey maps.

Table 3. Chi-squared test of association between 272 beech trees and 9 soil types at 2432 sample points within the study area. Sample points correspond to 311 section corners (4 samples each for 1244 samples) and 594 quarter section corners (2 samples each for 1188 samples). Expected values are in parentheses following the observed values. Degrees of freedom = 1. Significant X^2 values are indicated by asterisks (*p<0.05, critical value= 3.84; **p<0.01, critical value=6.64; ***p<0.001, critical value=10.83).

	BEECH			
SOIL TYPES	PRESENT	ABSENT	TOTAL	X^2
SOIL TYPE 1: Acidic fine to medium sand (without ortstein)				
PRESENT	14 (23)	196 (187)	210	
ABSENT	258(249)	1964 (1973)	2222	-4.7*
SOIL TYPE 2: Acidic fine to medium sand (with ortstein)				
PRESENT	142(75)	532(599)	674	
ABSENT	130(197)	1628(1561)	1758	+91.7***
SOIL TYPE 3: Acidic to pH-neutral loamy sand (over gravelly till)				
PRESENT	34(14)	94(114)	128	
ABSENT	238(258)	2066(2046)	2304	+32.2***
SOIL TYPE 4: Calcareous silty to fine sandy loam (over limestone or gravelly till)				
PRESENT	36(22)	164(178)	200	
ABSENT	236(250)	1996(1982)	2232	+10.2**
SOIL TYPE 5: Calcareous silty to fine sandy loam (over shallow clay)				
PRESENT	1 (9)	79(71)	80	
ABSENT	271(263)	2081(2089)	2352	-8.2**
SOIL TYPE 6: Calcareous clay to clayey loam				
PRESENT	0(6)	54 (48)	54	
ABSENT	272(266)	2106(2112)	2378	-7.0**
SOIL TYPE 7: Calcareous to pH-neutral gravelly loam				
PRESENT	1(11)	101(91)	102	
ABSENT	271(261)	2059(2069)	2330	-11.2***
SOIL TYPE 8: Acidic Peats and Mucks				
PRESENT	41(74)	625(592)	666	
ABSENT	231(198)	1535(1568)	1766	-23.3***
SOIL TYPE 9: Acidic sands and mucky peats (with ortstein in places)				
PRESENT	3(36)	315(282)	318	
ABSENT	269(236)	1845(1877)	2114	-38.6***

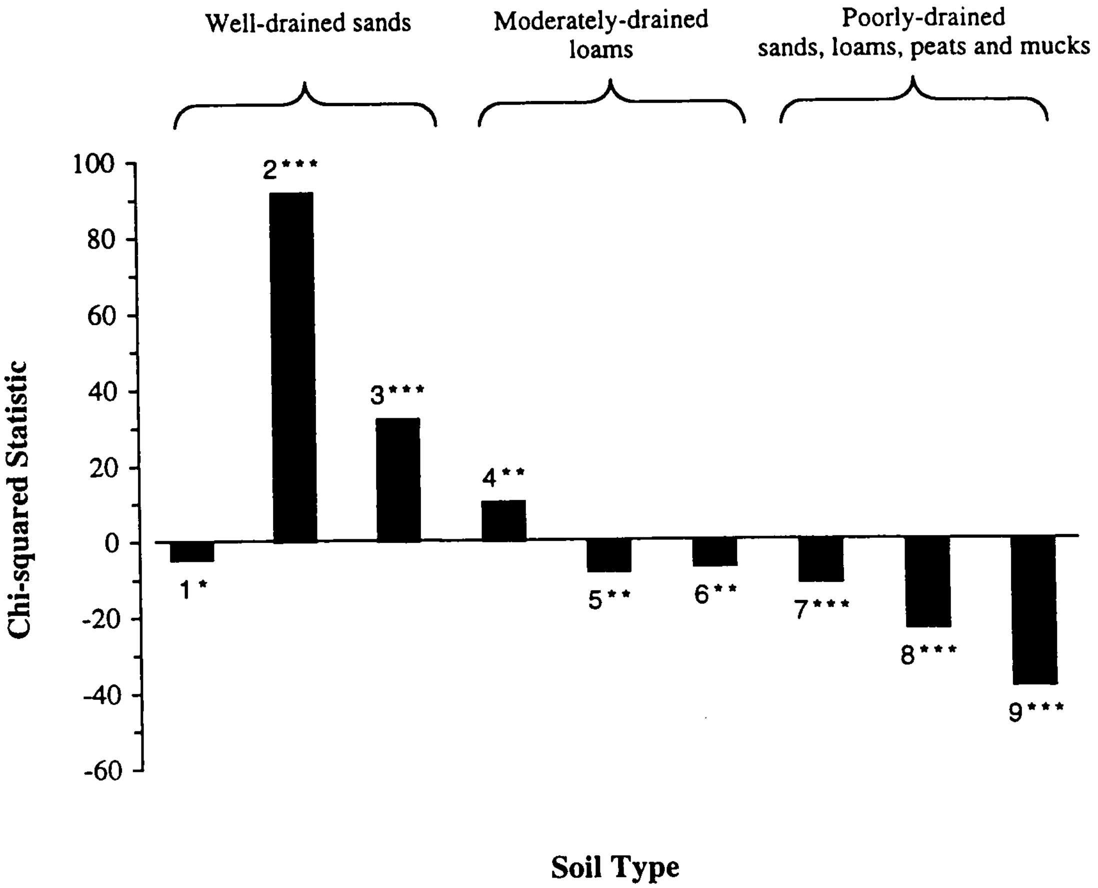


Figure 33. Graph of the chi-squared statistic for American beech and nine soil types. See Figure 31 for key to soil types. Significance levels shown by asterisks (*) where **=p<0.01, and ***=p<0.001.

throughout most of its range (Tubbs and Houston 1990). However, these results are in agreement with the many observations that beech tends to shift its abundance onto coarser-textured, drier soils in the northern portion of its range (Beschel *et al.* 1962, Maycock 1963, Leak 1978, Woods 1981).

B. Vegetation Histories of Palynological Sites

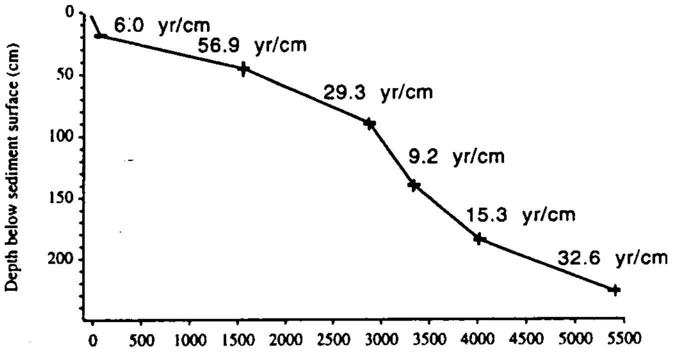
Radiocarbon dates, chronologies, and depth/age calculations of pollen samples for Beaverhouse Lake, Greylock Bog, US 2 Bog, and Carnegie Trail Pond are contained in Appendices C, D, and E, respectively. Graphs of sediment accumulation plotted against radiocarbon age for each of these sites are shown in Figure 34. Pollen diagrams from this study (Beaverhouse Lake, Greylock Bog, US 2 Bog and Carnegie Trail Pond) along with Elbow Lake (from Petty 1994) for comparison, are shown in Figure 35. All taxa identified in sediment cores, their common names and additional taxa mentioned in the text are listed in Appendix F. Complete palynomorph data for Beaverhouse Lake, Greylock Bog, US 2 Bog, and Carnegie Trail Pond are contained in Appendices H, I, J, and K, respectively. Below I describe the fossil-pollen stratigraphy for each of these sites.

Beaverhouse Lake

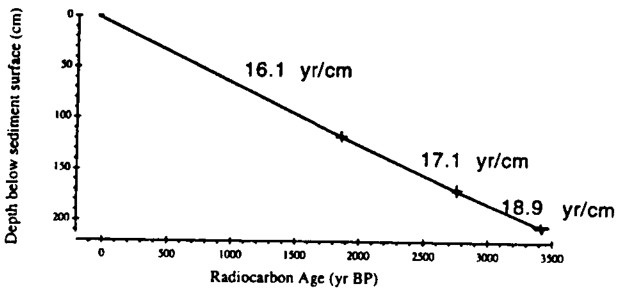
Beaverhouse Lake, located just east of Lake Millecoquins (Fig. 8) is a small (5 ha), shallow (maximum water depth of 1.8m) lake with a flat bottom. The modern forest surrounding Beaverhouse Lake is sparse and consists primarily of *Pinus banksiana*, *Pinus strobus*, *Picea glauca*, *Populus tremuloides*, and *Acer rubrum*. Abundant rooted, floating, and submerged aquatic macrophytes occur throughout the lake consisting mainly of *Brasenia schreberi*, *Nuphar luteum*, and *Potamogeton* spp. The lithostratigraphy of the Beaverhouse Lake core in centimenters below the sediment surface is as follows:

Figure 34. Graphs of sediment accumulation vs. radiocarbon age for sites from this study: A) Beaverhouse Lake, B) Greylock Bog, C) US 2 Bog, and D) Carnegie Trail Pond; and other sites within the local study area: E) Elbow Lake (Petty 1994), Nelson Lake (Nester 1999), and Ryerse Lake (Futyma 1982).

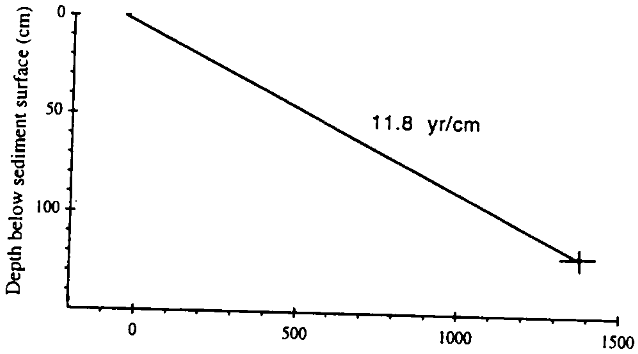
A. BEAVERHOUSE LAKE



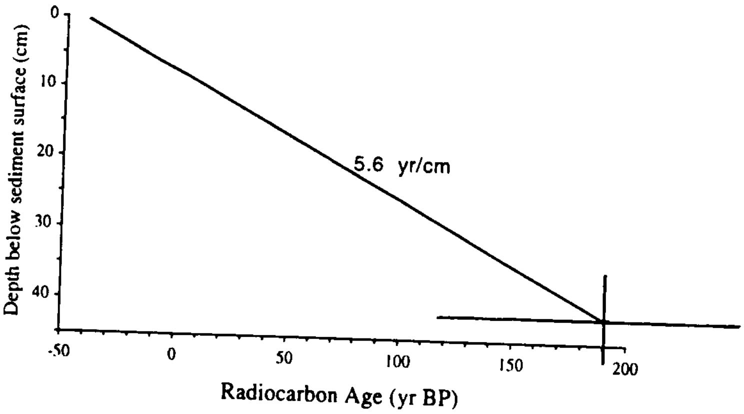
B. GREYLOCK BOG



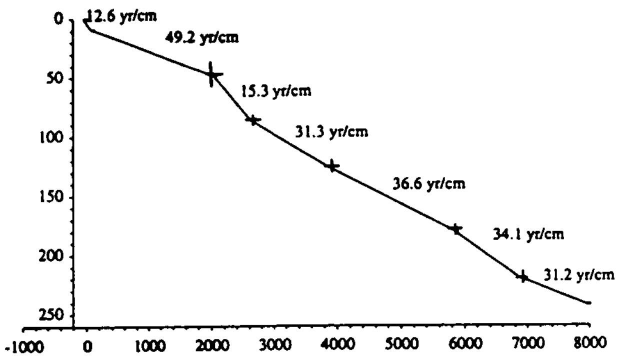
C. US 2 BOG



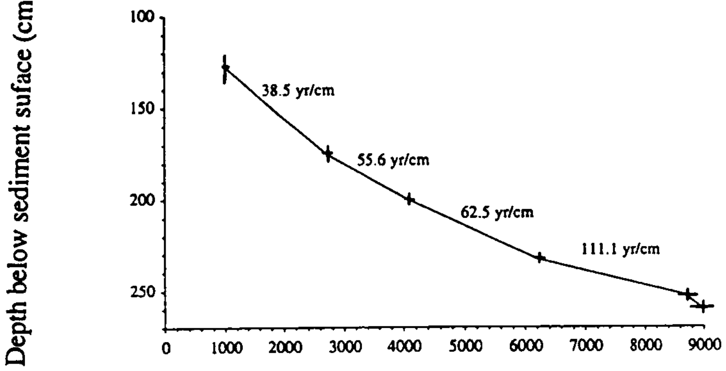
D. CARNEGIE TRAIL POND



E. Elbow Lake



F. Ryerse Lake



G. Nelson Lake

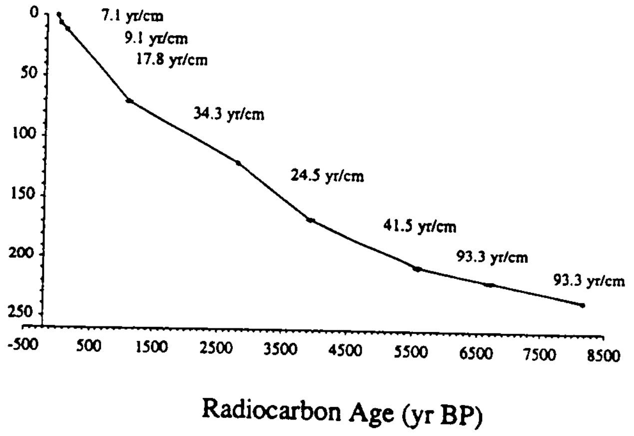
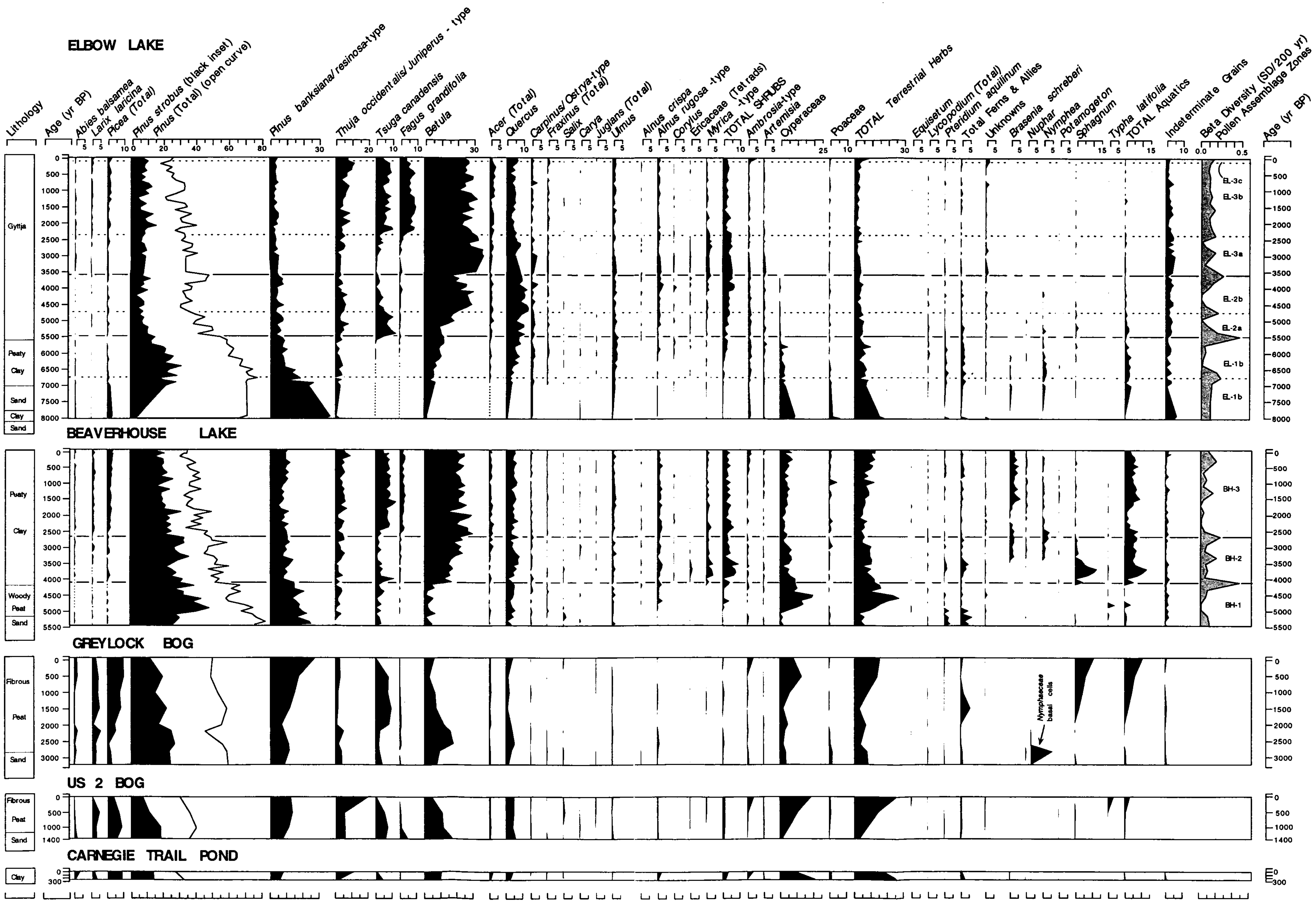


Figure 34. (continued)

Figure 35. Pollen stratigraphy from Elbow Lake (modified from Petty 1994), Beaverhouse Lake, Greylock Bog, US 2 Pond, and Carnegie Trail, within the study area. Dashed lines on Elbow Lake diagram divide pollen assemblage zones in subzones. See figure 8 for location of sites.



Analyst: William Petty Rivers, 1998

Depth (cm below water/sediment interface)	Lithology
0-31	Loosely-consolidated, fibrous peaty clay, 10YR2/2 (all color determinations are based upon the Munsell Color Chart (Munsell Color 1975).
31-145	Moderately-consolidated, fibrous peaty clay, 10YR2/2.
145-190	Woody, fibrous peaty clay, 10YR 2/2, with larger cross-sections of woody material (possible water-lily rhizomes) at depths of 145-148, 154-156, and 162-164 cm depth, lower contact gradational.
190-219	Clayey, woody-coarse peat, 10YR3/2, horizontally layered with wood fragment at 217-219 cm depth.
219-230	Slightly fine-sandy, finely-textured, fibrous peaty clay, 10YR2/2.
230-240	Fine to medium quartz sand, 10YR5/1, with sparse plant fragments, wood fragment at 232-234 cm depth, lower contact gradational into a leached zone of a forest paleosol (Spodisol).
240-254	Medium to coarse quartz sand, 10YR5/4, with sparse plant fragments, no laminations.

The biostratigraphy of the sediment core (Fig. 35) consists of three informal pollen assemblage zones, BHL-1, BHL-2, and BHL-3. The division of the core into these zones is primarily to facilitate the description of the biostratigraphy. The divisions are based upon identified times of vegetation change as determined by peaks in beta diversity (discussed below).

Ordination of pollen spectra.

Ordination plots of species scores and sample scores are presented in Figures 36 and 37. Data on which these figures are based are contained in Appendix G. The first

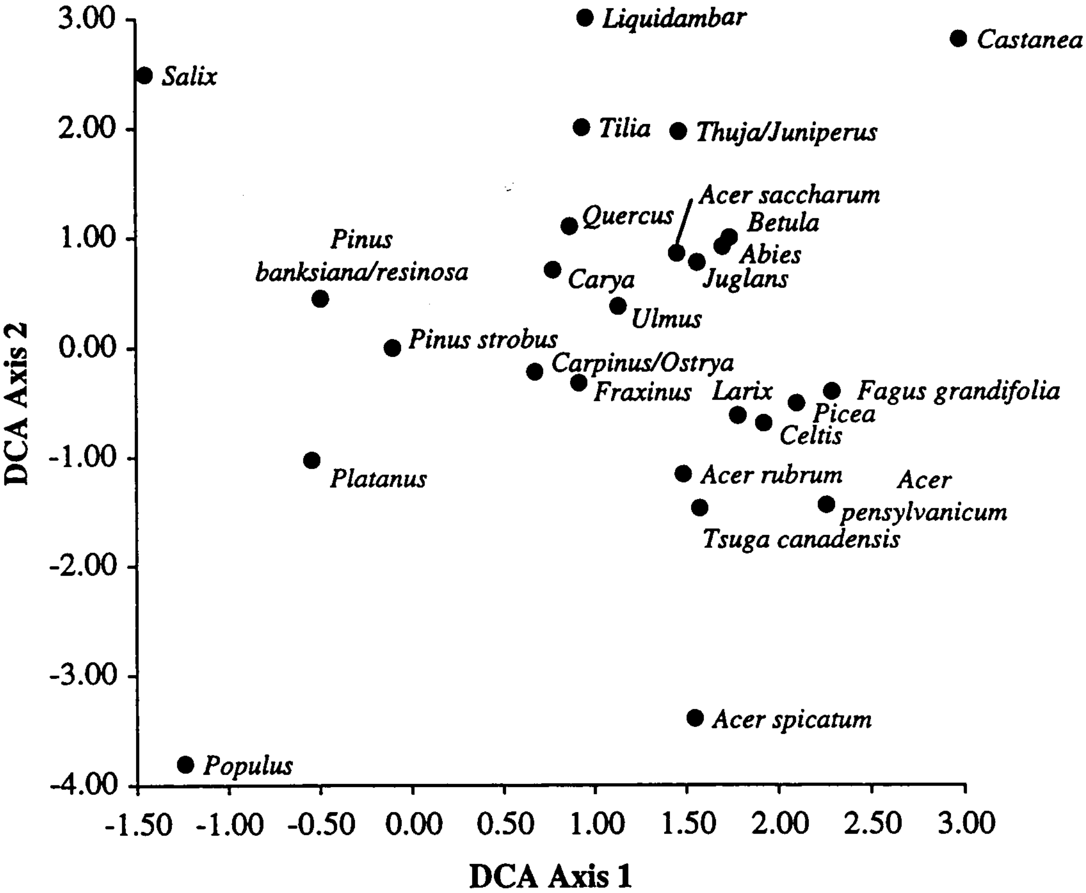


Figure 36. Detrended Correspondence Analysis of taxa scores for Beaverhouse Lake, Mackinac County, Michigan..

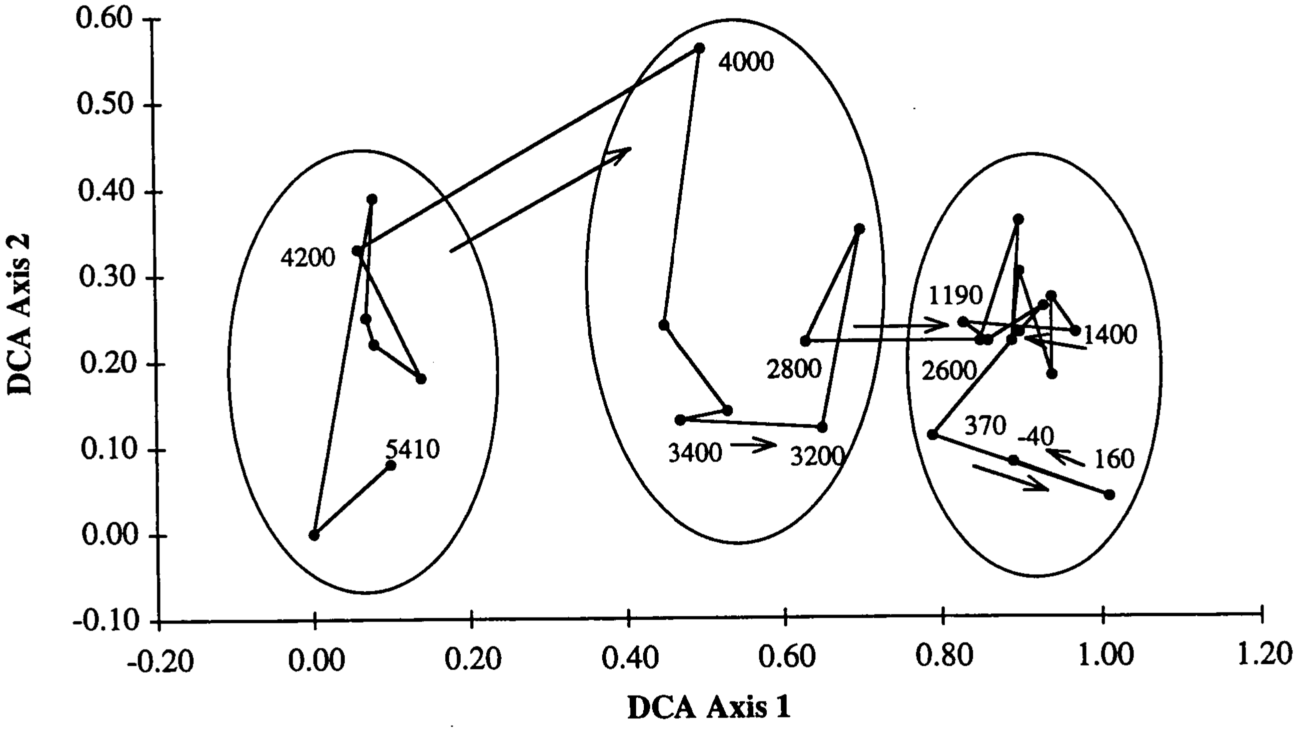


Figure 37. Detrended Correspondence Analysis of sample scores (200 yr/SD) for Beaverhouse Lake, Mackinac County, Michigan. Selected radiocarbon ages indicated at sample dots.

DCA axis of the species plot has a length of 4.4 SD and separates taxa out along a continuum from xeric (and early successional taxa) (negative values on the left) to mesic/hydric (and late successional taxa) (positive values on the right). Xeric and early successional taxa, *Pinus banksiana/resinosa*-type (Diploxylon pine), *Pinus strobus* (Haploxylon pine), *Populus*, and *Salix*, occur farthest to the left, followed by *Carpinus/Ostrya*-type, *Quercus*, *Fraxinus* (total), *Tilia*, and *Ulmus*. More mesic (and late successional) taxa, including *Juglans* (total), *Tsuga canadensis*, *Acer saccharum*, *Acer pensylvanicum*, *Betula*, *Abies balsamea*, *Picea*, and *Fagus grandifolia* occur toward the right end of DCA axis 1, along with the more hydric taxa, *Larix laricina* and *Thuja occidentalis*. *Castanea dentata* and *Liquidambar styraciflua* do not, and almost definitely did not, grow within the northern Great Lakes region; their presence in the Holocene pollen record was probably because of long-distance and northward transport of their pollen by extra-regional winds.

Samples represent fossil-pollen assemblages in temporally successive stratigraphic levels in the sediment core. A plot of samples (at 200 year intervals) in ordination space (Fig. 37) similarly separates samples out along the first DCA axis (total length 1.0 SD), which is also interpreted as a gradient from xeric to increasingly mesic conditions spanning the past 5400 years. Upon visual inspection of the samples plotted in ordination space, one can detect three main groupings. The first grouping includes samples from 5410 to 4200 yr BP, the second from 4000 to 2800 yr BP, and the third from 2600 to –40 yr BP (corresponding to AD 1990). These sample groupings identify times of relative paleoecological stability of pollen assemblage, separated by two times of accelerated compositional change. To better identify these times of accelerated vegetational change on uplands near Beaverhouse Lake, the distance between sample scores along DCA axis 1 was plotted with varying temporal resolution as a measure of beta diversity (Beta SD units) through comparable increments of radiocarbon time (Fig. 38A,B,C,D). At 100 year

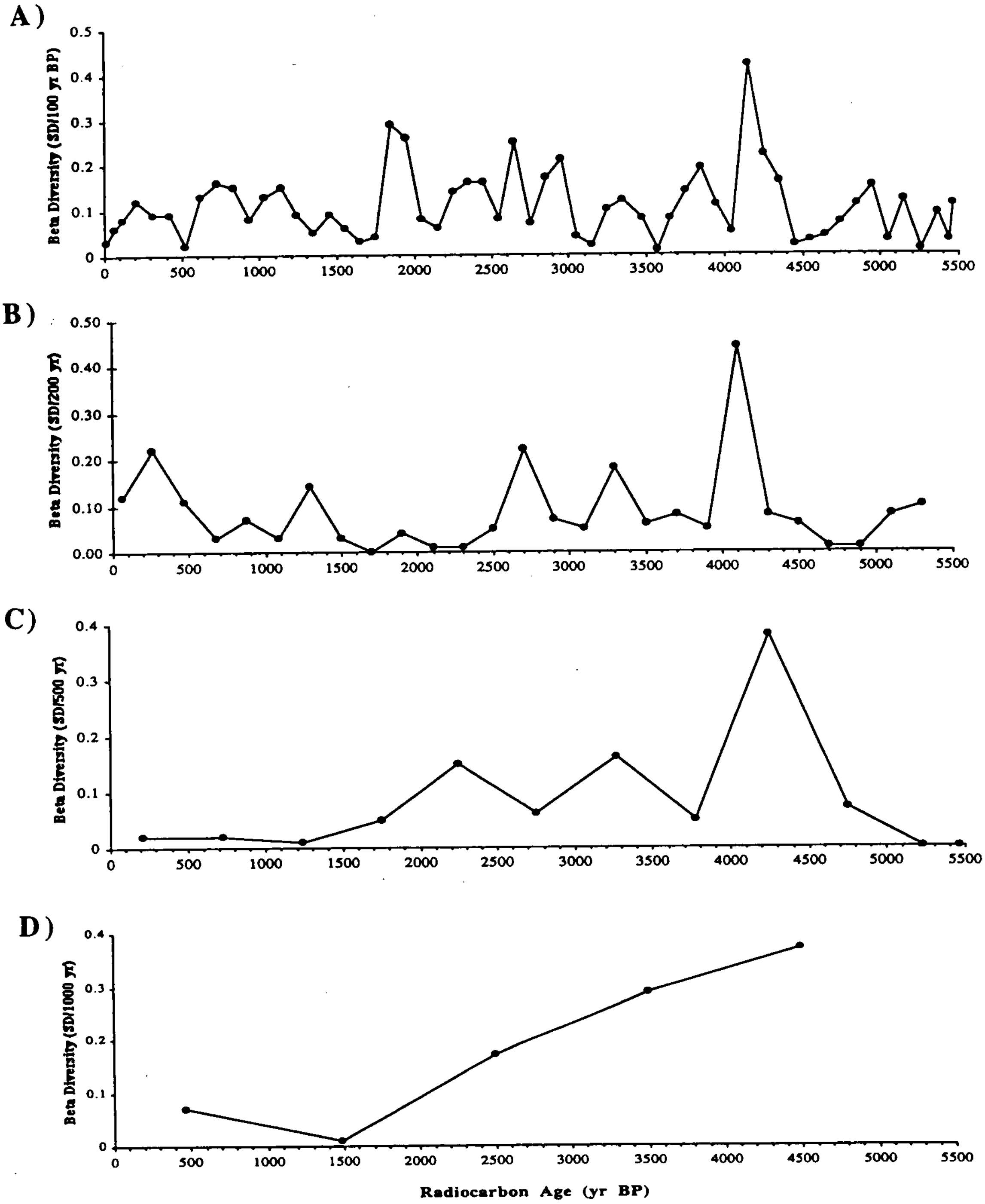


Figure 38. Graphs of beta diversity through time for Beaverhouse Lake at resolutions of a)100 yr/SD, b) 200 yr/SD, c) 500 yr/SD, and d) 1000 yr/SD.

intervals, beta diversity shows 15 separate peaks. When the resolution of DCA analysis was reduced to 200 year intervals (Fig. 38B) the number of peaks drops to 8, with 2 main peaks. The peaks that do not appear at the coarser temporal resolution are interpreted as non-directional changes or oscillations in the vegetational composition. The plot of beta diversity for samples at 200 year intervals shows peaks representative of directional changes in vegetation over the past 5400 years. With rates of change exceeding 0.20 Beta SD/200yr, these two major peaks occur at 4100 and 2700 yr BP.

Biostratigraphy

Two main peaks in beta diversity at 4100 and 2700 from the 200 yr/SD analysis were used to delineate three pollen assemblage zones within the sediment stratigraphy of Beaverhouse Lake (Fig. 35). The following description is based on the taxa shown in Figure 35. Additional taxa present within each zone can be found in Appendix H.

BHL-1 Pollen Assemblage Zone, 5460 to 4100 yr BP. *Pinus strobus* dominates the arboreal pollen during this interval along with *Pinus banksiana/resinosa*-type. Combined, total pines account for 60 to over 80% of the total terrestrial pollen (TTP). *Betula* is low, with maximum pollen percentages of 6%. Similarly, *Quercus*, *Thuja occidentalis/Juniperus*-type, and *Tsuga canadensis* have maximum percentages around 5%. Minor tree taxa include *Larix laricina*, *Picea*, *Salix*, *Ulmus*, *Fraxinus*, *Acer*, and *Fagus grandifolia*. *Fagus grandifolia* pollen occurs discontinuously in this assemblage zone with percentages generally below 0.5% TTP. Fagus influx values range from 4 to 22 grains cm^{-2} yr^{-1}. *Alnus rugosa* -type is the main shrub taxon present with a maximum of 3% TTP. Among the terrestrial herb pollen present during this interval, Cyperaceae is the most abundant, reaching a peak of 21% TTP at 4500 yr BP. Pollen from the following taxa occur sporadically: *Ambrosia* -type, *Artemisia*, Poaceae, Tubuliflorae, and Umbelliferae. Spores from ferns and fern allies are at their maximum levels during this interval (5%), consisting mainly of *Pteridium aquilinum*, *Lycopodium*, and *Polypodium*. Aquatic taxa are sparse during this interval, consisting mainly of *Typha latifolia* and *Sphagnum*, with isolated occurrences of *Brasenia schreberi*, *Nuphar*, *Nymphea*, and *Potamogeton*. Total pollen influx in this zone began around 10 000 grains cm^{-2} yr^{-1} and then dropped to between 2000 to 3000 grains cm^{-2} yr^{-1} by 5100 yr BP.

BHL-2 Pollen Assemblage Zone, 4100 to 2700 yr BP. This second interval is marked by an initial drop in percentages of *Pinus banksiana/resinosa*-type to less than 15% TTP and reduction of total *Pinus* to the range of 60 to 45% TTP. *Quercus* peaks at about 7% TTP *circa* 3500 yr BP. *Thuja occidentalis/Juniperus*-type, *Tsuga canadensis*, and *Ulmus* generally remain at previous values during this interval. *Betula* pollen, however, increases dramatically from 4 % just prior to this zone at 4200 yr BP to 23% by 3000 yr BP. Other arboreal taxa with modest increases include, *Acer saccharum*, *Picea*, and *Abies*. The curve for *Fagus grandifolia* pollen becomes nearly continuous, with positive values occurring consecutively beginning at 4100 yr BP, although percentages remain low (0.4 - <2% TTP). The running average of percent *Fagus grandifolia* passes the threshold of 0.5% at 4000 yr BP, indicating local establishment and maintenance of populations in nearby uplands. Influx values for *Fagus grandifolia* range from 30 grains cm^{-2} yr^{-1} at 4000 to 122 grains cm^{-2} yr^{-1} at 3100 yr BP. Total pollen from shrub taxa increase to 5%, with persistence of *Alnus rugosa*-type in addition to *Myrica*-type, *Corylus*, and Ericaceae pollen during this interval. Pollen from herbaceous taxa drops to between 5 and 10% with the decline of Cyperaceae. *Ambrosia*-type and *Artemisia* pollen remain at low (<1.0%) but nearly continuous values throughout this zone. Fern and fern allies occur sporadically with *Pteridium aquilinum* pollen reaching a maximum of 2% at 3700 yr BP, immediately prior to a brief increase in *Pinus banksiana/resinosa*-type beginning at 3600 yr BP.

Total aquatic pollen increases dramatically at the beginning of this interval, primarily due to a rise in *Sphagnum* to a maximum of 7% at 3700 yr BP. From this peak, *Sphagnum* declines to 0.8% by 2700 yr BP. Open water macrophytes of *Brasenia schreberi*, *Nuphar*, and *Nymphea* increase as *Sphagnum* declines, beginning around 3400 yr BP, indicating a gradual rise in lake-surface water levels. Peaks in *Brasenia* and *Nymphea* occur at 3300 yr BP and 2700 yr BP respectively, and correlate locally with peaks in beta diversity of biotic transition and regionally, with times of highstands of Lake Michigan (Fig. 12). Total pollen influx values within this zone rise dramatically from a low of 2550 grains cm^{-2} yr^{-1} at 4100 to peaks of 18 586 grains cm^{-2} yr^{-1} at 3300 yr BP and 29 478 grains cm^{-2} yr^{-1} at 2900 yr BP. After these peaks, pollen influx values return to between 3000 and 8000 grains cm^{-2} yr^{-1}.

BHL-3 Pollen Assemblage Zone, 2700 to present.

During the first 300 radiocarbon years of this pollen assemblage zone, from 2700 yr BP to 2400 yr BP, several tree taxa undergo sizeable changes in their pollen percentages. Most notably, total *Pinus* drops from 50% to 35% TTP. This drop in Pine reflects primarily the collapse in *Pinus strobus* populations (from 35 down to 20% TTP), *Pinus banksiana/resinosa*-type values remain consistently about 10% TTP. During this same interval, *Betula* pollen peaks at 30% at 2600 yr BP then fluctuates about a mean of 22% TTP by 2300 yr BP. Several other taxa undergo sustained increases between 2700 and 2400 yr BP, including *Larix laricina* (0.4 to 2%), *Picea* (Total) (1 to 2%), *Tsuga canadensis* (2 to 8%) and *Fagus grandiolia* (0.5 to 3%). All of the changes are reflected in the pollen influx for these taxa as well. *Fagus grandifolia* pollen influx rises from 23 to 128 grains cm^{-2} yr^{-1} between 2700 and 2400 yr BP. No clear trend is evident for *Quercus* or *Thuja occidentalis/Juniperus*-type, which both fluctuate between 3 and 7% during this zone. Among shrub taxa, *Alnus rugosa* and *Myrica*-type both have peaks at 2400 yr BP, after which they generally decline slightly to the present. Cyperaceae pollen gradually increases through this zone from 4% at 2700 yr BP to 8% at 260 yr BP. Total aquatic taxa decline markedly from 2200 to 1800 yr BP and then rise again between 1700 and 1400 yr BP. This decline and rise is most evident in *Brasenia schreberi* pollen although it occurs in *Nymphaea* as well. Total influx from 2700 to 260 yr BP ranges between 1080 grains cm^{-2} yr^{-1} at 1190 yr BP and 7857 grains cm^{-2} yr^{-1} at 2100 yr BP. Within the last 30 years, *Thuja occidentalis/Juniperus*-type pollen reaches its maximum abundance over the past 5460 years with a peak of 10% at 160 yr BP. *Tsuga canadensis* declines from 9 to 5 % and *Fagus grandifolia* pollen fluctuates between 2 and 3% with influx values ranging between 22 and 145 grains cm^{-2} yr^{-1}. *Ambrosia*-type pollen peaks at 5% at 70 yr BP (19cm depth) marking the time of logging in eastern Upper Michigan during the 1880's.

Greylock Bog

Greylock Bog is a sparse conifer swamp characterized by the following species: trees including *Thuja occidentalis* (white cedar), *Picea mariana* (black spruce), and *Larix laricina* (tamarack); shrubs including *Alnus* (alder), *Ledum groenlandicum* (laborator-tea), and *Kalmia polifolia* (swamp laurel). Herbaceous plants include *Sarracenia purpurea* (purple pitcher plant), *Eriophorum* (cotton grass), and *Sphagnum* (peat moss) hummocks which rise up to 50 cm above the ground water table. The lithostratigraphy of the sediment core is as follows:

Depth (cm below peat surface)	Lithology
0-14	Decomposed sphagnum surface of small swale, 10YR 2/2,

14-100	Horizontally layered, clayey finely-textured fibrous peat, 10YR 2/2, with sparse woody peat at 46-47 cm depth.
100-123	Clayey, fine-textured fibrous peat, 10YR 2/2, with horizontal layering from 117-122 cm depth, 10YR 2/1, and woody peat layer at 116-121cm depth.
123-175	Slightly fine-sandy, clayey fibrous peat, 10YR 2/2, with fine sand layer, 10YR 5/3, at 129 and 152 cm depth, and woody peat layer at 155-157 cm depth.
175-217	Fine quartz sand, 10YR 5/3, with organic bands, 10YR 2/2, at depths of 175-176, 177-178, 179-181, 192-196, 198-199, 202-206, 207-210, and 212-216 cm.

Biostratigraphy

The pollen diagram from Greylock Bog is shown in Figure 35. The sediment record covers the last 3400 years, during which time most of the beach-ridge complex south of Lake Millecoquins has formed (Figs. 8 and 12). The sediment core was sampled at 500 year intervals for pollen analysis. Total *Pinus* dominates this record, typically ranging between 50 and 60% TTP. At the stratigraphic level dated approximately 3200 yr BP, values for *Pinus strobus* are 25% TTP and gradually declines to 13% in modern sediments. This decline over the last 500 years includes the historic time since logging around the turn of the twentieth century. Over the total time of sediment accumulation at this site *Pinus banksiana/resinosa*-type has increased from 10% to 35%, reaching 20% by 500 yr BP. After 2500 yr BP, a significant shift in pollen pecentages occurs as *Tsuga canadensis*, *Picea*, and *Sphagnum* increase while *Quercus* and *Thuja occidentalis/Juniperus*-type decline. *Betula* values peak at about 15% TTP between 2500 and 2000 yr BP, then gradually decline to 6% TTP in the historic sample. The accelerated rise in percentages for both *Picea* and *Sphagnum* at 2200 yr BP marks the inititation and continued growth of the modern day peat bog with scattered, local *Picea* (*P. mariana*, black spruce). In contrast, *Thuja occidentalis/Juniperus*-type pollen declines after an intital peak in abundance from 3200 to 2200 grains cm^{-2} yr^{-1}. *Fagus grandifolia* pollen fluctuates throughout the core between 0 and 2% (indicating that extra-local pollen (>2 km) is supplying the bulk of its signal). Today, the nearest population of *Fagus grandifolia* is 4 km to the east around Elbow Lake (Fig. 8). Influx values for *Fagus grandifolia* are typically below 20 grains cm^{-2} yr^{-1}, although values from 2600 to 1800 yr BP reach 50 to 100 grains cm^{-2} yr^{-1}. Total shrub pollen occurs at very low levels (<2%) consisting of *Alnus rugosa*-type, *Myrica*-type, *Alnus crispa*, Ericaceae, and *Corylus*. Among herbaceous taxa, Poaceae pollen occurs at 2% from 3220 to 2820 yr BP after which it declines and becomes discontinuously present in temporally consecutive levels. Cyperaeae fluctuates around 4% from 3220 to 1500 yr BP, after which it increases to a maximum of 14% at 550 yr BP. *Ambrosia*-type is discontinuous until 550 yr BP and reaches a maximum of 4% in the modern sample. Fern and fern allies are scarce (<0.5%) in Greylock Bog except for a peak of 6% in *Osmunda regalis* spores at 1510 yr BP (Appendix I). *Nuphar* (and Nymphaeceae epidermal cells) peak near the base of the core (2810 yr BP). *Sphagnum* becomes continuously represented at 2200 yr BP and increases steadily to a maximum of 7% at the modern sediment surface. Total pollen influx for Greylock Bog varies from a low of 412 grains cm^{-2} yr^{-1} at its base (in organic rich sand dated at 3220 yr BP) to a maximum of 14 861 grains cm^{-2} yr^{-1} at 2000 yr BP. From 1500 yr BP to the present, total influx values for palynomorphs fluctuate between 2500 and 6500 grains cm^{-2} yr^{-1}.

US 2 Bog

This site of wet swamp includes abundant herbs of *Carex* (sedges), *Iris versicolor* (wild iris), *Typha latifolia* (cattail), shrubs of *Andromeda glaucophylla* (bog rosemary), and scattered trees of *Larix laricina* (tamarack). This site is bordered 20 m to the west and 40 m to the east by open forest with *Thuja occidentalis*, *Picea mariana* and low (< 1m) shrub layer of *Vaccinium* spp. (high bush blueberry). Below is a stratigraphic description of the sediment core from this site.

Depth (cm below peat surface)	Lithology
0-15	Fibrous rootmass of grasses, 10YR 2/2,
15-50	Clayey reed root mass and fibrous peat, 10YR 2/2,
50-100	Finely-textured humified fibrous peat, 10YR 2/2,
100-123	Slightly fine sandy humified fibrous peat, 10YR 2/2,
123-126	Humified fibrous-peaty fine quartz sand, 10YR 2/2.

Biostratigraphy

Over the past 1370 years, Total *Pinus* and *Pinus strobus* have decreased. *Pinus strobus* declines from 19% at 1370 yr BP to 7% today. During the same time interval *Pinus banksiana/resinosa*-type increases from 8% at 1370 to 14% at 510 yr BP. From 1370 yr BP to today both *Betula* and *Fagus grandifolia* decline dramatically from 18 to 5%, and from from 5 to 0.0%, respectively. Influx values for *Fagus grandifolia* begin at 571 grains cm^{-2} yr^{-1} and drop to 0.0 grains cm^{-2} yr^{-1} in contemporary sediments. This initially high abundance of *Fagus grandifolia* at US 2 Bog, when *Fagus grandifolia* pollen at Greylock Bog, 1.8 km to the north, is <1.0%, indicates that the population source of the *Fagus grandifolia* pollen was small and close by (< 1km) to the US 2 coring site. Today, the nearest *Fagus grandifolia* population is 4.5 km to the east of US 2 Bog around Elbow Lake (Fig. 8). A succession of taxa peak in pollen abundance concurrent with these declines including Total *Picea* (9%) and *Tsuga canadensis* (8%) at 1010 yr BP, *Larix laricina* (5%) at 510 yr BP, and *Thuja occidentalis/ Juniperus*-type (20%) today. Shrub taxa remain consistent throughout the span of this paleoecological record, while among herbaceous taxa, Cyperaceae increases dramatically from 2% at 1370 yr BP to 20% today. *Ambrosia*-type pollen reaches 5% in modern sediments and *Sphagnum* pollen never exceeds 0.5% throughout the record. Total influx of palynomorphs begins around 12 000 grains cm^{-2} yr^{-1} at 1370 yr BP and then declines to <2000 grains cm^{-2} yr^{-1} in modern sediments.

Carnegie Trail Pond

At this shallow-pool site, the aquatic vegetation consists of *Nuphar variegatum*, *Brasenia shreberi*, and *Sphagnum*. Terrestrial plant species include populations of Poaceae, *Vaccinium*, *Andromeda glaucophylla*, *Alnus rugosa*, *Acer rubrum*, *Thuja occidentalis*, *Picea mariana* and *Larix laricina*. This swale is between beach ridge #3 and #4, and today occurs 0.2 km from the Lake Michigan shoreline.

Stratigraphic description of the sediment core follows.

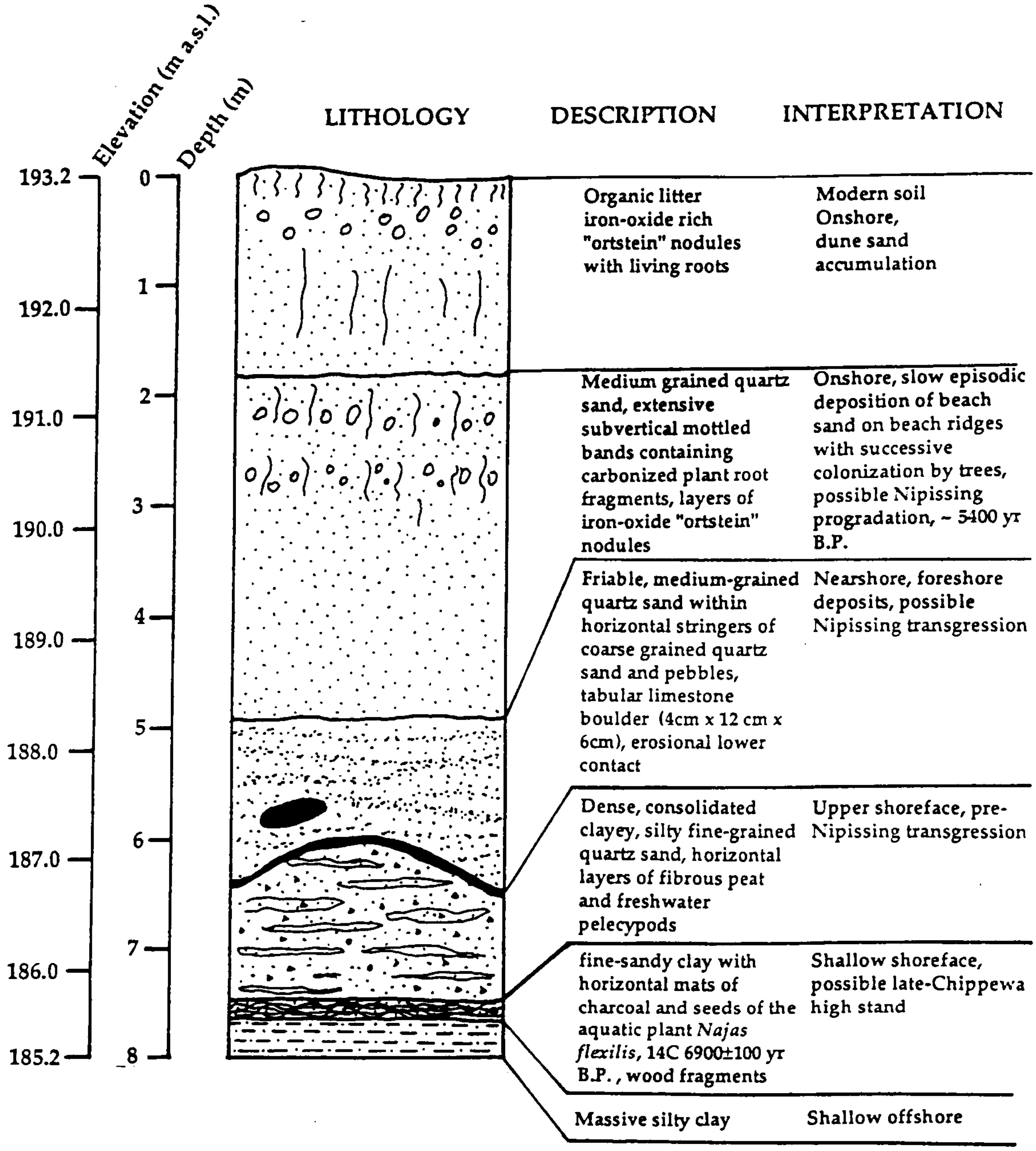
Depth (cm below water/sediment interface)	Lithology
0-8	Fine-sandy finely textured peat, 10YR 2/2.
8-50	Fine-textured, fibrous-peaty fine sandy clay, 10YR 2/2,with horizontally laminated quartz sand layers, at depths of 18-19, 23-24, 26-33, 34-35, 40-45, 46-48 and 49-50 cm depth, 10YR 5/4.

Biostratigraphy

The levels analyzed from Carnegie Trail Pond (200 yr BP and today) reflect the pre- and post- settlement vegetation changes which have occurred. Across this historic interval there are declines in total *Pinus* (33 to 28%), *Tsuga canadensis* (5 to 0.8%), *Larix laricina* (4 to 2) and Cyperaceae (24 to 10%). Several other taxa have increased, including balsam fir (*Abies balsamea*), *Thuja occidentalis/Juniperus*-type, *Alnus rugosa*, and *Ambrosia*-type. *Fagus grandifolia* pollen occurs at 0.8% at both levels with influx values of 100 grains cm^{-2} yr^{-1} each. Total palynomorph influx at this site is 12 740 grains cm^{-2} y^{-1}.

C. Dating of Ortstein Development

Within the study area ortstein layers occur in well-drained, fine to medium sands (Soil Type 2) and poorly drained acidic sands and muck peats (Soil Type 9) (Fig. 31). For these latter soils ortstein is a relict feature which formed prior to peat growth and when the ground water table was at least seasonally below the B horizon. Within the study area, four paleoecological sites provide evidence for the timing for ortstein development: Beaverhouse Lake, Millecoquins River Cutbank, Cranberry Lake Bog, and O'Neil Creek Bog (Petty *et al.* 1996). First, the exposed sandy depression of what is today Beaverhouse Lake has a core lithology with a leached zone of a forest spodisol (paleosol), possibly with a limited ortstein horizon below 254 cm depth. The basal age of circa 5460 yr BP of organic lacustrine sediments provides a potentially bounding age of earlier ortstein formation in upland soils in the mid-Holocene prior to *circa* 5500 yr BP (Petty *et al.* 1996). Second, at the cutbank exposure along the Millecoquins River (Figs. 8 and 39), organic rich deposits occur stratigraphically below beach and dune deposits both of which contain numerous ortstein nodules. Radiocarbon dating of *Najas flexilis* seeds from the organic layer yielded an age of 6900 yr BP (Petty *et al.* 1996). The several ortstein layers in the sand deposits situated above this dated material therefore have formed within the last



DESCRIPTION	INTERPRETATION
Organic litter iron-oxide rich "ortstein" nodules with living roots	Modern soil Onshore, dune sand accumulation
Medium grained quartz sand, extensive subvertical mottled bands containing carbonized plant root fragments, layers of iron-oxide "ortstein" nodules	Onshore, slow episodic deposition of beach sand on beach ridges with successive colonization by trees, possible Nipissing progradation, ~ 5400 yr B.P.
Friable, medium-grained quartz sand within horizontal stringers of coarse grained quartz sand and pebbles, tabular limestone boulder (4cm x 12 cm x 6cm), erosional lower contact	Nearshore, foreshore deposits, possible Nipissing transgression
Dense, consolidated clayey, silty fine-grained quartz sand, horizontal layers of fibrous peat and freshwater pelecypods	Upper shoreface, pre-Nipissing transgression
fine-sandy clay with horizontal mats of charcoal and seeds of the aquatic plant *Najas flexilis*, 14C 6900±100 yr B.P., wood fragments	Shallow shoreface, possible late-Chippewa high stand
Massive silty clay	Shallow offshore

Figure. 40. Stratigraphic column and environmental interpretation of Millecoquins River Cutbank (from Petty *et al.* 1996).

6900 years. Further refinement of this time interval is possible based on what is known about Lake Michigan high stands, dune formation within the study area, and the time required for ortstein formation. The high stand of Lake Michigan at 5400 yr BP (Fig. 12) rose above this site and likely deposited the sand in which the lower set of ortstien nodules occurs. Therefore, the ortstein within these sands formed sometime after 5400 yr BP. The upper set of ortstein nodules formed within dune deposits of quartz sand. Petty *et al.* (1996) present evidence that the dune sand at this site was deposited around 3900 yr BP, thus placing the time of development for these nodules sometime after 3900 yr BP.

Delcourt et al. (1996) note that Spot-Finch soils (with ortstein) form on mid-Holocene coastal terraces and beach ridges at least 3200 yr BP in age. On beach-ridge surfaces younger than 3200 yr BP no soils with ortstein horizons are mapped by Whitney (1995). Cranberry Lake Bog formed over ortstein soils, with paludification after 3500 yr BP (Petty *et al.* 1996).

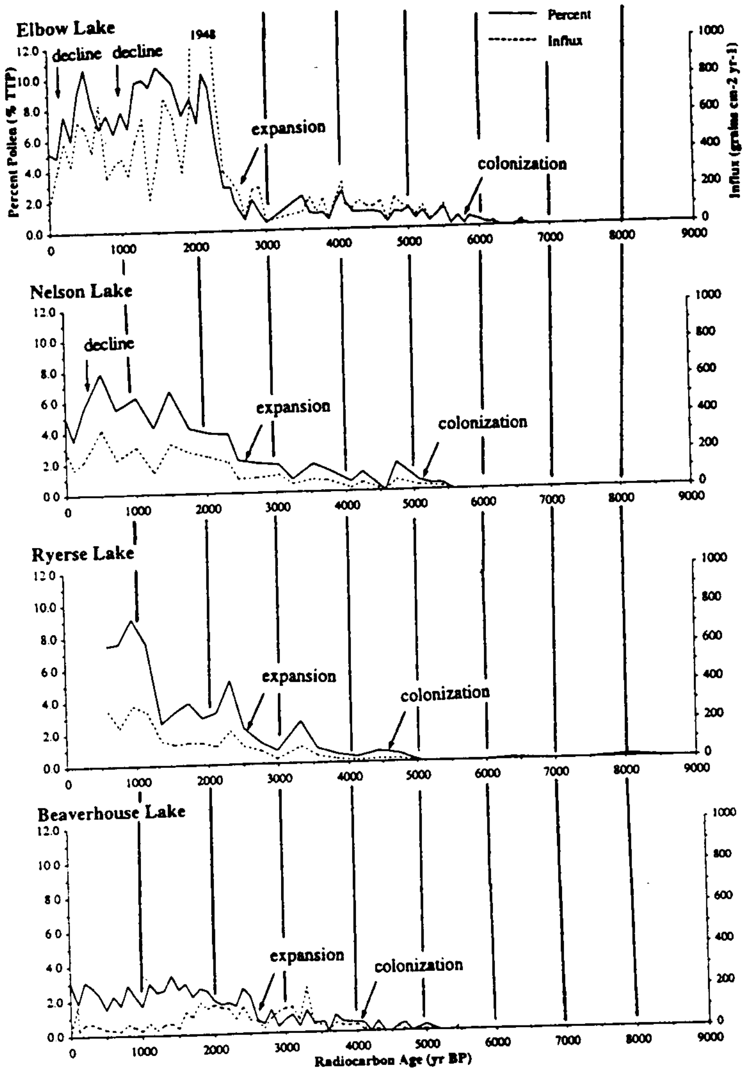
How long after 5400 and 3900 yr BP these ortstein layers formed is constrained by the minimum time required for ortstein to form *de nova* in sandy soils. I interpret three separate lines of information as evidence that this minimum time requirement is less than 1400 years. First, based on the chronofunctions of Barrett and Schaetzl (1992) the time necessary for the formation of ortstein within a soil profile is less than 3000 years. Second, at O'Neil Creek Bog (Fig. 8) radiocarbon dating of basal peat deposits along with the calibrated age of site formation provides an estimate of the time required for ortstein development. At this site a radiocarbon date of 2760 yr BP was obtained from organic rich sand overlying sand with ortstein (Petty *et al.* 1996, Appendix C). Based on the long-term beach-ridge formation rate of 72 years per ridge of Petty *et al.* (1996) and Delcourt *et al.* 1996), and the occurrence of 11 ridges (identified from infrared aerial photographs) between O'Neil Creek Bog and Greylock Bog (3410 yr BP), I estimate that this site formed around 4200 yr BP (72 yr per ridge X 11 ridges + 3410 yr BP = 4202 yr BP).

Thus, a time window of less than 1440 years was needed to form orstein prior to the accumulation of organic matter at 2760 yr BP. Thus, locally, ortstein can form in less than 1440 years. Finally, no soil on beach ridges within the study area that is known to have formed within the last 3200 years contains ortstein (based on Petty *et al.* 1996 and Whitney 1995). Using a conservative estimate of a maximum of no more than 1400 years required for ortstein formation, the ortstein nodules at the Millecoquins River Cutbank (which occur in sands which were deposited at 5400 yr BP and 3900 yr BP) formed during at least two periods, occurring as late as 4000 yr BP and 2500 yr BP (5400 – 1400 yr BP and 3900 –1400 yr BP, respectively). These times correspond broadly with known or hypothesized high stands of Lake Michigan (Fig. 12), which would have resulted in significant fluctuations in ground water tables, one of the catalysts of ortstein formation (De Coninck 1980).

D. Establishment of American Beech

Establishment within study area

Within the study area, *Fagus grandifolia* pollen records different arrival times for beech populations at each of the four lake sites with pollen records spanning more than the past 5000 radiocarbon years (Fig. 40). The running average of *Fagus grandifolia* pollen at Elbow Lake (Petty 1994) rose above the threshold of 0.5% TTP at 5790 yr BP. Elbow Lake was approximately 2.4 km from the shore of Lake Michigan at that time (based on the geomorphological data presented in Petty *et al.* 1996). At 5790 yr BP, *Fagus grandifolia* pollen was absent from both Nelson Lake (H. Delcourt, unpublished data) (13.7 km from Lake Michigan at this time) and Ryerse Lake (Futyma 1982) (7.3 km from Lake Michigan at this time), indicating that the *Fagus* pollen in Elbow Lake (2.4 km from Lake Michigan at this time) was not transported from a distant population but rather from a small outlying population near Elbow Lake (i.e. a population beyond the contiguous range limit of *Fagus*



Soil Type	Kilometers from Lake Michigan at Time of Arrival
Loam	2.4 km at 5790 yr BP
Loam	13.7 km at 5070 yr BP
Sand with Ortstein	7.3 km at 4430 yr BP
Sand without Ortstein	2.7 km at 4000 yr BP

Figure 40. American beech pollen curves for Elbow Lake (Petty 1994), Nelson Lake (H. Delcourt, unpublished), Ryerse Lake (Futyma 1982), and Beaverhouse Lake (this study) within the study area. Inclined arrows correspond to times of beech arrival (first arrow from the right) and beech expansion (second arrow from the right) within the study area. Vertical arrows indicate prehistoric times of population decline of American beech. Dominant soil type surrounding each site is listed to the right of each curve as is the distance each site was from Lake Michigan at the time of American beech arrival (based on the shoreline reconstructions by Petty *et al.* 1996).

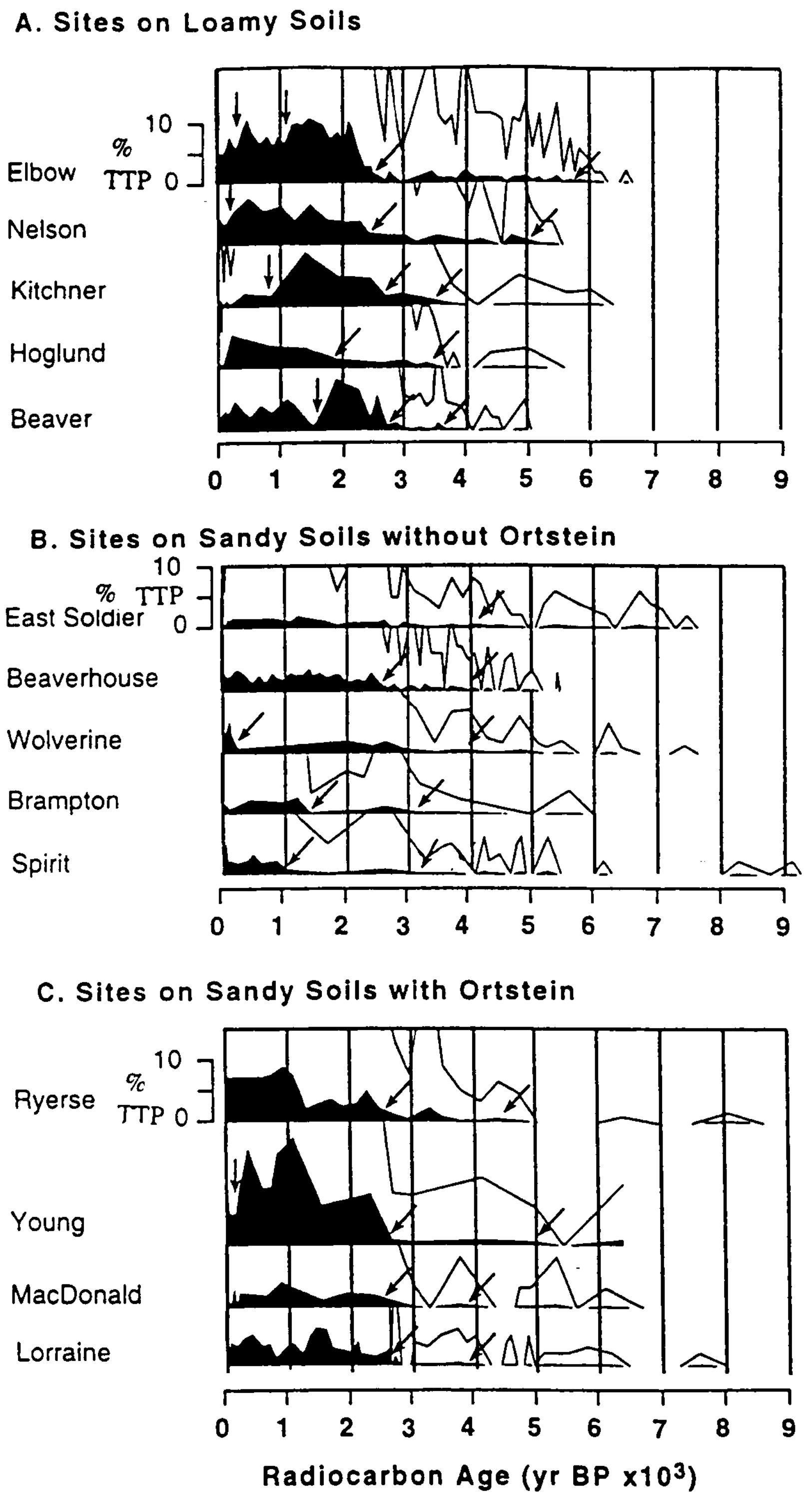
grandifolia at this time (Gilliam *et al.* 1967, Kapp 1977a, Rasmussen 1982, Liu 1990)). Nelson Lake is also surrounded by loamy soil (Type 4) but was 13.7 km inland from Lake Michigan at that time. The first appearance of *Fagus grandifolia* pollen at Nelson Lake is almost 400 years later at 5400 yr BP. Beech pollen at Nelson Lake did not pass the 0.5% TTP threshold until 5070 yr BP (H. Delcourt, unpublished data). I interpret these data to indicate a delay of over 700 years between the local arrival of *Fagus grandifolia* at Elbow Lake and its arrival at Nelson Lake (13.7 km inland)with the main difference being their increasing distance to the Lake Michigan shore. At Ryerse Lake (Futyma 1982) (21 km east of Elbow Lake and surrounded by sandy soils with ortstein) beech pollen did not become continuous until 4740 yr BP, with a running average percent of 0.5% TTP reached at 4430 yr BP when it was 7.3 km from the Lake Michigan shoreline (1360 years after Elbow Lake, and 640 years after Nelson Lake).

At Beaverhouse Lake, 4.8 km northwest of Elbow Lake and surrounded predominantly by sandy soils without ortstein (Soil Type 1), *Fagus grandifolia* pollen occurs sporadically until 4100 yr BP, after which it is continuously present. The running average of *Fagus grandifolia* pollen reaches 0.5% TTP at 4000 yr BP when Beaverhouse Lake was 2.7 km from the shore of Lake Michigan, during the Nipissing Highstand. This arrival date is 430 years after it reached this threshold criterion at Ryerse Lake, and 1790 years after Elbow Lake. In summary, the sequence of *Fagus grandifolia* arrival to the study area was first at Elbow Lake (5790 yr BP) (Petty 1994), then Nelson Lake (5070 yr BP) (H. Delcourt, unpublished data), Ryerse Lake (4430 yr BP) (Futyma 1982), and Beaverhouse Lake (4000 yr BP) (this study), with the first establishment at the site closest to the Lake Michigan shore (2.4 km), surrounded by fine-textured, loamy soil.

Regional establishment

The record of *Fagus grandifolia* arrival, expansion, and decline at additional sites in Upper Michigan and eastern Wisconsin is presented in Figure 41. American beech arrival times for sites throughout the Great Lakes region are presented in Figure 42. The arrival of *Fagus grandifolia* at Elbow Lake by 5790 yr BP is the earliest known establishment in Upper Michigan, and occurs approximately 200 to 400 years after the arrival of *Fagus grandifolia* in southeastern Wisconsin at Gass Lake (S. Webb 1986) (6050 yr BP) and Radtke Lake (6200 yr BP) (S. Webb 1986) (Figs. 7 and 42). Subsequent arrivals at other sites with loamy soils occurred at Nelson Lake (5070 yr BP) (H. Delcourt, unpublished data), Kitchner Lake (3480 yr BP) (Woods and Davis 1989), Hoglund (3500 yr BP) (Woods and Davis 1989) and Beaver Lake (3670 yr BP) (Woods and Davis 1989). At sites surrounded by sandy soils without ortstein, *Fagus grandifolia* became established at 4370 yr BP (East Soldier Lake) (Futyma 1982), 4000 yr BP (Beaverhouse Lake) (this study), 3950 yr BP (Wolverine Lake) (Futyma 1982), 3330 yr BP (Spirit Lake) (Woods and Davis 1989), and 3220 yr BP (Brampton Lake) (Woods and Davis 1989). Arrival times for sites which today have ortstein layers are 5000 yr BP (Young Lake) (Woods and Davis 1989), 4430 yr BP (Ryerse Lake) (Futyma 1989), 3890 yr BP (Lorraine Lake) (Woods and Davis 1989) and 3800 yr BP (MacDonald Lake) (Woods and Davis 1989). It should be noted, though, that several sites such as Ryerse Lake (Futyma 1982), East Soldier Lake (Futyma 1982), Wolverine Lake (Futyma 1982), Spirit Lake (Woods and Davis 1989), and Lorraine Lake (Woods and Davis 1989) have sporadic occurrence of beech pollen prior to 7000 yr BP (Fig. 41). All of these sites are surrounded by coarse-grained, xeric soils and may indicate much earlier undetected arrival of beech in Upper Michigan on loamy soils near these sites. These pollen levels (generally <0.5% TTP), may also be interpreted as: 1) consecutive unsuccessful colonizations of *Fagus grandifolia*, or 2) long-distance transport of pollen coming from extra-regional *Fagus grandifolia*

Figure 41. American beech pollen percent curves (%TTP) for regional study sites grouped according to dominant (>50%) soil type surrounding each site within a 2 km radius, with sites on A) loamy soils, B) sandy soils without ortstein, and C) sandy soils with ortstein. All sites are located in Upper Michigan except Beaver which is located in northeastern Wisconsin (Fig. 7, Appendix A). Within soil type groupings sites are arranged from east to west. Inclined arrows correspond to times of beech arrival (first arrow from the right) and beech expansion (second arrow from the right). Vertical arrows indicate times of decline of American beech. The scale of each curve is shown for the first curve within each grouping with the open silhouettes corresponding to 10x pollen percentages. See Figures 7 and 8 for site locations and Appendix A for exact dates of arrival, expansion, and decline of beech for each site.


A. Sites on Loamy Soils
10
%
TTP 0
Elbow
Nelson
Kitchner
Hoglund
Beaver
0 1 2 3 4 5 6 7 8 9
B. Sites on Sandy Soils without Ortstein
10
% TTP
0
East Soldier
Beaverhouse
Wolverine
Brampton
Spirit
0 1 2 3 4 5 6 7 8 9
C. Sites on Sandy Soils with Ortstein
10
%
TTP 0
Ryerse
Young
MacDonald
Lorraine
0 1 2 3 4 5 6 7 8 9
Radiocarbon Age (yr BP x10³)

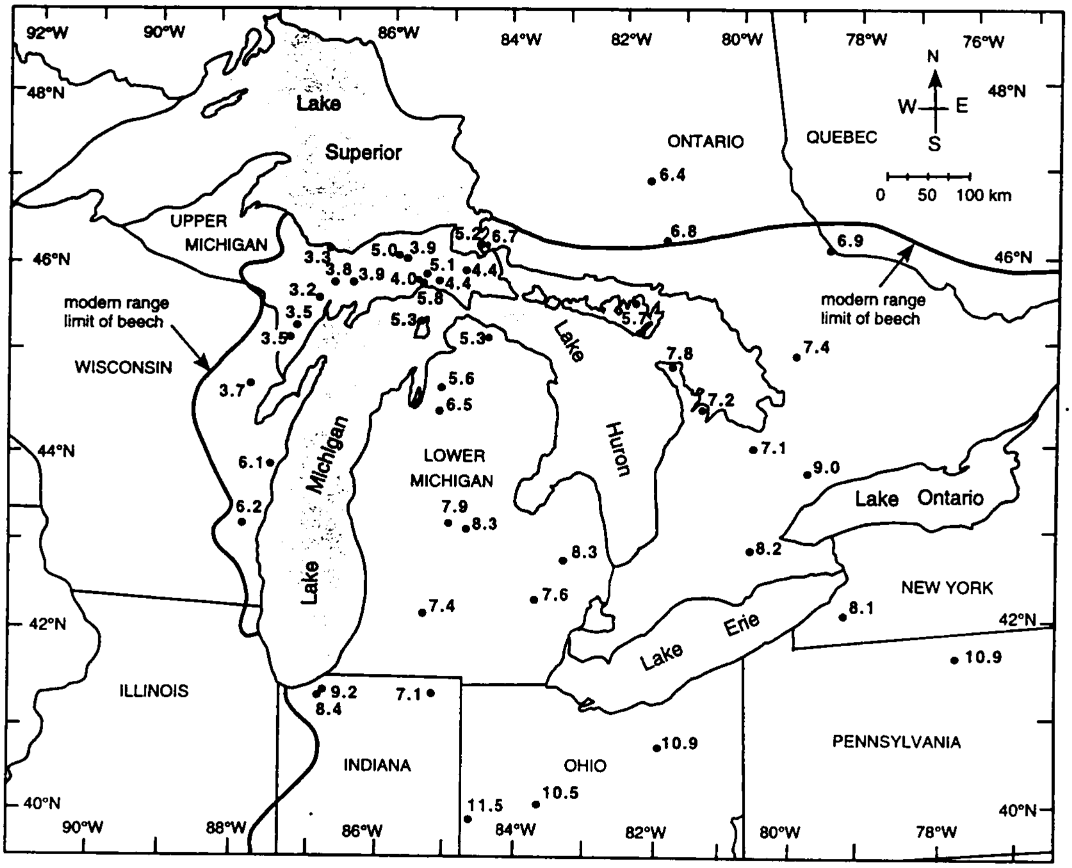


Figure 42. Arrival dates (in thousands of yr BP) for American beech in the Great Lakes region.

populations. Prior to 7000 yr BP, the closest known populations of *Fagus grandifolia* were >250 km away at Demont Lake (Kapp 1977a) and Bartley Lake (Bennett 1992) (Figs. 7 and 42).

E. Expansion of American Beech

Expansion within study area

The expansion of *Fagus grandifolia* at each site within the study area occurred within a 110 yr interval of radiocarbon time from 2550 yr BP to 2440 yr BP (Fig. 40). These expansion times are statistically simultaneous, since they are within the first standard deviation associated with each radiocarbon date (approximately ± 70 years). This apparently synchronous increase in *Fagus grandifolia* populations occurs after known times of ortstein development within the study area and perhaps reflects a biotic response to environmental changes, such as a local rise in water table around Nelson Lake *circa* 2870 yr BP (Nester 1999). The magnitude of the expansion which continued for more than 1500 yr in the cases of Nelson Lake and Ryerse Lake was greatest at Elbow Lake (9.4% TTP), followed by Ryerse Lake (7.9% TTP), Nelson Lake (6.0% TTP), and finally Beaverhouse Lake (3.1% TTP) (Appendix A).

Regional expansion

The late-Holocene expansion of *Fagus grandifolia* regionally occurs at a majority of sites between 2800 to 2300 yr BP (Fig. 41, Appendix A). Dramatic rises occur at sites which are surrounded by loamy soils at 2730 yr BP (Beaver Lake) and 2660 yr BP (Kitchner Lake), and sandy soils with ortstein at 2670 yr BP (Young Lake) and 2510 yr BP (Ryerse Lake). Pollen percentages at sites surrounded by sandy soils without ortstein all increase modestly during this late-Holocene period from 2800 to 2300 yr BP. These population increases, however, are typically small (East Soldier Lake), short lived

(Brampton Lake), or at sites (Beaverhouse Lake, Wolverine Lake) which are very close (within 5 km) to other sites with much more dramatic increases (>5%) (Elbow Lake and Young Lake, respectively). Three sites have expansions which meet the criteria of >25% increase in running averages within the last 1500 years (Wolverine Lake, Brampton Lake, and Spirit Lake, Fig. 41). All three of these sites are surrounded by course-grained sandy soils without ortstein. *Fagus grandifolia* pollen at Brampton Lake rises from 0.4% to 2.9% TTP between 1430 and 1240 yr BP. At Spirit Lake, *Fagus grandifolia* pollen increases from 1.0% at 1375 yr BP to 2.6% at 965 yr BP. Finally, at Wolverine Lake *Fagus grandifolia* pollen increases from 0.9% to 3.1% between 200 and 120 yr BP.

F. Decline of American Beech

Decline within study area

Within the study area, beech pollen percentages declined, meeting the criterion: a cumulative decline in the running average of >25% of *Fagus* values. These beech declines occurred during the last 2000 years at Elbow Lake (at 1100 yr BP and 310 yr BP) (Petty 1994), and Nelson Lake (at 260 yr BP) (Nester 1999), but not at Beaverhouse Lake or Ryerse Lake. Beech percentages at Ryerse Lake for the last 500 years cannot be evaluated since this portion of the unconsolidated sediment core was not recovered (Futyma 1982). Additionally, within the study area a population of beech near US 2 Bog gradually declined over the past 1370 years from 5% to 0% TTP (Fig. 35). This site is 700 m northeast of an isolated area of calcareous, loamy soil over shallow limestone (Soil Type 4, Figs. 8 and 32) which likely supported the small outlying beech population. To test the hypotheses that may explain this beech decline (Hypotheses 3a and 3b), I examined the complete pollen records from each site (when available) to see which if any other arboreal taxa increased or decreased concurrent with the decline in *Fagus grandifolia.* At Elbow Lake (Fig. 35), *Fagus grandifolia* pollen declines twice, first between 1200 and 1100 yr BP and second around 310 yr BP. During the first decline *Fagus* declines from 10 to 7% while *Acer* (Total) increases from 0.7 to 3% (this evidence supports Hypothesis 3a). For the second decline *Fagus* declines from 9 to 6%, while *Acer* pollen declines as well, along with *Betula*. Conversely, *Thujá occidentalis/Juniperus*-type pollen increases significantly from 8 to 12%. This second decline supports Hypothesis 3b.

Regional decline

Within the regional study area, five sites showed significant declines in fossil-pollen values for American beech. Four of these were at sites surrounded by loamy soils (Soil Type 4) and one was surrounded by sandy soils with ortstein layers. None of the sites surrounded by sandy soils had sufficient decreases (>25%) in beech pollen to be classified as declines. To remove artifacts related to EuroAmerican forest clearance I choose not to include any beech declines which began during the historic, post-settlement interval. Of these five sites, complete pollen diagrams were availbale for Elbow (Petty 1994) and Nelson Lakes (H. Delcourt, unpublished data), and for Kitchner Lake (Woods and Davis 1989). The pollen percent diagram from Kitchner Lake shows the most dramatic decline in beech in Upper Michigan (Figs. 41 and 43). At this site, American beech declines from 10% at 1400 yr BP to less than 1% by 200 yr BP. The percent pollen curves for other taxa from this site for the last 1500 years also show distinct trends. Marked percentage dropoffs are noted for other mesic, late-successional populations of tree species such as *Acer saccharum*, *Tsuga canadensis*, and *Tilia*. Most notably, *Thuja occidentalis/Juniperus*-type pollen increases from 5% to 13% during the last 1500 years, whereas *Acer saccharum* declines from 8% at 1500 to 2% by 300 yr BP. Thus, at Kitchner Lake, paludification of habitat, resulting in the expansion of cedar wetlands, appears to have contributed to the displacement of the late-successional cohort of *Fagus*, *Tsuga*, and *Acer* initially on upland mesic sites, supporting Hypothesis 3b.

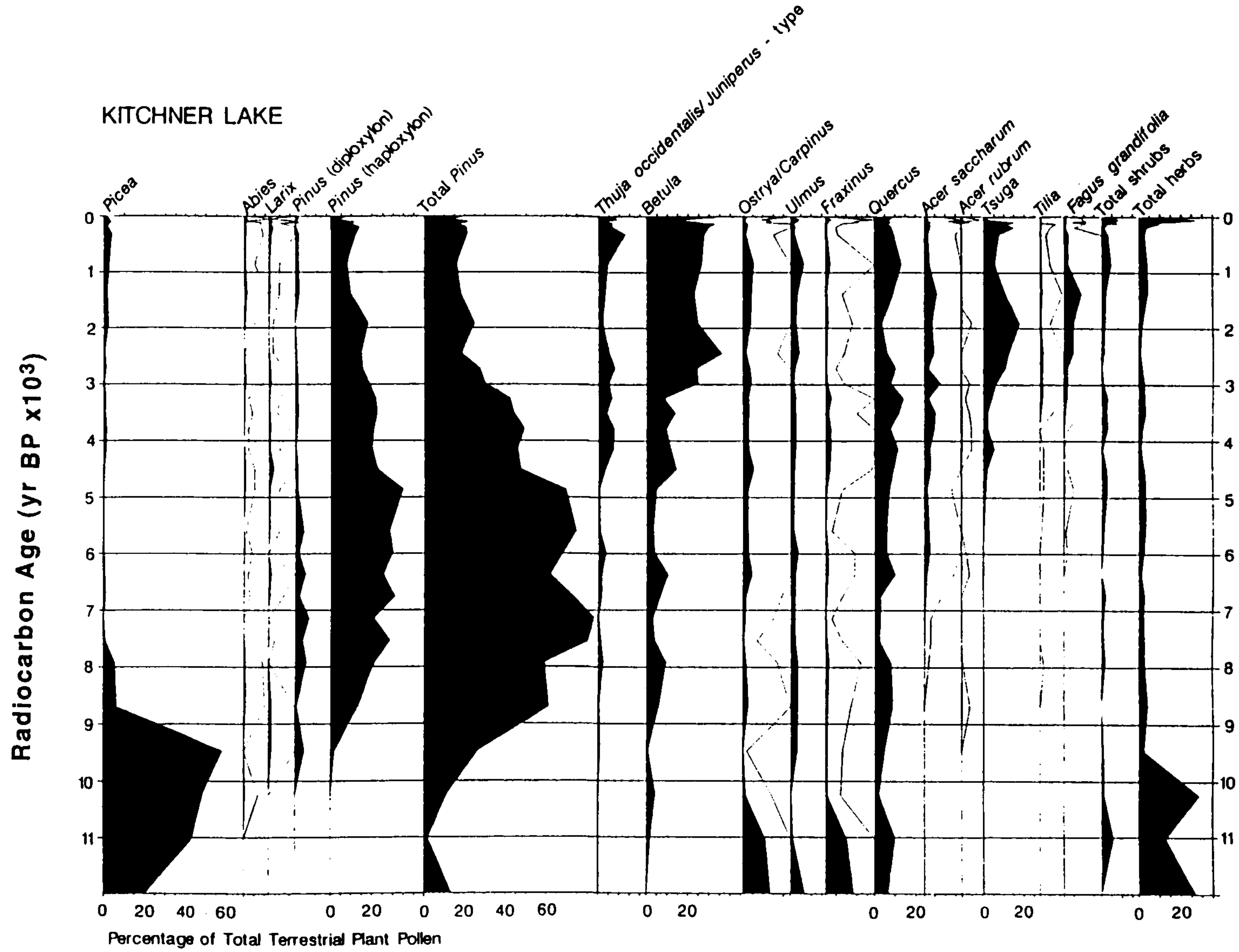


Figure. 43. Pollen diagram for Kitchner Lake, Michigan (modified from Woods and Davis 1989).

CHAPTER V

DISCUSSION

> "Beech is confined to the lake region, and appears to be especially indicative of lake influence, as it occupies different classes of soils and covers different geological formations."
>
> T.C. Chamberlain (1877, p. 180)

This observation of the beech forests along the western shore of Lake Michigan in Wisconsin, while made over 100 years ago, clearly describes a perceived linkage between the occurrence of American beech, the distribution of soil types, and the ameliorating effect of Lake Michigan. Results of the current study quantify the influence of Lake Michigan and of soil type on the late-Quaternary distribution and abundance of American beech in eastern Upper Michigan.

A. Establishment of American Beech

An outlying population of American beech became established along the norhernmost shore of Lake Michigan by 5790 yr BP at Elbow Lake, nearly 700 years before reaching Nelson Lake, just 13 km farther inland from Lake Michigan (Figs. 8 and 12). Beech was not significantly delayed in reaching the study area from Lower Michigan or Ontario and Hypothesis 1a is therefore not supported. Further evidence for the absence of a delay in beech arriving in Upper Michigan comes from comparing the migration rates of beech reaching Lower Michigan and Ontario with those of beech reaching Upper Michigan. The rates of migration from Rose Lake, Pennsylvania to Bartley Lake, Ontario and Cub Lake, Michigan (Figs. 7 and 42) were 160 and 161 m yr^{-1}, respectively. From these sites to Elbow Lake the migration rates were 162 m yr^{-1} from Bartley Lake and

212 m yr^{-1} from Cub Lake. Thus, with the addition of the date of 5750 yr BP for beech arriving in Upper Michigan it is clear that Lake Michigan and Lake Huron did not limit beech migration and might have even facilitated it if floating of beech nuts played an important role in beech migration.

Timing for successful colonization by beech was tied directly to proximity of the upland site to the coastline of the Great Lake. At 6900 yr BP, before the mid-Holocene beech arrival times, Lake Michigan had risen above modern lake levels (Petty *et al.* 1996). A second high stand occurred at around 5500 yr BP, a time when beech pollen first rose above 1.0% at Elbow Lake and became continuous, occurring in trace values in temporally-successive levels at Nelson Lake (Fig. 40). Since both of these paleoecological sites are surrounded by loamy, calcareous soils (soil type 4), I interpret these data as indicating that lake effect (ameliorating climate within 20 km of shore of Lake Michigan) played a significant role in the establishment of American beech within the study area (Hypothesis 1b is supported). To test the importance of soil type on beech arrival (Hypothesis 1c), the pollen records from Ryerse Lake and Beaverhouse Lake (coarse-textured sandy soil) was compared with those of Nelson Lake and Elbow Lake (fine-textured loamy soil). Ryerse Lake is located 21 km east of Nelson Lake and Elbow Lake, and is 7.3 km from Lake Michigan. Beech pollen was not detected in the sediment core from Ryerse Lake between 5980 and 5050 yr BP (based on four stratigraphic levels with greater than 600 grains of total terrestrial pollen counted per level, Futyma 1982). Beech pollen occurs continuously in the core from Elbow Lake during this interval, and is continuously present in the core from Nelson Lake during this interval beginning at 5400 yr BP. Beech did not arrive at Ryerse Lake (>0.5% TTP) until 4430 yr BP. Beaverhouse Lake is located less than 5 km northwest of Elbow Lake and was less than 2.7 km from Lake Michigan for 1400 years prior to beech arrival at 4000 yr BP, 1750 years after arrival at Elbow Lake. These paleoecological data support Hypothesis 1c, that fine-textured, loamy, calcareous soils were necessary for the earliest Holocene establishment of American beech. Thus, the dual environmental factors of soil type and of site proximity within the lake-effect zone of climatic influence were both necessary, but individually, either factor was insufficient to account for the mid-Holocene establishment of American beech in Upper Michigan. The fact that beech became established around Nelson Lake (loamy soil, 13.7 km from Lake Michigan) 640 years before it became established around Ryerse Lake (sandy soil with ortstein, 7.3 km from Lake Michigan) and 1070 years before Beaverhouse (sandy soil without ortstein, 2.7 km from Lake Michigan), indicates that soil type exerted a greater influence on beech establishment than did lake-effect climate. Within the study area, the loamy soil with which beech is positively associated (soil type 4) makes up only 8.2% of the study area (Figs. 31-33). I interpret these data as support that, within in Upper Michigan landscapes, beech was limited in its population growth by a lack of suitable edaphic substrate rather than by its dispersal capability during the mid-Holocene Hypsithermal interval.

Lake effect, seasonality, and beech autecology

On a subcontinental level, the distribution and abundance of American beech has been related to Milankovitch changes in seasonality of temperature driven by changes in the earth's orbit around the sun (Huntley *et al.* 1989, T. Webb 1986). Decreased solar radiation reaching the earth's surface in the summer and increased solar radiation reaching the earth's surface in the winter favors species such as beech which have temperature optima that are lower in July and higher in January (Watts 1988). As already discussed, one coastal effect of Lake Michigan on the mesoclimate of the surrounding shoreline is to decrease the range of temperature fluctuation. The mesoclimate along the shore of Lake Michigan is similar to the climate that correlates with the distribution and growth of American beech across the Great Lakes region.

Denton and Barnes (1987a,b) studied the modern distribution of tree species in relation to climatic variables in Michigan. They found that the distribution of American beech is negatively correlated with continentality and high heat sums (analogous to growing degree days) prior to the last spring freeze. The continentality index used in their study is a rough measure of the influence of the Great Lakes on regional climate, where increased continentality corresponds with increased distance of upland beech stands from the lakeshore. Their continentality index is based on the equation developed by Conrad (1946) where continentality is a function of annual temperature range in degrees Centigrade and is expressed as a percent of a maximum continentality from northeastern Siberia. The correlation with low heat sums prior to the last spring freeze may reflect the physiological limitation that beech flowers are very sensitive to frost damage (Tubbs and Houston 1990). The eastern range limit of European beech (*Fagus sylvatica*) in continental Europe has been correlated with frequent frost damage to young trees (Walter 1973). In the northern portion of the range of American beech in North America beech trees typically bloom in late April or early May (Tubbs and Houston 1990). Thus, the spring timing of the last killing frost may be very important in influencing successful seed production. For many tree species the critical night time low temperature is –2.2° C (28° F) (Eichenlaub *et al.* 1990). For eastern Upper Michigan, the average date of last freeze occurrence of –2.2° C (28° F) is typically May 7th. Additionally, initiation of woody cambial growth does not occur until the leaves of beech are fully expanded (Freisner 1942). Thus, a late-spring frost could severely damage expanding beech leaves and could also retard cambial growth. Liu and Muller (1993) found that a late spring frost in Kentucky reduced the cambial ring-width of beech for that year by 15%.

Graumlich (1993) found that the growth of mesic hardwoods, especially beech, is favored over that of xeric hardwoods such as oaks when April temperatures are cool. She attributes this differential growth to species-specific differences in wood anatomy. Beech has a diffuse-porous xylem anatomy (large xylem vessels are scattered throughout each growth ring), whereas oaks have a ring-porous xylem anatomy (large xylem vessels are concentrated in the early-wood portion of each growth ring) (Graumlich 1993). Cambial growth in oaks is favored by early spring warmth because cambial growth begins prior to leaf expansion (Friesner 1942) and the large early-wood vessels can transport large quantities of water and nutrients during the spring thaw. In contrast, beech is unable to take advantage of early spring time warmth since its large xylem vessels are scattered thoughout its growth rings, and as mentioned, cambial growth does not begin until leaves are almost fully expanded. Thus, beech growth of new wood and new leaves is favored by cooler spring-time temperatures which delay the break in dormancy until after the last hard freeze. Based on this insight, Graumlich (1993) urges that a "finer differentiation with respect to the seasonal timing of warmth is needed." This is also true for the seasonal timing of cool temperatures. This relationship adds to the understanding that beech is apparently favored by decreased seasonality. Owen Davis (1986) proposed that multiple thermal maxima during the Holocene may have controlled the expansion of temperate vegetation at varying elevations across Idaho. His curve for 45° N latitude showing the timing of thermal maximum also shows the timing of thermal minimum (Fig. 19). The period from 6000 to 2000 radiocarbon yr BP (calibrated to 8000 to 3500 calendar years before present, respectively) corresponds to the lowest values of solar insolation for April, during which the growth of beech would be most favored due to its diffuse porous wood anatomy. Thus, a finer differentiation of the timing of seasonality helps to explain not only the modern growth correlates of American beech but potentially its expansion during the late Holocene as well.

Migration route of beech into Upper Michigan

M. Davis *et al.* (1986) hypothesized that American beech migrated into Michigan's Upper Peninsula from its Lower Peninsula. Evidence from this study indicates, alternatively, that beech may have arrived in Upper Michigan from Ontario, a hypothesis first suggested by Kapp (1977b). Kapp's hypothesis is further supported by my calculations of beech migration rates into the Great Lakes region (Fig. 44). Overall rates average 177 m yr^{-1} and rates along a northern migration route (from Rose Lake (RsL) to Bartley Lake (BtL) to Elbow Lake (EL) average 161 m yr^{-1}. These values for Holocene beech migration across the Great Lakes region compare favorably with previous published estimates of 200 m yr^{-1} by Davis (1981), 169 m yr^{-1} by Delcourt and Delcourt 1987, and 150 m yr^{-1} by Bennett (1985). The migration rate estimates vary considerably when sites are spaced near each other, but approach a value very near the mean as the distance (and therefore time duration) increase (Fig. 44). This trend is interpreted as due to the law of averages and the errors associated with radiocarbon dating. Sites situated along the Niagara Escarpment (such as Bartley Lake) leave open the possibility that beech "island-hopped" along carbonate bedrock knolls to Upper Michigan between 8000 and 6000 yr BP, with beech finding suitable habitat along what is today the submerged shore of northern Lake Huron (Fig. 42).

B. Expansion of American Beech

American beech expanded onto coarse-textured sandy soils between 3000 and 2000 yr BP based on the pollen records from Beaverhouse Lake, Ryerse Lake, Young Lake, MacDonald Lake, and Lorraine Lake (Supports Hypothesis 2a). In some cases the expansion of beech onto sandy soils was dramatic; for example at Young Lake, beech rose from 1% to 8.5% during the 330 year interval from 2670 to 2340 yr BP. Coarse-textured sandy soils (soil types 1 and 2) collectively cover 36.3% of the study area (Fig. 32)

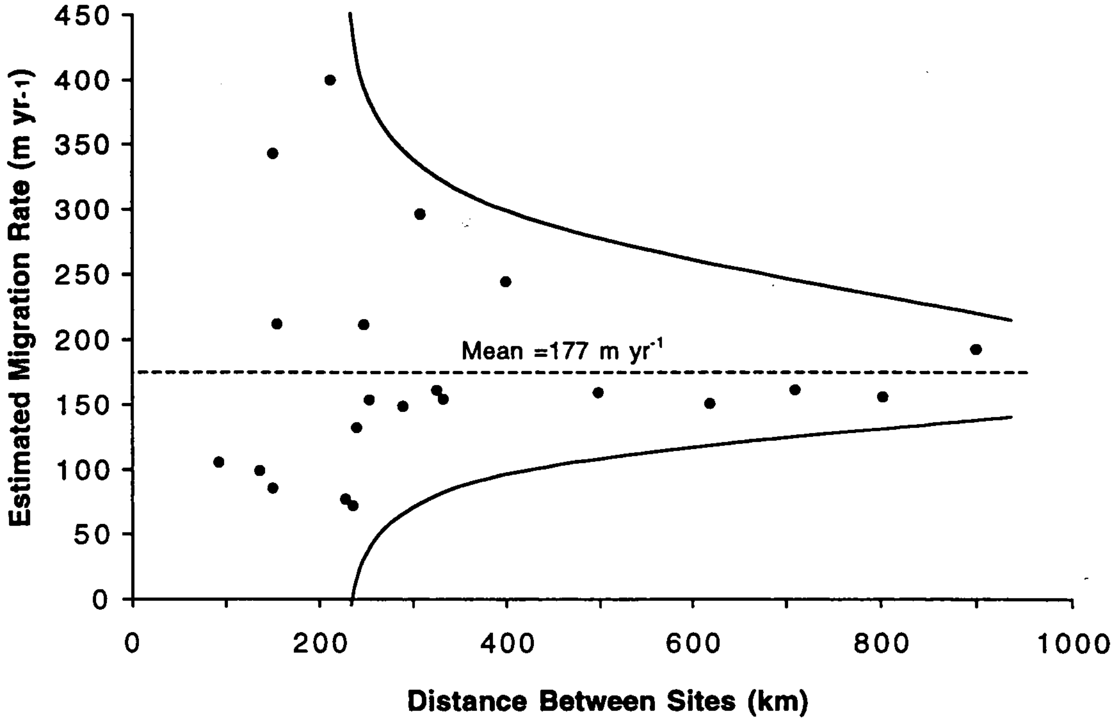


Figure 44. Migration rates between sites within the Great Lakes Region which record the Holocene arrival of American beech.

compared with just 13.7% for fine-textured loamy soils (soil types 4, 5, and 6). Therefore, movement by beech onto these soils represents a very large geographic expansion. This conclusion concerning edaphic substrate specificity supports Hypothesis 2a and is based upon the documented expansion of beech at several sites surrounded by sandy soils (Fig. 41) from initial loamy, calcareous sites of colonization. The rise to aerial importance reflects the significant positive association between presettlement beech and coarse-textured sandy soils (soil types 1 and 2 combined, $X^2= 58.4$, $p<0.001$). When the statistical association for beech occurrence and coarse-textured sandy soils was tested separately for quartz soils with and without ortstein (Hypothesis 2b), the association with sandy soils without ortstein (soil type 1) was not significant ($X^2=-0.1$), while the association with sandy soils with ortstein (soil type 2) was highly significant ($X^2=91.7$, $p<0.001$). The ecological preference by beech for sandy soils with ortstein is evident spatially from the presettlement beech map (Fig. 32) as well as temporally from the plant fossil record (Fig. 41). While paleoecological sites on sandy soils with or without ortstein both show increases in percent beech pollen between 3000 and 2000 yr BP, the temporal pattern for average increase is quite different. After 2000 yr BP, the average maximum percent for beech pollen at sites with ortstein is 9.5%, while only 3.5% for sites without ortstein. The pedogenic significance of ortstein is made even clearer for the Holocene history of beech in Upper Michigan when sites are compared which are spatially close to each other. For example, Wolverine Lake (sandy soil without ortstein) and Young Lake (sandy soil with ortstein) are only 4.4 km apart (Fig. 7) and yet show dramatically different beech records (Fig. 41) with beech reaching a maximum of 18% TTP at Young Lake while only reaching 6% TTP at Wolverine Lake. Similarly, Beaverhouse Lake (sandy soil without ortstein) and Ryerse Lake (sandy soil with ortstein) are only 24 km apart and have distinctively different beech records, again, most notably in the maximum abundance of beech reached at each site (4% vs. 9%, respectively).

This strong association of beech with coarse-textured, xeric soils in Upper Michigan is different than more southerly portions of the range of beech where beech is associated most strongly with fine-textured mesic soils (Tubbs and Houston 1990). Either there are ecotypic differences between beech populations along the northern portion of its range compared with populations farther south (and these ecotypes have different environmental tolerances), or some environmental factor (biotic or abiotic) is causing beech to shift its distribution onto coarser-textured, drier soils (as is typically shown by Beschel *et al.* (1962), inset Fig. 1). One possibility is that with decreased annual temperatures to the north, coarser-textured soils have increased soil moisture (relative to equivalent soils farther south) simply as a function of decreased evapotranspiration.

The importance of lake-effect snow

Lake effect snow may have increased the podzolization process by increasing the amount of spring-time leaching of soils by snow meltwater (Schaetzl and Isard 1990). Deeper snow pack in winter may also provide beech seedlings with valuable insulation protecting them (below the upper snow surface) from temperature minima below –41°C. If winter snow pack and spring thaw with greater spring infiltration of meltwater play an important role in establishment and expansion of beech, then one would expect to see increased beech populations in areas which receive greater amounts of lake-effect snow. For Upper Michigan, this snow belt occurs along the southern shore of Lake Superior (Fig. 24). This is also an area of extremely well-developed ortstein (Greg Whitney, Luce County Soil Survey, personal communication) as well as large populations of American beech (Fig. 45a). This association between beech and ortstein can also be extended to northern Lower Michigan. Schaetzl and Isard (1991) explored the role of lake-effect snowfall and ortstein development in Lower Michigan. When their map of spodosol distribution is compared with the distribution of American beech (Denton and Barnes

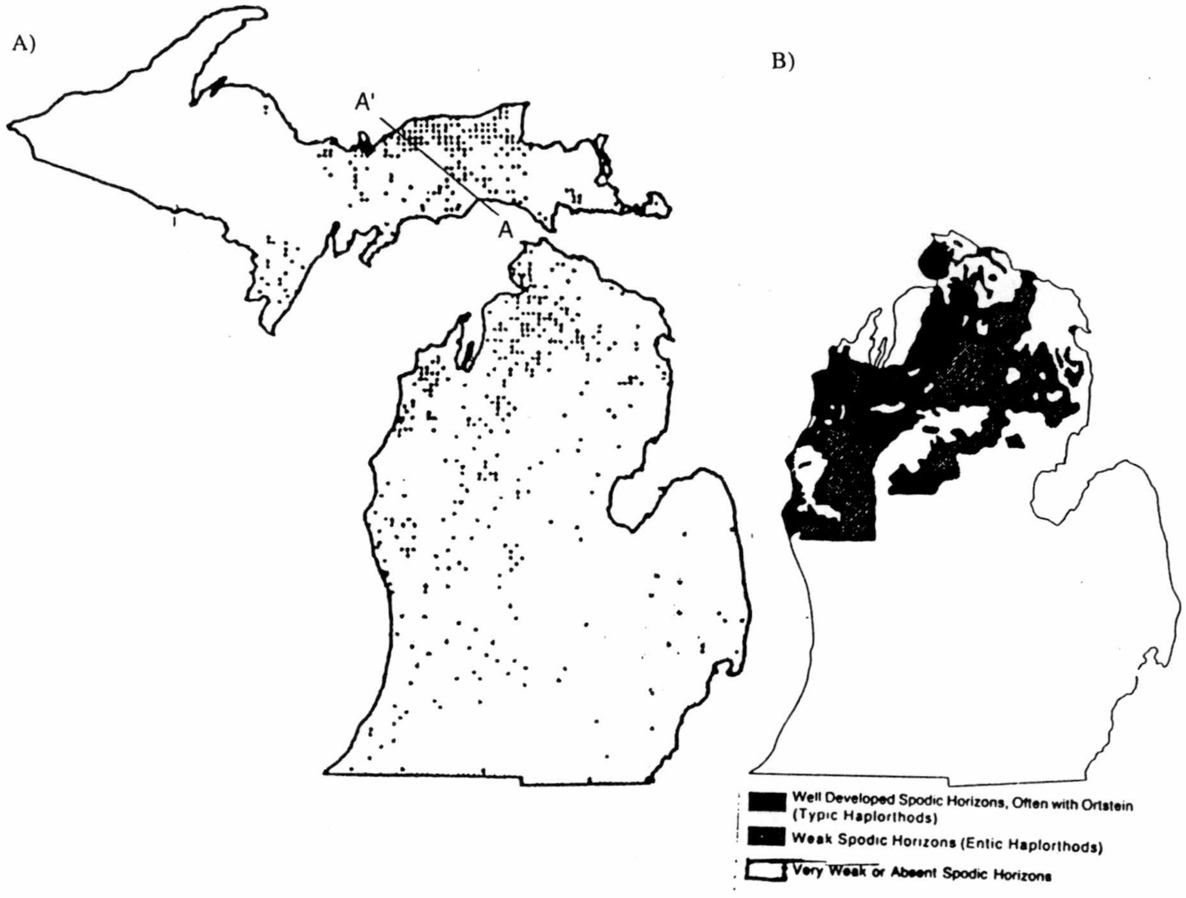


Figure 45. Modern distribution of A) American beech (*Fagus grandifolia*) in Upper and Lower Michigan, and B) soils with well-developed spodic horizons with ortstein in Lower Michigan .

1987b) it is clear that beech is strongly associated with well developed spodic horizons with ortstein (Fig. 45b). If Schaetzl and Isard (1990, 1991,1996) are correct in their assessment of the importance of lake-effect snow and ortstein development, the timing of the development of the association between American beech and ortstein is further supported by recent isotopic evidence that lake-effect snowfall, with depleted $\delta^{18}O$ values, increased dramatically after 2800 yr BP, (Nester *et al.* undated manuscript submitted for publication). Nester *et al.* (undated) propose a two-step increase in winter moisture levels at the mid- to late Holocene transition: meridional influx of winter precipitation from the Gulf of Mexico increasing after 4875 yr BP, then onset of cool moist conditions and maximum lake-effect precipitation from the local Great Lakes after 2800 yr BP.

A picture emerges in which several factors combined together after 5000 yr BP to favor ortstein development and beech expansion. Factors which promote ortstein development are an increase in the amount of lake-effect snowfall, a climatic shift to a moister and cooler climate, and decreased seasonality due to orbital forcing. Factors which would favor both ortstein development and beech expansion include: reduced fire frequency resulting in litter build up (increased fulvic acid leachate), and hemlock expansion just prior to beech expansion (podzolization, slow decomposition of organic litter, Al cycling through soil column). This idea is supported by the observation of Woods (1981) that beech often replaces hemlock in mesic temperate forests. Thus, hemlock may have facilitated beech expansion by facilitating podzolization and ortstein formation. Finally, factors which would favor the expansion of American beech include low continentality due to Great Lakes regionally.

C. Decline of American Beech

Hypothesis 3a (beech declined in response to competition from other mesic species such as sugar maple, hemlock, yellow birch) is supported, based on the pollen record for the late-Holocene decline of American beech at 1100 yr BP at Elbow Lake. However, a second decline in beech around Elbow Lake at 310 yr BP supports Hypothesis 3b (beech declined in response to paludification), since other mesic tree taxa such as sugar maple, hemlock, and yellow birch do not increase at this time while hydric cedar/juniper increase significantly. The record from US 2 Bog where beech declined from 5% to 0% over the past 1390 years shows significant evidence of paludification which led to white cedar expansion on lowland mesic sites (Fig. 35). At the same time, mesic beach ridges became more dry (due to continued isostatic rebound and downcutting of the Millicoquins River) resulting in a population increase for jack/red pine. Paludification (bog expansion) on select upland sands due to perching of the water table over ortstein (e.g. Cranberry Lake Bog, Futyma 1982) also was important in the decline of American beech within the study area. Since these factors are highly site specific, and therefore very patchy across the landscape, there has not been a regional signal preserved at all sites, but rather local population declines of beech. So, on a regional scale beech expansion was due to long-term soil development and climate change, but on a landscape scale, beech declined at some sites due to shifts in ground water hydrology, driven by isostatic rebound or paludification, with water ponding over a continuous ortstein layer.

The same shift toward a more mesic climate led to regional peatland expansion, such as at the Seney Wildlife Preserve in east-central Upper Michigan (Madsen 1987). Ortstein, as it becomes nearly continuous, tends to perch the water table (Whitney 1995). Thus, one might expect beech to decline as climate becomes more moist on sites with very well developed ortstein. A comparison of the records of Wolverine Lake and Young Lake (Fig. 41), just prior to European disturbance (120 and 130 yr BP), shows that beech populations dramatically declined at Young Lake (from 16% at 360 yr BP to 5% at 130 yr BP) which is surrounded by sandy soils with very well developed ortstein. At Wolverine Lake (just 4.4 km southeast of Young Lake) beech increased from 0.9% at

200 yr BP to 3% at 120 yr BP (sand without ortstein). This reversal in beech population trends at these two sites is suggestive of a shifting edaphic optimum for beech as climate became cooler and more moist during the Little Ice Age.

From these patterns of American beech arrival, expansion, and decline, an idealized Holocene model of shifting beech abundances can be drawn for Upper Michigan (Fig. 46). The superposition of beech abundances on three different soil types illustrates the influence of climate and soil water-holding capacity on the distribution and abundance of American beech. During the height of the Hypsithermal interval beech was only able to become established on the fine-textured loamy soils near the shore of the Great Lakes; however, as climate cooled and became more moist with the waning of the Hypsithermal interval (*circa* 3000 yr BP, Fig. 17), beech expanded onto coarser-textured soils with well developed ortstein layers. It is on these spatially abundant soils that American beech has been able to expand both its distribution and abundance in Upper Michigan during the last 3000 years. This expansion occurred in a two step process, first around 2500 yr BP and then around 1500 yr BP (Fig. 41). The climatic shift to a lake-effect regime at 2800 yr BP was lagged by 300 yr for tree colonization and then growth of mature trees to produce the pollen signal. During this time of beech expansion onto soils with ortstein, beech began to decline on loamy soils due to a shift to more hydric conditions. Within the last 1500 years, beech expanded on increasingly more mesic sandy soils without ortstein and declined on loamy soils and sandy soils with ortstein (Fig. 41). This pattern of shifting edaphic preferences with changes in climate has been demonstrated for the Holocene forests of western Upper Michigan beyond the range limit of American beech (Brubaker 1975). This diagnostic pattern is also predicted by spatially explicit models of forest response to near future global warming in northern Wisconsin (Pastor and Post 1988). My results provided a mid- to late Holocene example of this phenomenon for American beech.

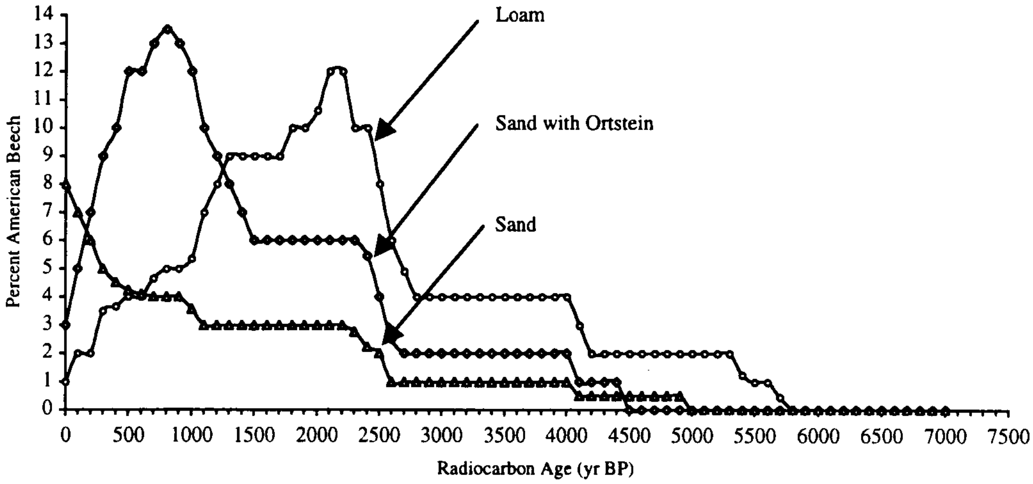


Figure 46. Idealized pollen curves for sites on loam, sand with ortstein, and sand.

D. Generality of Results

A broader understanding of this dual pattern of expansion and decline of American beech during the last 6000 yr BP can be gained by considering the predictable environmental changes which occur during glacial-interglacial cycles. In an application of a model developed by Iversen (1958), Birks (1986) describes the changes in climate, soil development, and vegetation during a generalized glacial-interglacial cycle for Denmark and Ireland. The general cycle consists of four phases, one glacial phase (cryocratic), lasting approximately 90 000 years, and three interglacial phases (protocratic, mesocratic, and oligocratic), lasting a total of approximately 10 000 years (Fig. 47). The protocractic phase is characterized by increasing temperatures, unleached mineral soils and, for Denmark, basic (pH) grassland and woodland vegetation. As interglacial climate continues to warm and soils continue to develop during the mesocratic phase, mixed deciduous forests grow on fertile brown-earth soils (Alfisols). From this peak in interglacial temperature, during the oligocratic phase climate begins to cool, weathering of soils continues, and the vegetation shifts to coniferous woodland and heaths growing on now leached, acidic, podsols (Spodosols). The growth of peats and acid humus also characterize this phase in western Ireland (Fig. 47). American beech, and its ecological equivalent in Europe, European beech (*Fagus sylvatica*), both tend to expand during the third or oligocratic phase at the end of interglacial cycles (Fig. 4). This repeated late-interglacial expansion of American and European beech indicates that optimal environmental conditions must exist during these times for the growth of beech. Decreased Milankovitch seasonality of solar radiation reaching the earth, and more specifically, the early-Holocene timing of thermal minimum during the spring, favored beech growth. In this study, late-Holocene expansion of American beech in Upper Michigan occurred onto spodosol soils with ortstein layers. I consider that increased podsolization during the oligocratic phase of glacial-interglacial cycles was one environmental factor favoring beech

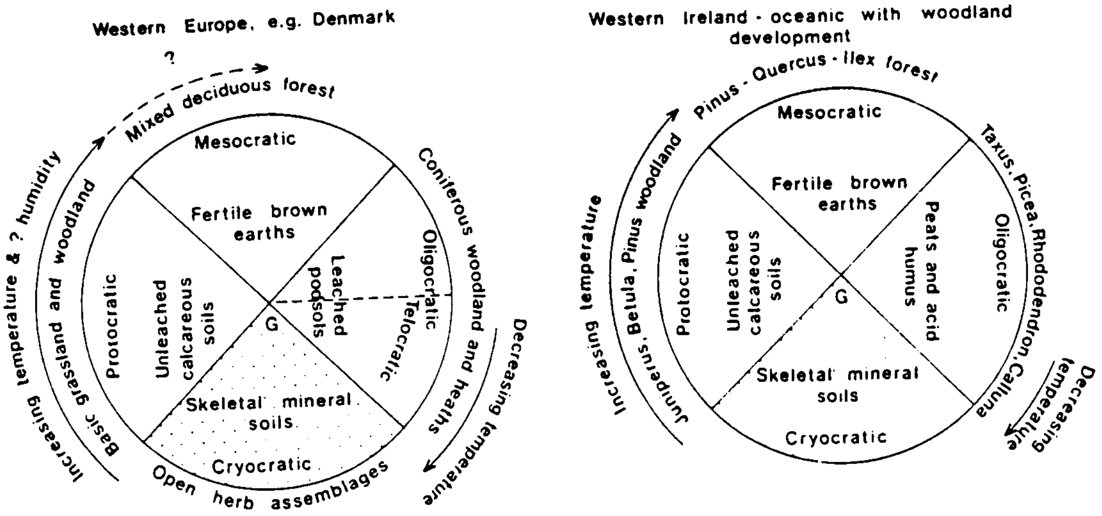


Figure 47. Model of predictable changes in vegetation and soils during glacial-interglacial cycles for Denmark and Ireland(from Birks 1986).

expansion during the late-stage interglacial. At the same time, the continued expansion of peatlands, in part facilitated by continued ortstein development, resulted in the subsequent decline of beech at sites inundated by paludification. Thus, predictable postglacial soil development during the last 6 000 years has resulted in the simultaneous expansion and decline of American beech populations on different topographic surfaces and hydrological settings within the same landscape mosaic.

European beech, like American beech, expanded northward in Europe onto podzolic soils during that last 3000 years (Huntley and Birks 1983). The role climate and natural soil development played in this expansion of European beech cannot be determined with confidence, however, due to the confounding effect of human-caused forest clearance on these soils immediately prior to beech expansion (Huntley and Birks 1983). In North America, while humans are now hypothesized to have played an important role in the expansion of American Chestnut (*Castanea dentata*) through the use of fire (Delcourt and Delcourt 1998), there is no evidence that American beech expansion between 3000 and 2000 yr BP on a regional scale was similarly facilitated by humans. Thus, this study provides a North American example of oligocratic beech expansion tied to both changes in Milankovitch seasonality and podzolic soil development.

E. Implications of Future Climate Change

Over the next one hundred years climate of the Great Lakes region is predicted to change dramatically due to global warming (Manabe and Wetherald 1987, Sanderson 1987, Wall 1988, and Hengeveld 1990). With a projected doubling of atmospheric carbon dioxide, general circulation models predict between a 3.5 and 4.5°C rise in global surface temperatures (Hengeveld 1990). This rise in temperature would have many repercussions for the climate of local regions. In a paper which summarizes the results of several models, Hengeveld (1990) presents several of the potential consequences of global warming for the

Great Lakes region. These include, 1) a 40 to 50% decrease in soil moisture in Upper Michigan, 2) reduced ice cover in winter, 3) earlier snowmelt and runoff, and 4) a 0.3 -0.8 m drop in Great Lakes water levels. The impact of these changes on the distribution and abundance of American beech in Upper Michigan could be dramatic.

Davis and Zabinski (1992) and Iverson and Prasad (1998) have modeled the response of American beech to greenhouse warming over the next 100 to 200 years. Under two different greenhouse world scenarios Davis and Zabinski (1992) modeled beech range shifts of several hundred kilometers northeast. In the more extreme scenario the new range does not overlap its current range. In this case, the mesic shores of Lake Michigan may lie outside the new climatic range of American beech and would potentially provide one of the few refugia within the current range of beech (Davis and Zabinski 1992). In a more recent study, Iverson and Prasad (1998) concluded that the higher elevations of the southern Appalachians would provide beech refugia under an enhanced greenhouse climate.

Any future adjustments in the range of American beech will likely be influenced by beech bark disease. Since the introduction of the scale insect to North America in AD 1890, it has expanded its range westward at a rate of 13 km yr^{-1} (calculated based on expansion history presented by Houston, 1994). At this rate, the scale insect and associated fungus could reach the study area (a distance of 590 km) in 46 years (*circa* AD 2043). Houston and Valentine (1988) studied the climate conditions which favor the population growth of the scale insect and found that *Cryptococcus fagisuga* does best when winter temperatures are mild with extremes above -30°C. Mild winter temperatures increase the survival of the over-wintering instar. Gove and Houston (1996) studied beech senescence in two populations in Maine, one close to the Atlantic coast (39 km from the ocean shore) and one farther inland (95 km). They found that the growth rates of infected co-dominant beech trees under the maritime influence declined 34 years earlier than growth rates of infected trees farther inland. They explain these results by suggesting that ameliorated climate near the ocean, specifically the milder winters, allowed the scale insect numbers to build more rapidly and reach higher values the following year. In contrast, the infected beech population farther inland under a more continental influence commonly experienced winter temperatures below -34°C, the temperature known to be lethal to the insect, thus, in the next fifty years, the beech trees growing along the ameliorated shores of the Great Lakes may suffer severely from beech bark disease, making these shoreline areas less favorable as refugia under a warmer Greenhouse climate. Given that the scale insect seems to do well under warmer climatic conditions in general, the hypothesized beech refugia in the southern Appalachians may also be threatened (Iverson and Prasad 1998).

CHAPTER VI

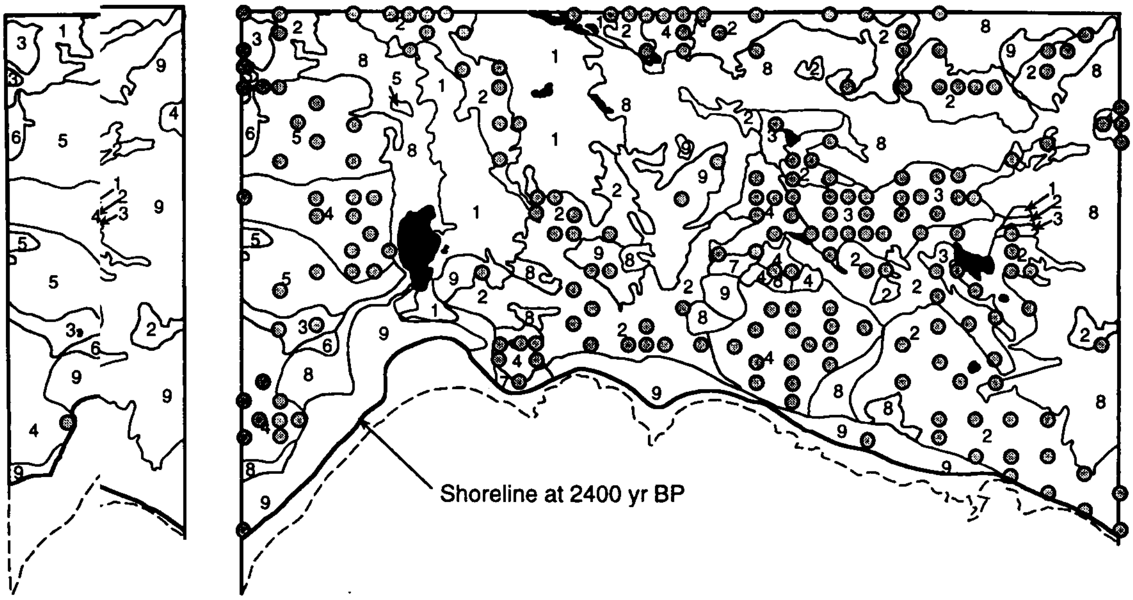
SUMMARY

From the results of this study and the above discussion, I have created a time series of speculative landscape maps which show how the distribution of American beech and soil types changed over the last 5400 years and how they might change 400 years in the future (Fig. 48). I have chosen six times to map for this time series based on when beech underwent the most dramatic changes in abundance and distribution. These times are: 5400 yr BP, 3900 yr BP, 2400 yr BP, 1000 yr BP, presettlement (AD 1850), and future (AD 2100). Below I describe the probable changes in beech and soils each time period illustrates.

By 5400 yr BP, American beech trees were only established along the shore of the study area on moderately-drained, fine-textured, loamy soils (Soil Type 4) (Fig. 48A). In addition to the area around Elbow Lake, beech was very likely established elsewhere along the shore where this soil type occurred. Note that the area of Soil Type 4 to the east of Elbow Lake is poorly drained in the present (Soil Type 7) but would have been much drier at 5400 yr BP and likely suitable for beech colonization. While the difference between these two soil types is not solely a function of drainage class, they are treated as such for this analysis due to the likelihood that beech would colonize Soil Type 7 at times when it was not poorly drained. Sandy soils without ortstein were more extensive at 5400 yr BP than at present, occurring in areas which today either have ortstein layers (east of Elbow Lake) or have peat accumulations (west of Ryerse Lake). Sandy soils with ortstein (Soil Type 2) were present in limited areas during this time but would have been too dry for beech to grow on. Most of the lakes in the area were well below their modern levels

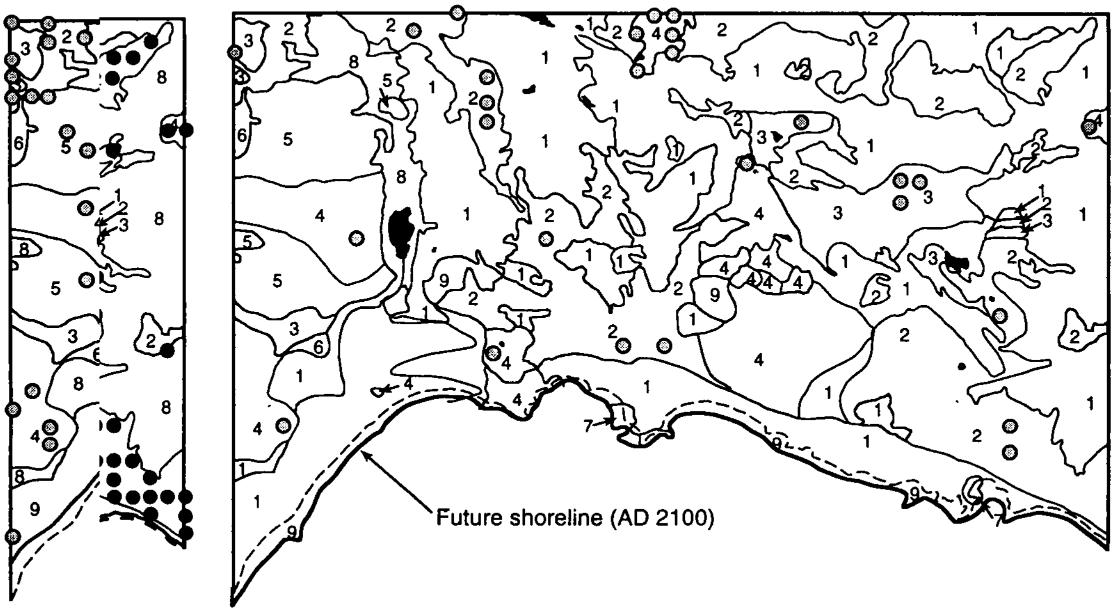
A. 5

C. 2400 yr BP



D. 1

F. Future (AD 2100)



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(Futyma 1982, Petty *et al.* 1996, Nester 1999), in spite of the high stand in Lake Michigan that occurred at this time (Petty *et al.* 1996).

American beech trees were still sparse across the landscape at 3900 yr BP (Fig. 48B), but had expanded inland onto upland, fine-textured loams and had also become established on sandy soils which had ortstein layers, some of which were newly formed. Lake levels had risen and were close to their present levels by 3500 yr BP.

By 2400 yr BP, beech had dramatically increased on sandy soils with ortstein (Soil Type 2) and were at their greatest abundance on moderately-drained, fine-textured loams (Soil Types 4, 5, and 6) (Fig. 48C). Extensive paludification had occurred by this time causing a loss of Soil Types 1, 2 and 9 in low-lying areas, forming Cranberry Lake peatland south of Nelson Lake. As Lake Michigan receded due to isostatic rebound, new land formed south of Lake Millicoquins which was mostly unsuitable for beech growth, being either too wet in low-lying swales, or too dry on recently stabilized sand dunes (Petty *et al.* 1996).

American beech trees reached their greatest abundance on the landscape by 1000 yr BP due to continued climatic cooling and the areal dominance of sandy soils with ortstein (Fig. 48D). While still quite abundant, beech populations on loamy soils began to decline at selected sites due to a rise in water tables (converting Soil Type 4 to Soil Type 7 east of Elbow Lake), and continued expansion of peatlands. These factors also resulted in the increased suitability of sandy soils without ortstein (Soil Type 1), onto which beech became established.

The presettlement distribution of beech and soil types (Fig. 48E) was as discussed earlier, with the majority of beech trees (52%) growing on sandy soils with ortstein (Soil Type 2). Of note is the relative stability of the shallow, loamy soils west of Lake Millicoquins. These soils have changed little over the past 5400 years due to their fine textures, and upland positions. Beech was likely more abundant on these soils during previous times as the competitive balance with sugar maple changed as a function of reciprocal replacement (Woods 1979) and disturbance regime (Poulson and Platt 1996).

The landscape 100 years in the future (Fig. 48F) will be larger as Lake Michigan continues to regress. Relative to the land, the lake level may be 1.0 meters lower than it is today (0.8 m lower due to decreased runoff and 0.2 meters due to isostatic rebound). This drop in lake level will result in a regression of as much as 500 m in places. This new land will mostly form poorly drained sandy soils intermixed with drier, sandy ridges (Soil Type 9). Inland lake levels will fall as a result of increased summer warmth and decreased precipitation.

The results of climate modeling efforts predict that present and expected changes in climate will dramatically affect the long term survival of American beech trees in the Great Lakes region (Davis and Zabinski 1992, Iverson and Prasad 1998). If regional climate becomes unsuitable for beech growth and reproduction in the Great Lakes region, beech may find refuge in areas of the landscape where microclimate and edaphic features combine to provide suitable habitat. Several factors need to be taken into account in order to determined where these areas are likely to be.

Beech bark disease will reach the study area within the next one hundred years and likely result in 75% initial mortality of beech trees (Houston 1997). Infestation may well be most severe near the ameliorated shore of Lake Michigan due to the reduced winter extremes in temperature that tend to lower the abundance of the fungi-carrying scale insect which is part of the beech bark disease complex ((Houston and Valentine 1988). Additionally, as climate warms, soil moisture is predicted to decline resulting in increased fire frequency. With the increased fuel load due to beech bark disease these fires will likely be extensive and deadly to most of the remaining thin-bark beech trees, further reducing beech abundance. Decreased precipitation will likely dry out large peatlands which would be consumed by the increased fire frequency. Fire would return these drier peatlands to mineral soil, usually sand. In areas where the peatlands are over sandy paleosols with ortstein, the ortstein may deteriorate without a thick humus layer to supply the organic acids needed to form the organometalic sesquioxides for cementation (Hole 1975).

With these changes, the mostly likely areas where beech could find suitable habitat would be on fine-textured loamy soils along the uplands running from Nelson Lake to Ryerse Lake. These soils will continue to have high water holding capacities and their landscape position farther from Lake Michigan may provide reduced infestation by beech bark disease due to colder winter extreme temperatures (above the critical -41° C for beech survival but below the necessary -31°C needed to reduce the scale insect associated with beech bark disease). Thus, while the future landscape will be similar to that of 5400 yr BP (climate will be warmer and drier than at present), it will not be analogous for American beech given the added stress of beech bark disease.

From the results of this study the following major conclusions can be made:

- In Upper Michigan, a small outlying population of American beech became established by 5790 yr BP on loamy soil around Elbow Lake, along the climatically ameliorated shore of Lake Michigan.

- American beech did not arrive on similar loamy soils farther inland until 700 years later (5070 yr BP) at Nelson Lake, 13.7 km from the Lake Michigan shore.

- American beech probably arrived in Upper Michigan at 5790 yr BP by way of Ontario, either island hopping along the Niagara Escarpment (via avian transport or floating along the shores of the Great Lakes) or sweeping through uplands to the north of Lake Huron.

- Between 3000 and 2000 yr BP, beech populations increased on fine-textured, calcareous, loamy soils (where it was already established) and expanded onto coarse-textured, quartz, sandy soils (where it had previously been absent or at very low levels). This late-Holocene expansion follows the mid- to late Holocene formation of ortstein layers in the B horizon of sandy soils and correlates with a late-Holocene shift to a more cool-mesic climate and increased precipitation in the form of lake-effect snow.

- A strong association between American beech and spodic soils with ortstein layers provides a North American example of the linkage between the oligocratic climate phase of Birks (1986), long-term soil development in deglaciated terrains, and the Holocene migrational response of American beech.

- Declines in American beech over the past 3000 years at selected sites, first on loamy soils then on sandy soils with ortstein, combined with presettlement increases on increasingly more mesic sandy soils without ortstein, reveal the occurrence of shifting edaphic optima as late-Holocene climate has cooled and become more moist across Michigan's Upper Peninsula.

- During the past 2000 yr BP, selected populations of American beech declined in response to loss of habitat as lowland mesic sites became more hydric in response to paludification. Other populations collapsed as upland mesic sites became more xeric in response to lowering of the water table due to isostatic rebound, river downcutting, and possibly, gradual soil degradation and a shift in vegetation toward more low-nutrient tolerant, fire-promoting tree species (e.g., oaks and pines).

- Under a warmer, drier greenhouse climate American beech may find refuge along the upland, fine-textured loamy soils with high water holding capacity. These soils are inland (more continental) and away from the ameliorated shore of Lake Michigan where beech bark disease is predicted to be most severe.

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APPENDICES

Appendix A. Sites that document the Holocene timing (in yr BP) of American beech (*Fagus grandifolia*) migration into the Great Lakes region. Radiocarbon dates of beech arrival are determined by the stratigraphic level at which the running average of beech pollen percentages (across three consecutive levels) rises above 0.5% of total terrestrial pollen (TTP). Radiocarbon dates of beech expansion and decline are determined by the level at which the running average of beech percent rises or falls by 25% of the percent TTP. All data and site chronologies are based on site references listed unless otherwise noted. Site abbrev-iations refer to those given on Figure 7. Magnitude of expansion calculate by subtracting the percent of beech at time of expansion from the max-imum percent. Magnitude of beech decline calculated by subtracting the percent of beech at minimum following decline from the percent of beech prior to decline.

Site Abbr.	Name	Location (lat., long.)	Elev. (m)	Area (ha)	Time of Beech Arrival (yr BP)	Time of Beech Expansion (yr BP)	Magnitude of Beech Expansion (% TTP)	Time of Beech Decline (yr BP)	Magnitude of Beech Decline (%TTP)	Soil Series and Type (ort) [§]	Km from L. Mich. at time of arrival
Sites used in analysis of lake effect, soil type, regional arrival, expansion and decline											
BL	Beaverhouse Lake[1]	46.15°N, 85.49°W	192	6.0	4000	2500	3.1	—	—	Rubicon sand[30]	2.7
EL	Elbow Lake[2]	46.02°N, 85.46°W	203	3.0	5790	2550	9.4	1100	-4.7	Battydoe loam[30]	2.4
NL	Nelson Lake[3]	46.22°N, 85.37°W	254	10.5	5070	2440	6.0	260	-4.4	Battydoe loam[30]	13.7
RL	Ryerse Lake[4]	46.13°N, 85.18°W	259	8.0	4430	2510	7.9	—	—	Kalkaska sand(ort)[30]	7.3
Sites used in analysis of soil type, regional arrival, expansion and decline											
BrL	Brampton Lake[5]*	45.93°N, 87.02°W	215	9.5	3220	1240	2.5	—	—	Rubicon sand[34]	
BvL	Beaver Lake[5]*	44.92°N, 88.15°W	228	3.5	3670	2730	7.2	1650	-7.3	Onaway loam[36]	
EsL	East Soldier Lake[4]	46.35°N, 84.85°W	275	4.8	4370	—	—	—	—	Rubicon sand[31]	
HL	Hoglund Lake[5]*	45.48°N, 87.48°W	218	4.0	3500	1900	4.5	—	—	Onaway loam[36]	
KL	Kitchner Lake[5]†	45.67°N, 87.45°W	237	4.0	3479	2660	6.8	760	-8.0	Onaway loam[35]	
LL	Lorraine Lake[5]*	46.15°N, 86.48°W	219	5.5	3890	2560	6.2	—	—	Kalkaska sand(ort)[34]	
ML	MacDonald Lake[5]*	46.03°N, 86.80°W	229	12	3800	2400	3.7	—	—	Kalkaska sand(ort)[34]	
SL	Spirit Lake[5]†	46.47°N, 86.93°W	203	6.0	3330	966	2.5	—	—	Rubicon sand[34]	
WL	Wolverine Lake[4]	46.43°N, 85.67°W	259	3.2	3950	120	2.2	—	—	Rubicon sand[32]	
YL	Young Lake[5]*	46.43°N, 85.71°W	262	2.5	5000	2670	16.8	130	-10.5	Wallace sand(ort)[33]	
Sites used in analysis of regional arrival											
BnL	Barney Lake[7]*	45.70°N, 85.50°W	195	7.6	5260						
BtL	Bartley Lake[8]*	45.22°N, 81.48°W	221	6.9	7800						
CB	Chippewa Bog[9]†	43.10°N, 83.30°W	270	5.5	8330						
CbL	Cub Lake[10]†	44.70°N, 85.95°W	360	18	6520						
DL	Demont Lake[12]†	43.50°N, 85.00°W	248	1.5	7890						
EdL	Edward Lake[13]†	44.40°N, 80.30°W	518	18.7	7080						
FL	Frains Lake[14]†	42.30°N, 83.60°W	271	6.6	7610						
GL	Gass Lake[6]	44.05°N, 87.73°W	211	2.5	6050						
GB	Greenbush Swamp[15]	45.90°N, 81.90°W	312	—	5740						
GrL	Green Lake[16]†	44.90°N, 85.10°W	305	16.2	5620						
HdL	Hudson Lake[11]	41.67°N, 86.53°W	239	175	9190						

Appendix A. (continued)

Site Abbr.	Name	Location (lat., long.)	Elev. (m)	Area (ha)	Time of Beech Arrival (yr BP)
Sites used in analysis of regional arrival (continued)					
HmL	Hams Lake[17†]	43.23°N, 80.42°W	282	2.4	8210
JL	Jack Lake[18†]	47.32°N, 81.77°W	430	5.2	6350
LB	Lac Bastien[17†]	46.40°N, 78.92°W	305	8.0	6950
CL	Clear Lake[11]	41.65°N, 86.53°W	244	20	8420
LS	Lake Sixteen[19†]	45.69°N, 84.31°W	216	50	5300
MrL	Mary Lake[9*]	44.73°N, 81.00°W	236	14.7	7180
NnL	Nina Lake[18†]	46.70°N, 81.50°W	380	2.3	6830
NtL	Nutt Lake[17†]	45.22°N, 79.45°W	305	7.9	7360
PL	Prince Lake[20†]	46.57°N, 84.55°W	290	8.7	5190
PB	Protection Bog[21]	42.62°N, 78.47°W	430	—	8060
PtL	Pretty Lake[22†]	41.60°N, 85.30°W	294	74.5	7060
QL	Quadrangle Lake[23*]	46.43°N, 84.38°W	312	‡	6660
QS	Quillin Site[24†]	41.00°N, 81.97°W	305	—	10850
RdL	Radtke Lake[6]	43.47°N, 88.1°W	274	4.0	6250
RsL	Rose Lake[25†]	41.90°N, 77.90°W	690	‡	10920
SiL	Silver Lake[26†]	40.40°N, 83.70°W	332	86	10520
SS	Stotzel-Leis Site[24†]	40.20°N, 84.70°W	312	—	11500
VB	Vestaburg Bog[27†]	43.42°N, 84.75°W	255	1	8260
VL	Van Nostrand Lake[28†]	44.00°N, 79.40°W	297	‡	8980
WnL	Wintergreen Lake[29†]	42.42°N, 85.38°W	271	14.6	7420

References: [1]this study, [2]Petty (1994), [3]H. Delcourt (unpublished), Nester (1998), [4]Futyma (1982), [5]Woods and Davis (1989), [6]Webb (1983, 1987), [7]Kapp *et al.* (1969), [8]Bennett (1987), [9]Ahearn and Bailey (1980), [10]Rasmussen (1982), [11]Bailey (1972), [12]Kapp (1977a), [13]McAndrews (1981), [14]Kerfoot (1974), [15]Warner *et al.* (1984), [16]Lawrenz (1975), [17]Bennett (1987, 1988), [18]Liu (1990), [19]Futyma and Miller (1986), [20]Saarnisto (1974), [21]Miller (1973), [22]Williams (1974), [23]Terasmae (1967), [24]Shane (1987), [25]Cotter and Crowl (1981), [26]Ogden (1963), [27]Gilliam *et al.* (1967), [28]McAndrews (1970, 1976), [29]Manny *et al.* (1978), [30]Whitney (1995), [31]Whitney (1992), [32]Veatch *et al.* (1929), [33]G. Whitney (personal communication), [34]Berndt (1977), [35]Schwenner (1989), [36]Roberts (1988).

[§] The letters "ort" in parentheses follow soil types which contain ortstein layers in the B horizon.

* Percent beech pollen from these sites were taken directly from published pollen diagrams and converted to % Total Terrestrial Pollen when necessary.

[†] Beech pollen data from these sites obtained from the NOAA pollen database maintained by Eric Grimm at the Illinois State Museum in Springfield , Illinois, USA.

‡ Data not available.

Appendix B: Chemical treatment used for extraction of pollen and spores.

1. Transfer sediment and tablet(s) of exotic pollen to a 15-ml polypropylene centrifuge tube with 10 ml 10% hydrocholoric acid (HCl), stir, heat several min. in a boiling water bath until reaction with calcareous sediments and matrix of Eucalyptus tablets stops; add tertiary butyl alcohol (TBA) to wet particles that otherwise might float on the meniscus; centrifuge 2 min., decant supernatant into a bucket containing sodium bicarbonate to neutralize excess acid.

2. Add 10 ml 10% potassium hydroxide (KOH); stir; heat for 2 min. on boiling water bath; add TBA; centrifuge 2 min.; decant. This step disperses organic matter and breaks down humic substances.

3. Add 10 ml warm 5% sodium pyrophosphate; stir; heat for 5 min. in water bath. This step assists in deflocculating clay-sized sediments.

4. If sediment is sandy or contains large bits of organic matter, sieve through a 250 µm mesh screen with distilled water. Retain all material collected in a beaker beneath screen. Concentrate by centrifugation, adding TBA each time; decant.

5. Wash with 10 ml distilled water until supernatant is clear, stir, add TBA, centrifuge, and decant after each water wash. These washes remove humic substances and clay-size particles that, if not removed, would later interfere with dispersion.

6. Add 10 ml 10% HCl, stir, add TBA, centrifuge, decant.

7. Add 5 ml concentrated hydrofluoric acid (HF), stir, heat on boiling water bath 20 min., stirring after 10 min.; add 95% ethyl alcohol (EtOH) to reduce density, add TBA, centrifuge, decant; if still silty, repeat this step. This step removes silicate minerals.

8. Add 5 ml concentrated HCl, stir, heat on boiling water bath 20 min., stirring after 10 min., add EtOH, centrifuge, decant; repeat if necessary. If this material threatens to boil over, squirt with EtOH in centrifuge tube. This step removes the silicofluoride gel that may form from HF reaction with silicate-rich sediments.

9. Rinse with 10 ml glacial acetic acid to further dehydrate, stir, add TBA, centrifuge, decant.

10. Acetolyze with 4.5 ml acetic anhydride + 0.5 ml concentrated sulfuric acid, added directly to each centrifuge tube and keep well-stirred; heat 1 min. in boiling water bath, stirring well after 30 sec.; add 5 ml glacial acetic acid, stir, centrifuge, decant.

11. Rinse with 10 ml glacial acetic acid to remove the acid-soluble products of acetylation, stir, add TBA, centrifuge, decant.

12. Rinse with 7 ml water + 3 ml 10% KOH to neutralize and disperse material, stir, add TBA, centrifuge, decant.

13. Add 10 ml water + 1 drop 0.5% Safranin O stain, stir, add TBA, centrifuge, decant.

14. Wash with 10 ml TBA to dehydrate, stir, centrifuge, decant.

15. Transfer to labeled 1 dram vials with TBA, centrifuge, decant.

16. Add a few drops of silicone oil (2000 centistokes viscosity), stir, allow TBA to evaporate overnight in a dust-free place.

Appendix C: List of radiocarbon dates from this study (BETA, Beta Analytic Inc., Coral Gables, FL).

Lab No.	**Date (yr BP)** (^{13}C corrected)	**Material (depth interval)** [1]	**Site Name (Abbrev.)**	**Elevation of site m (ft)**	**Elevation of ^{14}C date(m)**
Beta-64045	2760±70	Organic sand (110-130 cm)	O'Neil Creek Bog[2]	191.7 (629)	190.3
Beta-64042	190±70	Clay (33-50 cm)	Carnegie Trail Pond	177.7 (583)	176.9
Beta-64043	1370±70	Peat (115-125 cm)	US 2 Bog[3]	180.7 (593)	179.5
Beta-66026	1860±60	Peat (113-123 cm)	Greylock Bog[4]	186.5 (612)	185.3
Beta-66027	2750±70	Peat (165-175 cm)	Greylock Bog[4]	186.5 (612)	184.8
Beta-64044	3410±130	Organic sand (195-215 cm)*	Greylock Bog[4]	186.5 (612)	184.5
Beta-72545	1550±60	Peaty clay (40-50 cm)	Beaverhouse Lake (BL)	192.6 (632)	190.3
Beta-72546	2870±60	Peaty clay (85-95 cm)	Beaverhouse Lake (BL)	192.6 (632)	189.9
Beta-71074	3330±60	Peaty clay (135-145 cm)	Beaverhouse Lake (BL)	192.6 (632)	189.4
Beta-71075	4020±80	Peaty clay (180-190 cm)	Beaverhouse Lake (BL)	192.6 (632)	188.9
Beta-64047	5390±70	Peaty clay (224-230 cm)	Beaverhouse Lake (BL)	192.6 (632)	188.5

[1] Depth interval is reported as centimeters below water/sediment interface.
[2] Referred to as Great Lakes Pipeline 629' in Petty (1994) and Petty *et al.* (1996).
[3] Referred to as US 2 Pond in Petty (1994) and Petty *et al.* (1996).
[4] Referred to as Great Lakes Pipeline 612' in Petty (1994) and Petty *et al.* (1996).
* Note correction in depth interval made for sediment used for ^{14}C date. Reported as 181.-217. cm in Petty (1994) and Petty *et al.* (1996).

Appendix D. Chronologies for lake-sediment cores from Beaverhouse Lake, Greylock Bog, US 2 Bog, and Carnegie Trail Pond, Mackinac County, Michigan.

Radiocarbon Age ±1 std. dev. (yr BP)[1]	Depth Interval (cm) (below platform)	Depth Interval (cm) (below w/s I)[5]	Midpoint Depth (cm) (below w/s I)	Sediment Accumulation(cm) (core thickness)	Time Span (years)	Sediment Accumulation Rate (cm/yr)	Sediment Deposition Rate (yr/cm)
BEAVERHOUSE LAKE							
-43 (AD 1993)[2]	210.0	0.0	0.0	19.0	113	0.17	5.95
70 ± 5 (*Ambrosia* rise)[3]	239.0	19.0	19.0	26.0	1480	0.02	56.92
1550 ± 60 (Beta-72545)[4]	250.0-260.0	40.0-50.0	45.0	45.0	1320	0.03	29.33
2870 ± 60 (Beta-72546)	295.0-305.0	85.0-95.0	90.0	50.0	460	0.11	9.20
3330 ± 60 (Beta-71074)	345.0-355.0	135.0-145.0	140.0	45.0	690	0.07	15.33
4020 ± 80 (Beta-71075)	390.0-400.0	180.0-190.0	185.0	42.0	1370	0.03	32.62
5390 ± 70 (Beta-64047)	434.0-440.0	224.0-230.0	227.0				
GREYLOCK BOG							
-43 (AD 1993)	-----[6]	0.0	0.0	118.0	1903	0.06	16.13
1860 ± 60 (Beta-66026)	-----	113.0-123.0	118.0	52.0	890	0.06	17.12
2750 ± 70 (Beta-66027)	-----	165.0-175.0	170.0	35.0	660	0.05	18.86
3410 ± 130 (Beta-64044)	-----	195.0-215.0	205.0				

Appendix D. (continued)

Radiocarbon Age ±1 std dev (yr BP)[1]	Depth Interval (cm) (below platform)	Depth Interval (cm) (below w/s I)[5]	Midpoint Depth (cm) (below w/s I)	Sediment Accumulation(cm) (core thickness)	Time Span (years)	Sediment Accumulation Rate (cm/yr)	Sediment Deposition Rate (yr/cm)
US 2 BOG							
-43 (AD 1993)	-----	0.0	0.0	120.0	1413	0.08	11.78
1370 ± 70 (Beta-64043)	-----	115.0-125.0	120.0				
CARNEGIE TRAIL POND							
-43 (AD 1993)	-----	0.0	0.0	41.5	233	0.18	5.61
190 ± 70 (Beta-64042)	-----	33.0-50.0	41.5				

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[1] Radiocarbon dates are ^{13}C corrected and presented in years Before Present (yr BP).

[2] Sediment core was collected in June 1993, radiocarbon year -43 (i.e. 43 yr after AD1950).

[3] Based on historical records (Rowe *et al.*, 1977) uplands around Beaverhouse Lake were logged in AD 1880, and is marked in the sediment core by an increase in *Ambrosia*-type pollen from 1.5% to 3.3% total terrestrial pollen.

[4] Lab number of sample sent to Beta Analytic, Inc.

[5] Depth given as centimeters below water/sediment interface.

6 Sediment core began at land surface.

Appendix E. Depth and age calculations for Beaverhouse Lake, Greylock Bog, US 2 Bog, and Carnegie Trail Pond, Mackinac County, Michigan.

BEAVERHOUSE LAKE

Depth[1] (cm)	Age (yr BP) (calculated)	Age (yr BP) (plotted)
1.0	-37	-40
17.0	58	60
19.0	70	70
20.6	161	160
22.4	263	260
24.2	366	370
26.0	468	470
27.8	571	570
29.6	673	670
31.4	775	780
33.2	878	880
35.0	980	980
36.9	1088	1090
38.7	1190	1190
40.5	1290	1290
42.3	1396	1400
44.1	1499	1500
46.7	1600	1600
50.1	1700	1700
53.5	1799	1800
56.9	1899	1900
60.3	1999	2000
63.8	2101	2100
67.2	2201	2200
70.6	2301	2300
74.0	2401	2400
77.4	2500	2500
80.8	2600	2600
84.2	2700	2700
87.6	2800	2800
93.3	2900	2900
100.0	2962	3000
115.0	3100	3100
125.9	3200	3200
136.7	3300	3300
144.6	3401	3400
154.3	3549	3550
157.6	3600	3600
164.1	3700	3700
170.7	3801	3800
177.2	3900	3900

Appendix E. (continued)

BEAVERHOUSE LAKE (continued)

Depth[1] (cm)	Age (yr BP) (calculated)	Age (yr BP) (plotted)
183.7	4000	4000
187.5	4102	4100
190.5	4199	4200
193.6	4301	4300
196.6	4398	4400
199.7	4499	4500
202.8	4601	4600
205.8	4698	4700
208.9	4800	4800
212.0	4901	4900
215.0	4999	5000
218.1	5100	5100
221.2	5201	5200
225.0	5325	5320
227.5	5406*	5410
229.0	5455*	5460

GREYLOCK BOG

Depth[1] (cm)	Age (yr BP) (calculated)	Age (yr BP) (plotted)
0.0	-43	-40
37.0	554	550
66.8	1034	1030
96.6	1515	1510
126.2	2000	2000
137.9	2201	2200
161.2	2600	2600
173.0	2807	2810
195.0	3222	3220

US 2 BOG

Depth[1] (cm)	Age (yr BP) (calculated)	Age (yr BP) (plotted)
2.5	-14	-10
47.3	514	510
89.1	1007	1010
120.0	1371	1370

CARNEGIE TRAIL POND

Depth[1] (cm)	Age (yr BP) (calculated)	Age (yr BP) (plotted)
2.5	-29	-30
43.0	198*	200

[1] Depth reported in centimeters below water/sediment interface.

*Age extrapolated using sediment accumulation rate of previous (younger) time interval.

Appendix F. List of Taxa Identified in Sediment Cores and Discussed in Text. Below is a list of all taxa identified and their common names used in the following DCA ordination scores (Appendix G) and palynomorph tabulations (Appendices H-K).

Scientific Names	**Common Names**
TREES	
Abies balsamea	Balsam fir
Acer (Total)	Maple
Acer pensylvanicum	Moosewood maple
Acer rubrum	Red maple
Acer saccharum	Sugar maple
Acer spicatum	Mountain maple
Betula	Birch
Carpinus/Ostrya type	Ironwood
Carya	Hickory
Castanea dentata	Chestnut
Celtis occidentalis	Redbud
Fagus grandifolia	American beech
Fraxinus (Total)	Ash
Fraxinus americana/pennsylvanica type	White/green ash
Fraxinus nigra	Black ash
Juglans (Total)	Walnut
Juglans cinerea	Butternut, white walnut
Juglans nigra	Black walnut
Larix laricina	Tamarack
Liquidambar styraciflua	Sweet gum
Picea	Spruce
Picea glauca	White spruce
Picea mariana	Black spruce
Pinus (Total)	Pine
Pinus banksiana/resinosa (Diploxylon)	Jack/red pine
Pinus strobus (Haploxylon)	White pine
Platanus occidentalis	Sycamore
Populus	Aspen, poplar,
Prunus	Cherry
Quercus	Oak
Salix	Willow
Thuja occidentalis/Juniperus type	White cedar/juniper
Tilia americana	Basswood
Tsuga canadensis	Hemlock
Ulmus	Elm
SHRUBS	
Alnus (Total)	Alder
Alnus crispa	Green alder
Alnus rugosa type	Speckled alder

Appendix F. (continued)

Cephalanthus occidentalis	Buttonbush
Corylus	Hazelnut
Ericaceae Tetrads	Heath family
Ilex/Nemopanthus type	Holly/mountain holly
Myrica type	Bayberry family
Morus rubra	Mulberry
Rosaceae	Rose family
Rhamnus	Buckthorn
Sambucus	Elder
Vitis	Wild grape
HERBS	
Ambrosia type	Ragweed
Artemisia	Sage, mugwort
Campanulaceae	Harebell family
Caryophyllaceae	Pink family
Chenopodium type	Goosefoot
Cornus canadensis type	Bunchberry
Cyperaceae	Sedge family
Labiatae	Mint family
Menyanthes trifoliata	Buckbean
Petalostemum	Prairie-clover
Poaceae	Grass family
Polygonum	knotweed, smartweed
Potentilla-type	Cinquefoil
Rumex	Dock, sorrel
Saxifragaceae	Saxifrage family
Thalictrum	Meadow rue
Tubuliflorae	High-spined composite
FERN AND FERN ALLIES	
Botrychium	Grape fern
Equisetum	Horsetail
Lycopodium (Total)	Clubmosses
Lycopodium annotinum	Clubmoss
Lycopodium clavatum	Running pine
Lycopodium complanatum/tristachyum	Ground cedar
Lycopodium innundatum	Clubmoss
Lycopodium lucidulum	Clubmoss
Lycopodium obscurum	Ground pine
Monolete spores undifferentiated	
Osmunda cinnamomea	Cinnamon fern
Osmunda regalis-type	Royal fern
Polypodium	Polypody
Pteridium aquilinum	Bracken fern

Appendix F. (continued)

AQUATICS	
Brasenia schreberi	Water shield
Caltha	Marsh marigold
Isoetes	Quillwort
Myriophyllum exalbescens type	Water-milfoil
Nuphar	Yellow water lily
Nymphaea	Water lily
Potamogeton	Pondweed
Sphagnum	Peat moss
Sparganium type	Bur-reed
Typha latifolia	Cattail
Utricularia	Bladderwort

Appendix G. Ordination scores from Detrended Correspondence Analysis (DCA).

Beaverhouse Lake DCA taxa scores

Taxa	DCA Axis 1	DCA Axis 2
Abies	1.71	0.91
Acer pensylvanicum	2.27	-1.44
Acer rubrum	1.49	-1.16
Acer saccharum	1.46	0.85
Acer spicatum	1.55	-3.39
Betula	1.75	0.99
Carpinus/Ostrya-type	0.68	-0.22
Carya	0.78	0.70
Castanea dentata	2.98	2.80
Celtis occidentalis	1.93	-0.69
Fagus grandifolia	2.30	-0.40
Fraxinus (total)	0.92	-0.32
Juglans (total)	1.57	0.77
Larix laricina	1.79	-0.62
Liquidambar styraciflua	0.96	3.00
Picea (total)	2.11	-0.51
Pinus banksiana/resinosa-type	-0.49	0.45
Pinus strobus	-0.10	0.00
Platanus occidentalis	-0.54	-1.02
Populus	-1.24	-3.80
Quercus	0.87	1.10
Salix	-1.45	2.50
Thuja occidentalis/Juniperus-type	1.47	1.96
Tilia americana	0.94	2.00
Tsuga canadensis	1.58	-1.47
Ulmus	1.14	0.37

Beaverhouse Lake DCA sample scores at 100 yr intervals

Age (yr BP)	Median Age (yr BP)	Beta Diversity (SD/100 yr)	DCA Axis 1	DCA Axis 2
-40	10	0.03	0.95	0.43
60	65	0.06	0.92	0.45
70	115	0.08	0.98	0.40
160	210	0.12	1.06	0.53
260	315	0.09	0.94	0.25
370	420	0.09	0.85	0.40
470	520	0.02	0.94	0.35
570	620	0.13	0.96	0.33
670	725	0.16	0.83	0.37
780	830	0.15	0.99	0.29
880	930	0.08	0.84	0.30
980	1035	0.13	0.92	0.34

Appendix G. (continued)

1090	1140	0.15	1.05	0.36
1190	1240	0.09	0.90	0.36
1290	1345	0.05	0.99	0.37
1400	1450	0.09	1.04	0.34
1500	1550	0.06	0.95	0.36
1600	1650	0.03	1.01	0.28
1700	1750	0.04	1.04	0.27
1800	1850	0.29	1.00	0.41
1900	1950	0.26	0.71	0.23
2000	2050	0.08	0.97	0.36
2100	2150	0.06	0.89	0.39
2200	2250	0.14	0.95	0.40
2300	2350	0.16	0.81	0.28
2400	2450	0.16	0.97	0.27
2500	2550	0.08	0.81	0.40
2600	2650	0.25	0.89	0.53
2700	2750	0.07	0.64	0.51
2800	2850	0.17	0.71	0.49
2900	2950	0.21	0.54	0.38
3000	3050	0.04	0.75	0.45
3100	3150	0.02	0.71	0.36
3200	3250	0.10	0.73	0.55
3300	3350	0.12	0.63	0.46
3400	3475	0.08	0.51	0.46
3550	3575	0.01	0.59	0.36
3600	3650	0.08	0.58	0.51
3700	3750	0.14	0.66	0.47
3800	3850	0.19	0.52	0.33
3900	3950	0.11	0.71	0.42
4000	4050	0.05	0.60	0.00
4100	4150	0.42	0.55	0.35
4200	4250	0.22	0.13	0.19
4300	4350	0.16	0.35	0.34
4400	4450	0.02	0.19	0.21
4500	4550	0.03	0.17	0.23
4600	4650	0.04	0.14	0.29
4700	4750	0.07	0.18	0.22
4800	4850	0.11	0.11	0.19
4900	4950	0.15	0.00	0.27
5000	5050	0.03	0.15	0.07
5100	5150	0.12	0.18	0.54
5200	5260	0.01	0.06	0.45
5320	5365	0.09	0.05	0.18
5410	5435	0.03	0.14	0.26
5460	5460		0.11	0.39

Appendix G. (continued)

DCA results for pollen spectra at 200 yr intervals for Beaverhouse Lake.

Age (yr BP)	Median Age (yr BP)	Beta Diversity (SD/200 yr)	DCA Axis 1	DCA Axis 2
-40	60	0.12	0.89	0.08
160	265	0.22	1.01	0.04
370	470	0.11	0.79	0.11
570	675	0.03	0.90	0.23
780	880	0.07	0.93	0.26
980	1085	0.03	0.86	0.22
1190	1295	0.14	0.83	0.24
1400	1500	0.03	0.97	0.23
1600	1700	0.00	0.94	0.27
1800	1900	0.04	0.94	0.18
2000	2100	0.01	0.90	0.30
2200	2300	0.01	0.89	0.22
2400	2500	0.05	0.90	0.36
2600	2700	0.22	0.85	0.22
2800	2900	0.07	0.63	0.22
3000	3100	0.05	0.70	0.35
3200	3300	0.18	0.65	0.12
3400	3500	0.06	0.47	0.13
3600	3700	0.08	0.53	0.14
3800	3900	0.05	0.45	0.24
4000	4100	0.44	0.50	0.56
4200	4300	0.08	0.06	0.33
4400	4500	0.06	0.14	0.18
4600	4700	0.01	0.08	0.22
4800	4900	0.01	0.07	0.25
5000	5100	0.08	0.08	0.39
5200	5305	0.10	0.00	0.00
5410		0.10	0.10	0.08

DCA results for pollen spectra at 500 yr intervals

Age (yr BP)	Median Age (yr BP)	Beta Diversity (SD/200 yr)	DCA Axis 1	DCA Axis 2
-40	215	0.02	0.02	0.53
470	725	0.02	0.04	0.34
980	1240	0.01	0.06	0.40
1500	1750	0.05	0.05	0.43
2000	2250	0.15	0.00	0.24
2500	2750	0.06	0.15	0.26
3000	3275	0.16	0.21	0.31
3550	3775	0.05	0.37	0.41
4000	4250	0.38	0.42	0.00
4500	4750	0.07	0.80	0.47
5000	5230	0.00	0.87	0.20
5460		0.00	0.87	0.53

Appendix G. (continued)

DCA results for pollen spectra at 1000 yr intervals for Beaverhouse Lake

Age (yr BP)	Median Age (yr BP)	Beta Diversity (SD/1000 yr)	DCA Axis 1	DCA Axis 2
-40	470	0.07	0.00	0.43
980	1490	0.01	0.07	0.26
2000	2500	0.17	0.06	0.02
3000	3500	0.29	0.23	0.08
4000	4500	0.37	0.52	0.00
5000			0.89	0.28

Appendix H. Beaverhouse Lake Palynomorph Tabulation

Beaverhouse Lake, Mackinac County, Michigan

Depth (cm below platform)	211.0				227.0				229.0				230.6			
Depth (cm below water/sediment interface)	1.0				17.0				19.0				20.6			
Age (yr BP)	-40				60				70				160			
Taxa	Count (No.)	Percent (%)	Conc. (gr cm^{-3})	Influx (gr cm^{-2} yr^{-1})	Count (No.)	Percent (%)	Conc. (gr cm^{-3})	Influx (gr cm^{-2} yr^{-1})	Count (No.)	Percent (%)	Conc. (gr cm^{-3})	Influx (gr cm^{-2} yr^{-1})	Count (No.)	Percent (%)	Conc. (gr cm^{-3})	Influx (gr cm^{-2} yr^{-1})
Abies	3	0.6	27	4.5	7	1.3	503	84.6	3	0.7	417	7.5	2	0.4	348	6.3
Acer (undiff.)	3	0.6	27	4.5	1	0.2	72	12.1	0	0.0	0	0.0	0	0.0	0	0.0
A. pensylvanicum	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	1	0.2	174	3.1
A. rubrum	0	0.0	0	0.0	2	0.4	144	24.2	0	0.0	0	0.0	2	0.4	348	6.3
A. saccharum	4	0.8	35	6.0	9	1.7	647	108.7	4	0.9	556	10.0	4	0.8	696	12.5
A. spicatum	0	0.0	0	0.0	1	0.2	72	12.1	0	0.0	0	0.0	0	0.0	0	0.0
Acer (total)	7	1.4	62	10.4	13	2.0	935	157.1	4	0.8	556	10.0	7	1.2	1218	21.9
Betula	99	19.8	877	147.3	116	22.0	8342	1401.4	108	24.8	14999	270.0	125	25.2	21747	391.5
Carpinus/Ostrya —type	1	0.2	9	1.5	9	1.7	647	108.7	4	0.9	556	10.0	3	0.6	522	9.4
Carya	0	0.0	0	0.0	1	0.2	72	12.1	0	0.0	0	0.0	1	0.2	174	3.1
Castanea dentata	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	6	1.2	1044	18.8
Celtis occidentalis	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Fagus grandifolia	15	3.0	133	22.3	12	1.9	863	145.0	10	2.0	1389	25.0	18	3.1	3132	56.4
Fraxinus (undiff.)	3	0.6	27	4.5	0	0.0	0	0.0	3	0.7	417	7.5	4	0.8	696	12.5
Fraxinus americana/pennsylvanica —type	0	0.0	0	0.0	3	0.6	216	36.2	0	0.0	0	0.0	0	0.0	0	0.0
Fraxinus nigra	0	0.0	0	0.0	1	0.2	72	12.1	0	0.0	0	0.0	1	0.2	174	3.1
Fraxinus (total)	3	0.6	27	4.5	4	0.6	288	48.3	3	0.6	417	7.5	5	0.9	870	15.7
Juglans (undiff.)	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	1	0.2	174	3.1
Juglans cinerea	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Juglans nigra	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Juglans (total)	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	1	0.2	174	3.1
Larix laricina	3	0.6	27	4.5	11	2.1	791	132.9	7	1.6	972	17.5	4	0.8	696	12.5
Liquidambar styraciflua	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Picea (undiff.)	16	3.2	142	23.8	20	3.8	1438	241.6	22	5.0	3055	55.0	20	4.0	3480	62.6
Picea marina	4	0.8	35	6.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Picea glauca	1	0.2	9	1.5	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Picea (total)	21	4.2	186	31.3	20	3.1	1438	241.6	22	4.3	3055	55.0	20	3.5	3480	62.6
Pinus (undiff.)	53	10.6	469	78.9	54	10.2	3883	652.4	35	8.0	4861	87.5	47	9.5	8177	147.2
Pinus banksiana/resinosa (Diploxylon)	56	11.2	496	83.3	62	9.6	4458	749.0	51	10.0	7083	127.5	58	10.0	10091	181.6
Pinus strobus (Haploxylon)	70	14.0	620	104.2	111	21.0	7982	1341.0	86	19.7	11944	215.0	75	15.1	13048	234.9
Pinus (total)	179	35.7	1586	266.4	227	35.2	16324	2742.4	172	33.6	23888	430.0	180	31.1	31316	563.7
Platanus occidentalis	1	0.2	9	1.5	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Populus	1	0.2	9	1.5	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Prunus	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Quercus	28	5.6	248	41.7	32	6.1	2301	386.6	26	6.0	3611	65.0	24	4.8	4175	75.2
Salix	0	0.0	0	0.0	2	0.4	144	24.2	1	0.2	139	2.5	2	0.4	348	6.3
Thuja occidentalis/Juniperus —type	28	5.6	248	41.7	38	7.2	2733	459.1	32	7.3	4444	80.0	49	9.9	8525	153.4
Tilia americana	1	0.2	9	1.5	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Tsuga canadensis	24	4.8	213	35.7	30	5.7	2157	362.4	38	8.7	5278	95.0	35	7.1	6089	109.6
Ulmus	8	1.6	71	11.9	6	1.1	431	72.5	6	1.4	833	15.0	14	2.8	2436	43.8
ARBOREAL POLLEN (TOTAL)	422	84.2	3738	628.0	528	81.9	37969	6378.8	436	85.2	60553	1090.0	496	85.7	86293	1553.3

Appendix H. Beaverhouse Lake Palynomorph Tabulation (continued).

Beaverhouse Lake, Mackinac County, Michigan

Depth (cm below platform)	211.0				227.0				229.0				230.6			
Depth (cm below water/sediment interface)	1.0				17.0				19.0				20.6			
Age (yr BP)	-40				60				70				160			
Taxa	Count (No.)	Percent (%)	Conc. (gr cm^{2})	Influx (gr cm^{2} yr^{1})	Count (No.)	Percent (%)	Conc. (gr cm^{2})	Influx (gr cm^{2} yr^{1})	Count (No.)	Percent (%)	Conc. (gr cm^{2})	Influx (gr cm^{2} yr^{1})	Count (No.)	Percent (%)	Conc. (gr cm^{2})	Influx (gr cm^{2} yr^{1})
Alnus crispa	1	0.2	9	1.5	1	0.2	72	12.1	0	0.0	0	0.0	0	0.0	0	0.0
Alnus rugosa-type	5	1.0	44	7.4	15	2.3	1079	181.2	10	1.9	1389	25.0	8	1.4	1392	25.1
Cephalanthus occidentalis	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Corylus	1	0.2	9	1.5	1	0.2	72	12.1	1	0.2	139	2.5	1	0.2	174	3.1
Ericaceae (tetrads)	1	0.2	9	1.5	1	0.2	72	12.1	1	0.2	139	2.5	0	0.0	0	0.0
Ilex/Nemopanthus —type	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	2	0.3	348	6.3
Myrica —type	4	0.8	35	6.0	17	2.6	1222	205.4	9	1.7	1250	22.5	6	1.0	1044	18.8
Moraceae	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Sambucus	1	0.2	9	1.5	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Total Shrubs	13	2.6	115	19.3	35	5.4	2517	422.8	21	4.1	2917	52.5	17	2.9	2958	53.2
Vitis	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Epiphytes	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Ambrosia —type	13	2.6	115	19.3	17	2.6	1222	205.4	17	3.3	2361	42.5	9	1.5	1566	28.2
Artemisia	8	1.6	71	11.9	2	0.3	144	24.2	6	1.1	833	15.0	1	0.2	174	3.1
Campanulaceae	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Caryophyllaceae	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Chenopodium —type	4	0.8	35	6.0	0	0.0	0	0.0	0	0.0	0	0.0	2	0.3	348	6.3
Cornus canadensis —type	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Cyperaceae	28	5.6	248	41.7	55	8.3	3955	664.5	23	4.4	3194	57.5	40	6.8	6959	125.3
Labiatae	1	0.2	9	1.5	1	0.2	72	12.1	0	0.0	0	0.0	0	0.0	0	0.0
Menyanthes trifoliata	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Petalostemum purpureum -type	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Poaceae	10	2.0	89	14.9	7	1.1	503	84.6	7	1.3	972	17.5	10	1.7	1740	31.3
Polygonum	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Potentilla —type	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Rosaceae	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Rhamnus	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Rubiaceae	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Rumex	1	0.2	9	1.5	0	0.0	0	0.0	1	0.2	139	2.5	0	0.0	0	0.0
Saxifragaceae	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Thalictrum	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Tubuliflorea	1	0.2	9	1.5	0	0.0	0	0.0	1	0.2	139	2.5	4	0.7	696	12.5
Umbelliferae	0	0.0	0	0.0	0	0.0	0	0.0	0.0	0.0	0	0.0	0.0	0.0	0	0.0
Ephedra —type	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Total NonArboreal Herbs	66	13.2	585	98.2	82	12.7	5897	990.6	55	10.7	7639	137.5	66	11.4	11483	206.7
Total Terrestrial Pollen	501	100.0	4438	745.6	645	100.0	46383	7792.3	512	100.0	71109	1280.0	579	100.0	100734	1813.2
Adiantum/Dennstaedtia	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Botrychium	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Equisetum	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Lycopodium annotinum	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Lycopodium clavatum	0	0.0	0	0.0	1	0.2	72	12.1	0	0.0	0	0.0	0	0.0	0	0.0
Lycopodium complanatum -type	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0

Appendix H. Beaverhouse Lake Palynomorph Tabulation (continued).

Beaverhouse Lake, Mackinac County, Michigan

Depth (cm below platform)	211.0				227.0				229.0				230.6			
Depth (cm below water/sediment interface)	1.0				17.0				19.0				20.6			
Age (yr BP)	-40				60				70				160			
Taxa	Count (No.)	Percent (%)	Conc. (gr cm^{-3})	Influx (gr cm^{-2} yr^{-1})	Count (No.)	Percent (%)	Conc. (gr cm^{-3})	Influx (gr cm^{-2} yr^{-1})	Count (No.)	Percent (%)	Conc. (gr cm^{-3})	Influx (gr cm^{-2} yr^{-1})	Count (No.)	Percent (%)	Conc. (gr cm^{-3})	Influx (gr cm^{-2} yr^{-1})
Lycopodium inundatum	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Lycopodium lucidulum	0	0.0	0	0.0	0	0.0	0	0.0	3	0.6	417	7.5	0	0.0	0	0.0
Lycopodium obscurum	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	1	0.2	174	3.1
Lycopodium (undiff.)	1	0.2	9	1.5	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Lycopodium (total)	1	0.2	9	1.5	1	0.2	72	12.1	3	0.6	417	7.5	1	0.2	174	3.1
Monolete spores (undiff.)	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Osmunda cinnamomea	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Osmunda regalis -type	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Polypodium	0	0.0	0	0.0	4	0.6	288	48.3	3	0.6	417	7.5	3	0.5	522	9.4
Pteridium aquilinum	3	0.6	27	4.5	4	0.6	288	48.3	3	0.6	417	7.5	5	0.8	870	15.7
Trilete spores (undiff.)	0	0.0	0	0.0	1	0.2	72	12.1	1	0.2	139	2.5	0.0	0.0	0	0.0
Selaginella	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Total Ferns and Allies	4	0.8	35	6.0	10	1.5	719	120.8	10	1.9	1389	25.0	9	1.5	1566	28.2
Unknowns	1	0.2	9	1.5	4	0.6	288	48.3	0	0.0	0	0.0	3	0.5	522	9.4
Total Upland Pollen & Spores	506	100.0	4482	753.0	659	100.0	47389	7961.4	522	100.0	72498	1305.0	591	100.0	102821	1850.8
Brasenia schreberi	15	2.8	133	22.3	24	3.5	1726	289.9	19	3.5	2639	47.5	21	3.3	3654	65.8
Caltha	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Drosera	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Isoetes	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Myriophyllum exalbescens —type	0	0.0	0	0.0	1	0.1	72	12.1	0	0.0	0	0.0	0	0.0	0	0.0
Nuphar	4	0.8	35	6.0	4	0.6	288	48.3	4	0.7	556	10.0	4	0.6	696	12.5
Nymphea	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	9	1.4	1566	28.2
Potamogeton	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Sagittaria	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Sphagnum	1	0.2	9	1.5	2	0.3	144	24.2	1	0.2	139	2.5	3	0.5	522	9.4
Typha latifolia	0	0.0	0	0.0	1	0.1	72	12.1	1	0.2	139	2.5	1	0.2	174	3.1
Sparganium —type	1	0.2	9	1.5	0	0.0	0	0.0	0	0.0	0	0.0	1	0.2	174	3.1
Utricularia	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Total Aquatics	21	4.0	186	31.3	32	4.6	2301	386.6	25	4.6	3472	62.5	39	6.2	6785	122.1
Total Determinable Pollen and Spores	527	100.0	4668	784.3	691	100.0	49691	8348.0	547	100.0	75970	1367.5	630	100.0	109606	1972.9
Indeterminate grains	13	2.4	115	19.3	16	2.3	1151	193.3	25	4.4	3472	62.5	9	1.4	1566	28.2
Total Pollen and Spores	540	100.0	4784	803.6	707	100.0	50841	8541.3	572	100.0	79442	1430.0	639	100.0	111172	2001.1
Pediastrum colonies	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	1	0.2	174	3.1
Nymphaeceae basal cells	56	10.4	496	83.3	0	0.0	0	0.0	217	37.9	30138	542.5	236	36.9	41059	739.1
Nymphaeceae sclerids	29	5.4	257	43.2	0	0.0	0	0.0	69	12.1	9583	172.5	47	7.4	8177	147.2
Eucalyptus grains counted	281				450				233				93			
No. of *Eucalyptus* tablets	1				1				1				1			
Sample volume (cm^3)	6.5				0.5				0.5				1.0			
Accumulation rate (cm yr^{-1})	0.17				0.17				0.02				0.02			
Eucalyptus grains added	16180				16180				16180				16180			
Eucalyptus concentration (gr cm^{-3})	2489				32360				32360				16180			
Total Pollen Influx (gr cm^{-2} yr^{-1})	804				8541				1430				2001			

Appendix H. Beaverhouse Lake Palynomorph Tabulation (continued).

Beaverhouse Lake, Mackinac County, Michigan																
Depth (cm below platform)	232.4				234.2				236.0				237.8			
Depth (cm below water/sediment interface)	22.4				24.2				26.0				27.8			
Age (yr BP)	260				370				470				570			
Taxa	Count (No.)	Percent (%)	Conc. (gr cm^{-3})	Influx (gr cm^{-2} yr^{-1})	Count (No.)	Percent (%)	Conc. (gr cm^{-3})	Influx (gr cm^{-2} yr^{-1})	Count (No.)	Percent (%)	Conc. (gr cm^{-3})	Influx (gr cm^{-2} yr^{-1})	Count (No.)	Percent (%)	Conc. (gr cm^{-3})	Influx (gr cm^{-2} yr^{-1})
Abies	2	0.4	400	7.2	0	0.0	0	0.0	6	1.3	1294	23.3	4	0.9	466	8.4
Acer (undiff.)	1	0.2	200	3.6	2	0.4	376	6.8	3	0.7	647	11.6	2	0.4	233	4.2
A. pensylvanicum	2	0.4	400	7.2	0	0.0	0	0.0	1	0.2	216	3.9	2	0.4	233	4.2
A. rubrum	2	0.4	400	7.2	1	0.2	188	3.4	1	0.2	216	3.9	0	0.0	0	0.0
A. saccharum	4	0.8	799	14.4	4	0.8	753	13.5	6	1.3	1294	23.3	5	1.1	582	10.5
A. spicatum	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Acer (total)	9	1.6	1798	32.4	7	1.3	1317	23.7	11	2.0	2373	42.7	9	1.7	1048	18.9
Betula	103	21.9	20575	370.3	101	20.8	19002	342.0	110	24.7	23731	427.2	102	22.6	11873	213.7
Carpinus/Ostrya —type	3	0.6	599	10.8	1	0.2	188	3.4	5	1.1	1079	19.4	2	0.4	233	4.2
Carya	1	0.2	200	3.6	0	0.0	0	0.0	3	0.7	647	11.6	3	0.7	349	6.3
Castanea dentata	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Celtis occidentalis	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	1	0.2	116	2.1
Fagus grandifolia	16	2.8	3196	57.5	13	2.4	2446	44.0	8	1.5	1726	31.1	12	2.3	1397	25.1
Fraxinus (undiff.)	2	0.4	400	7.2	2	0.4	376	6.8	2	0.4	431	7.8	2	0.4	233	4.2
Fraxinus americana/pennsylvanica —type	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Fraxinus nigra	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Fraxinus (total)	2	0.4	400	7.2	2	0.4	376	6.8	2	0.4	431	7.8	2	0.4	233	4.2
Juglans (undiff.)	1	0.2	200	3.6	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Juglans cinerea	0	0.0	0	0.0	2	0.4	376	6.8	1	0.2	216	3.9	0	0.0	0	0.0
Juglans nigra	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	1	0.2	116	2.1
Juglans (total)	1	0.2	200	3.6	2	0.4	376	6.8	1	0.2	216	3.9	1	0.2	116	2.1
Larix laricina	7	1.5	1398	25.2	6	1.2	1129	20.3	6	1.3	1294	23.3	6	1.3	698	12.6
Liquidambar styraciflua	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Picea (undiff.)	21	4.5	4195	75.5	17	3.5	3198	57.6	16	3.6	3452	62.1	18	4.0	2095	37.7
Picea marina	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Picea glauca	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Picea (total)	21	3.7	4195	75.5	17	3.1	3198	57.6	16	3.0	3452	62.1	18	3.5	2095	37.7
Pinus (undiff.)	55	11.7	10986	197.8	54	11.1	10160	182.9	45	10.1	9708	174.7	51	11.3	5937	106.9
Pinus banksiana/resinosa (Diploxylon)	56	9.9	11186	201.4	70	12.7	13170	237.1	57	10.6	12297	221.3	49	9.4	5704	102.7
Pinus strobus (Haploxylon)	97	20.6	19376	348.8	101	20.8	19002	342.0	87	19.5	18769	337.8	93	20.6	10825	194.9
Pinus (total)	208	36.7	41549	747.9	225	40.7	42331	762.0	189	35.1	40774	733.9	193	37.0	22466	404.4
Platanus occidentalis	1	0.2	200	3.6	1	0.2	188	3.4	3	0.7	647	11.6	1	0.2	116	2.1
Populus	3	0.6	599	10.8	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Prunus	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Quercus	21	4.5	4195	75.5	33	6.8	6209	111.8	25	5.6	5393	97.1	23	5.1	2677	48.2
Salix	0	0.0	0	0.0	2	0.4	376	6.8	0	0.0	0	0.0	0	0.0	0	0.0
Thuja occidentalis/Juniperus —type	22	4.7	4395	79.1	29	6.0	5456	98.2	19	4.3	4099	73.8	24	5.3	2794	50.3
Tilia americana	3	0.6	599	10.8	0	0.0	0	0.0	0	0.0	0	0.0	3	0.7	349	6.3
Tsuga canadensis	43	9.1	8589	154.6	38	7.8	7149	128.7	37	8.3	7982	143.7	41	9.1	4773	85.9
Ulmus	5	1.1	999	18.0	8	1.6	1505	27.1	5	1.1	1079	19.4	7	1.5	815	14.7
ARBOREAL POLLEN (TOTAL)	471	83.1	94084	1693.5	485	87.7	91248	1642.5	446	82.9	96217	1731.9	452	86.8	52614	947.1

Appendix H. Beaverhouse Lake Palynomorph Tabulation (continued).

Beaverhouse Lake, Mackinac County, Michigan																
Depth (cm below platform)	232.4				234.2				236.0				237.8			
Depth (cm below water/sediment interface)	22.4				24.2				26.0				27.8			
Age (yr BP)	260				370				470				570			
Taxa	Count (No.)	Percent (%)	Conc. (gr cm^{-3})	Influx (gr cm^{-2} yr^{-1})	Count (No.)	Percent (%)	Conc. (gr cm^{-3})	Influx (gr cm^{-2} yr^{-1})	Count (No.)	Percent (%)	Conc. (gr cm^{-3})	Influx (gr cm^{-2} yr^{-1})	Count (No.)	Percent (%)	Conc. (gr cm^{-3})	Influx (gr cm^{-2} yr^{-1})
Alnus crispa	0	0.0	0	0.0	3	0.5	564	10.2	0	0.0	0	0.0	1	0.2	116	2.1
Alnus rugosa-type	13	2.3	2597	46.7	8	1.4	1505	27.1	19	3.5	4099	73.8	10	1.9	1164	21.0
Cephalanthus occidentalis	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Corylus	0	0.0	0	0.0	0	0.0	0	0.0	2	0.4	431	7.8	0	0.0	0	0.0
Ericaceae (tetrads)	0	0.0	0	0.0	0	0.0	0	0.0	1	0.2	216	3.9	0	0.0	0	0.0
Ilex/Nemopanthus —type	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Myrica —type	10	1.7	1998	36.0	5	0.9	941	16.9	7	1.3	1510	27.2	4	0.7	466	8.4
Moraceae	0	0.0	0	0.0	1	0.2	188	3.4	0	0.0	0	0.0	0	0.0	0	0.0
Sambucus	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Total Shrubs	23	4.1	4594	82.7	17	3.1	3198	57.6	29	5.4	6256	112.6	15	2.9	1746	31.4
Vitis	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Epiphytes	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Ambrosia —type	12	2.1	2397	43.1	10	1.8	1881	33.9	5	0.9	1079	19.4	10	1.9	1164	21.0
Artemisia	4	0.7	799	14.4	3	0.5	564	10.2	3	0.5	647	11.6	4	0.7	466	8.4
Campanulaceae	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Caryophyllaceae	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Chenopodium —type	0	0.0	0	0.0	2	0.4	376	6.8	2	0.4	431	7.8	2	0.4	233	4.2
Cornus canadensis —type	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Cyperaceae	48	8.3	9588	172.6	30	5.3	5644	101.6	35	6.4	7551	135.9	27	5.0	3143	56.6
Labiatae	2	0.3	400	7.2	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Menyanthes trifoliata	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Petalostemum purpureum -type	0	0.0	0	0.0	0	0.0	0	0.0	6	1.1	1294	23.3	0	0.0	0	0.0
Poaceae	6	1.0	1199	21.6	4	0.7	753	13.5	7	1.3	1510	27.2	6	1.1	698	12.6
Polygonum	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Potentilla —type	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Rosaceae	0	0.0	0	0.0	0	0.0	0	0.0	2	0.4	431	7.8	0	0.0	0	0.0
Rhamnus	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Rubiaceae	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Rumex	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Saxifragaceae	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Thalictrum	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Tubuliflorea	1	0.2	200	3.6	2	0.4	376	6.8	3	0.5	647	11.6	4	0.7	466	8.4
Umbelliferae	0	0.0	0	0.0	0.0	0.0	0	0.0	0.0	0.0	0	0.0	0.0	0.0	0	0.0
Ephedra —type	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	1	0.2	116	2.1
Total NonArboreal Herbs	73	12.9	14582	262.5	51	9.2	9595	172.7	63	11.7	13591	244.6	53	10.2	6169	111.0
Total Terrestrial Pollen	567	100.0	113260	2038.7	553	100.0	104041	1872.7	538	100.0	116065	2089.2	521	100.0	60646	1091.6
Adiantum/Dennstaedtia	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Botrychium	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Equisetum	0	0.0	0	0.0	0	0.0	0	0.0	1	0.2	216	3.9	0	0.0	0	0.0
Lycopodium annotinum	2	0.3	400	7.2	0	0.0	0	0.0	0	0.0	0	0.0	3	0.6	349	6.3
Lycopodium clavatum	1	0.2	200	3.6	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Lycopodium complanatum -type	0	0.0	0	0.0	2	0.4	376	6.8	0	0.0	0	0.0	1	0.2	116	2.1

Appendix H. Beaverhouse Lake Palynomorph Tabulation (continued).

Beaverhouse Lake, Mackinac County, Michigan																
Depth (cm below platform)	232.4				234.2				236.0				237.8			
Depth (cm below water/sediment interface)	22.4				24.2				26.0				27.8			
Age (yr BP)	260				370				470				570			
Taxa	Count (No.)	Percent (%)	Conc. (gr cm^{-3})	Influx (gr cm^{-2} yr^{-1})	Count (No.)	Percent (%)	Conc. (gr cm^{-3})	Influx (gr cm^{-2} yr^{-1})	Count (No.)	Percent (%)	Conc. (gr cm^{-3})	Influx (gr cm^{-2} yr^{-1})	Count (No.)	Percent (%)	Conc. (gr cm^{-3})	Influx (gr cm^{-2} yr^{-1})
Lycopodium inundatum	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Lycopodium lucidulum	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Lycopodium obscurum	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Lycopodium (undiff.)	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Lycopodium (total)	3	0.5	599	10.8	2	0.4	376	6.8	0	0.0	0	0.0	4	0.7	466	8.4
Monolete spores (undiff.)	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Osmunda cinnamomea	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Osmunda regalis -type	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Polypodium	1	0.2	200	3.6	1	0.2	188	3.4	1	0.2	216	3.9	4	0.7	466	8.4
Pteridium aquilinum	3	0.5	599	10.8	4	0.7	753	13.5	7	1.3	1510	27.2	5	0.9	582	10.5
Trilete spores (undiff.)	0.0	0.0	0	0.0	0.0	0.0	0	0.0	0.0	0.0	0	0.0	0.0	0.0	0	0.0
Selaginella	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Total Ferns and Allies	7	1.2	1398	25.2	7	1.2	1317	23.7	9	1.6	1942	34.9	13	2.4	1513	27.2
Unknowns	3	0.5	599	10.8	3	0.5	564	10.2	1	0.2	216	3.9	2	0.4	233	4.2
Total Upland Pollen & Spores	577	100.0	115258	2074.6	563	100.0	105923	1906.6	548	100.0	118222	2128.0	536	100.0	62392	1123.1
Brasenia schreberi	30	4.8	5993	107.9	14	2.3	2634	47.4	36	6.0	7766	139.8	20	3.5	2328	41.9
Caltha	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Drosera	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Isoetes	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Myriophyllum exalbescens —type	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Nuphar	7	1.1	1398	25.2	6	1.0	1129	20.3	7	1.2	1510	27.2	2	0.4	233	4.2
Nymphea	6	1.0	1199	21.6	6	1.0	1129	20.3	5	0.8	1079	19.4	3	0.5	349	6.3
Potamogeton	0	0.0	0	0.0	0	0.0	0	0.0	1	0.2	216	3.9	1	0.2	116	2.1
Sagittaria	0	0.0	0	0.0	0	0.0	0	0.0	3	0.5	647	11.6	0	0.0	0	0.0
Sphagnum	2	0.3	400	7.2	8	1.3	1505	27.1	0	0.0	0	0.0	3	0.5	349	6.3
Typha latifolia	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Sparganium —type	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Utricularia	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Total Aquatics	45	7.2	8989	161.8	34	5.7	6397	115.1	52	8.7	11218	201.9	29	5.1	3376	60.8
Total Determinable Pollen and Spores	622	100.0	124246	2236.4	597	100.0	112319	2021.7	600	100.0	129440	2329.9	565	100.0	65768	1183.8
Indeterminate grains	9	1.4	1798	32.4	7	1.2	1317	23.7	5	0.8	1079	19.4	7	1.2	815	14.7
Total Pollen and Spores	631	100.0	126044	2268.8	604	100.0	113636	2045.5	605	100.0	130519	2349.3	572	100.0	66582	1198.5
Pediastrum colonies	0	0.0	0	0.0	10	1.7	1881	33.9	5	0.8	1079	19.4	8	1.4	931	16.8
Nymphaeceae basal cells	242	38.4	48340	870.1	266	44.0	50045	900.8	194	32.1	41852	753.3	190	33.2	22117	398.1
Nymphaeceae sclerids	30	4.8	5993	107.9	23	3.8	4327	77.9	22	3.6	4746	85.4	16	2.8	1862	33.5
Eucalyptus grains counted	81				86				75				139			
No. of *Eucalyptus* tablets	1				1				1				1			
Sample volume (cm^3)	1.0				1.0				1.0				1.0			
Accumulation rate (cm yr^{-1})	0.02				0.02				0.02				0.02			
Eucalyptus grains added	16180				16180				16180				16180			
Eucalyptus concentration (gr cm^{-3})	16180				16180				16180				16180			
Total Pollen Influx (gr cm^{-2} yr^{-1})	2269				2045				2349				1198			

Appendix H. Beaverhouse Lake Palynomorph Tabulation (continued).

Beaverhouse Lake, Mackinac County, Michigan																
Depth (cm below platform)	239.6				241.4				243.2				245.0			
Depth (cm below water/sediment interface)	29.6				31.4				33.2				35.0			
Age (yr BP)	670				780				880				980			
Taxa	Count (No.)	Percent (%)	Conc. (gr cm⁻³)	Influx (gr cm⁻² yr⁻¹)	Count (No.)	Percent (%)	Conc. (gr cm⁻³)	Influx (gr cm⁻² yr⁻¹)	Count (No.)	Percent (%)	Conc. (gr cm⁻³)	Influx (gr cm⁻² yr⁻¹)	Count (No.)	Percent (%)	Conc. (gr cm⁻³)	Influx (gr cm⁻² yr⁻¹)
Abies	4	0.8	535	9.6	4	0.9	799	14.4	6	1.1	1001	18.0	4	0.8	490	8.8
Acer (undiff.)	3	0.6	401	7.2	3	0.7	599	10.8	1	0.2	167	3.0	0	0.0	0	0.0
A. pensylvanicum	1	0.2	134	2.4	1	0.2	200	3.6	3	0.6	500	9.0	2	0.4	245	4.4
A. rubrum	2	0.4	267	4.8	1	0.2	200	3.6	1	0.2	167	3.0	0	0.0	0	0.0
A. saccharum	2	0.4	267	4.8	6	1.3	1199	21.6	5	0.9	834	15.0	1	0.2	123	2.2
A. spicatum	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Acer (total)	8	1.5	1070	19.3	11	2.1	2197	39.6	10	1.7	1668	30.0	3	0.5	368	6.6
Betula	92	19.3	12302	221.4	99	21.9	19776	356.0	120	22.6	20016	360.3	113	22.9	13851	249.3
Carpinus/Ostrya —type	6	1.3	802	14.4	3	0.7	599	10.8	0	0.0	0	0.0	3	0.6	368	6.6
Carya	1	0.2	134	2.4	0	0.0	0	0.0	0	0.0	0	0.0	2	0.4	245	4.4
Castanea dentata	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Celtis occidentalis	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Fagus grandifolia	9	1.7	1203	21.7	15	2.9	2996	53.9	13	2.2	2168	39.0	10	1.7	1226	22.1
Fraxinus (undiff.)	3	0.6	401	7.2	3	0.7	599	10.8	0	0.0	0	0.0	1	0.2	123	2.2
Fraxinus americana/pennsylvanica —type	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	1	0.2	123	2.2
Fraxinus nigra	0	0.0	0	0.0	0	0.0	0	0.0	2	0.4	334	6.0	1	0.2	123	2.2
Fraxinus (total)	3	0.6	401	7.2	3	0.6	599	10.8	2	0.3	334	6.0	3	0.5	368	6.6
Juglans (undiff.)	0	0.0	0	0.0	0	0.0	0	0.0	1	0.2	167	3.0	1	0.2	123	2.2
Juglans cinerea	1	0.2	134	2.4	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Juglans nigra	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Juglans (total)	1	0.2	134	2.4	0	0.0	0	0.0	1	0.2	167	3.0	1	0.2	123	2.2
Larix laricina	11	2.3	1471	26.5	6	1.3	1199	21.6	9	1.7	1501	27.0	5	1.0	613	11.0
Liquidambar styraciflua	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Picea (undiff.)	14	2.9	1872	33.7	17	3.8	3396	61.1	15	2.8	2502	45.0	14	2.8	1716	30.9
Picea marina	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Picea glauca	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Picea (total)	14	2.6	1872	33.7	17	3.3	3396	61.1	15	2.6	2502	45.0	14	2.3	1716	30.9
Pinus (undiff.)	55	11.6	7355	132.4	70	15.5	13983	251.7	46	8.7	7673	138.1	61	12.3	7477	134.6
Pinus banksiana/resinosa (Diploxylon)	62	11.7	8291	149.2	49	9.4	9788	176.2	65	11.2	10842	195.2	60	9.9	7355	132.4
Pinus strobus (Haploxylon)	109	22.9	14575	262.4	83	18.3	16580	298.4	140	26.4	23353	420.3	102	20.6	12503	225.0
Pinus (total)	226	42.7	30220	544.0	202	38.8	40350	726.3	251	43.4	41868	753.6	223	36.9	27334	492.0
Platanus occidentalis	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Populus	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Prunus	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Quercus	26	5.5	3477	62.6	23	5.1	4594	82.7	32	6.0	5338	96.1	34	6.9	4168	75.0
Salix	1	0.2	134	2.4	0	0.0	0	0.0	1	0.2	167	3.0	0	0.0	0	0.0
Thuja occidentalis/Juniperus —type	31	6.5	4145	74.6	20	4.4	3995	71.9	16	3.0	2669	48.0	24	4.9	2942	53.0
Tilia americana	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Tsuga canadensis	33	6.9	4413	79.4	44	9.7	8789	158.2	46	8.7	7673	138.1	46	9.3	5638	101.5
Ulmus	10	2.1	1337	24.1	6	1.3	1199	21.6	9	1.7	1501	27.0	9	1.8	1103	19.9
ARBOREAL POLLEN (TOTAL)	476	90.0	63650	1145.7	453	87.1	90488	1628.8	531	91.7	88573	1594.3	494	81.8	60552	1089.9

Appendix H. Beaverhouse Lake Palynomorph Tabulation (continued).

Beaverhouse Lake, Mackinac County, Michigan

Depth (cm below platform)	239.6				241.4				243.2				245.0			
Depth (cm below water/sediment interface)	29.6				31.4				33.2				35.0			
Age (yr BP)	670				780				880				980			
Taxa	Count (No.)	Percent (%)	Conc. (gr cm^{-3})	Influx (gr cm^{-2} yr^{-1})	Count (No.)	Percent (%)	Conc. (gr cm^{-3})	Influx (gr cm^{-2} yr^{-1})	Count (No.)	Percent (%)	Conc. (gr cm^{-3})	Influx (gr cm^{-2} yr^{-1})	Count (No.)	Percent (%)	Conc. (gr cm^{-3})	Influx (gr cm^{-2} yr^{-1})
Alnus crispa	0	0.0	0	0.0	1	0.2	200	3.6	0	0.0	0	0.0	3	0.5	368	6.6
Alnus rugosa-type	10	1.9	1337	24.1	7	1.3	1398	25.2	8	1.4	1334	24.0	14	2.3	1716	30.9
Cephalanthus occidentalis	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Corylus	0	0.0	0	0.0	6	1.1	1199	21.6	0	0.0	0	0.0	2	0.3	245	4.4
Ericaceae (tetrads)	0	0.0	0	0.0	1	0.2	200	3.6	0	0.0	0	0.0	1	0.2	123	2.2
Ilex/Nemopanthus —type	3	0.6	401	7.2	0	0.0	0	0.0	0	0.0	0	0.0	2	0.3	245	4.4
Myrica —type	6	1.1	802	14.4	6	1.1	1199	21.6	5	0.9	834	15.0	11	1.8	1348	24.3
Moraceae	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Sambucus	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Total Shrubs	19	3.6	2541	45.7	21	4.0	4195	75.5	13	2.2	2168	39.0	33	5.5	4045	72.8
Vitis	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Epiphytes	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Ambrosia —type	5	0.9	669	12.0	1	0.2	200	3.6	5	0.9	834	15.0	5	0.8	613	11.0
Artemisia	1	0.2	134	2.4	6	1.1	1199	21.6	2	0.3	334	6.0	6	1.0	735	13.2
Campanulaceae	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Caryophyllaceae	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Chenopodium —type	0	0.0	0	0.0	0	0.0	0	0.0	1	0.2	167	3.0	0	0.0	0	0.0
Cornus canadensis —type	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Cyperaceae	19	3.5	2541	45.7	32	5.9	6392	115.1	20	3.4	3336	60.0	30	4.9	3677	66.2
Labiatae	1	0.2	134	2.4	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Menyanthes trifoliata	1	0.2	134	2.4	1	0.2	200	3.6	0	0.0	0	0.0	0	0.0	0	0.0
Petalostemum purpureum -type	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Poaceae	4	0.7	535	9.6	6	1.1	1199	21.6	4	0.7	667	12.0	32	5.2	3922	70.6
Polygonum	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Potentilla —type	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Rosaceae	1	0.2	134	2.4	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Rhamnus	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Rubiaceae	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Rumex	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	1	0.2	123	2.2
Saxifragaceae	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Thalictrum	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Tubuliflorea	2	0.4	267	4.8	0	0.0	0	0.0	3	0.5	500	9.0	3	0.5	368	6.6
Umbelliferae	0.0	0.0	0	0.0	0.0	0.0	0	0.0	0.0	0.0	0	0.0	0.0	0.0	0	0.0
Ephedra —type	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Total NonArboreal Herbs	34	6.4	4546	81.8	46	8.8	9189	165.4	35	6.0	5838	105.1	77	12.7	9438	169.9
Total Terrestrial Pollen	529	100.0	70737	1273.3	520	100.0	103872	1869.7	579	100.0	96580	1738.4	604	100.0	74036	1332.6
Adiantum/Dennstaedtia	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Botrychium	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Equisetum	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Lycopodium annotinum	0	0.0	0	0.0	4	0.7	799	14.4	0	0.0	0	0.0	2	0.3	245	4.4
Lycopodium clavatum	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	1	0.2	123	2.2
Lycopodium complanatum -type	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0

Appendix H. Beaverhouse Lake Palynomorph Tabulation (continued).

Beaverhouse Lake, Mackinac County, Michigan																
Depth (cm below platform)	239.6				241.4				243.2				245.0			
Depth (cm below water/sediment interface)	29.6				31.4				33.2				35.0			
Age (yr BP)	670				780				880				980			
Taxa	Count (No.)	Percent (%)	Conc. (gr cm^{-3})	Influx (gr cm^{-2} yr^{-1})	Count (No.)	Percent (%)	Conc. (gr cm^{-3})	Influx (gr cm^{-2} yr^{-1})	Count (No.)	Percent (%)	Conc. (gr cm^{-3})	Influx (gr cm^{-2} yr^{-1})	Count (No.)	Percent (%)	Conc. (gr cm^{-3})	Influx (gr cm^{-2} yr^{-1})
Lycopodium inundatum	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Lycopodium lucidulum	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Lycopodium obscurum	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Lycopodium (undiff.)	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Lycopodium (total)	0	0.0	0	0.0	4	0.7	799	14.4	0	0.0	0	0.0	3	0.5	368	6.6
Monolete spores (undiff.)	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Osmunda cinnamomea	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Osmunda regalis -type	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Polypodium	2	0.4	267	4.8	3	0.6	599	10.8	1	0.2	167	3.0	3	0.5	368	6.6
Pteridium aquilinum	7	1.3	936	16.8	6	1.1	1199	21.6	0	0.0	0	0.0	0	0.0	0	0.0
Trilete spores (undiff.)	0.0	0.0	0	0.0	3.0	0.6	599	10.8	0.0	0.0	0	0.0	0.0	0.0	0	0.0
Selaginella	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Total Ferns and Allies	9	1.7	1203	21.7	16	3.0	3196	57.5	1	0.2	167	3.0	6	1.0	735	13.2
Unknowns	1	0.2	134	2.4	3	0.6	599	10.8	0	0.0	0	0.0	2	0.3	245	4.4
Total Upland Pollen & Spores	539	100.0	72075	1297.3	539	100.0	107667	1938.0	580	100.0	96746	1741.4	612	100.0	75016	1350.3
Brasenia schreberi	31	5.4	4145	74.6	17	3.0	3396	61.1	20	3.3	3336	60.0	16	2.5	1961	35.3
Caltha	0	0.0	0	0.0	1	0.2	200	3.6	0	0.0	0	0.0	0	0.0	0	0.0
Drosera	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Isoetes	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Myriophyllum exalbescens —type	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Nuphar	5	0.9	669	12.0	0	0.0	0	0.0	6	1.0	1001	18.0	9	1.4	1103	19.9
Nymphea	1	0.2	134	2.4	4	0.7	799	14.4	3	0.5	500	9.0	6	0.9	735	13.2
Potamogeton	1	0.2	134	2.4	3	0.5	599	10.8	2	0.3	334	6.0	1	0.2	123	2.2
Sagittaria	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Sphagnum	1	0.2	134	2.4	1	0.2	200	3.6	3	0.5	500	9.0	2	0.3	245	4.4
Typha latifolia	1	0.2	134	2.4	0	0.0	0	0.0	1	0.2	167	3.0	2	0.3	245	4.4
Sparganium —type	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Utricularia	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Total Aquatics	40	6.9	5349	96.3	26	4.6	5194	93.5	35	5.7	5838	105.1	36	5.6	4413	79.4
Total Determinable Pollen and Spores	579	100.0	77423	1393.6	565	100.0	112860	2031.5	615	100.0	102585	1846.5	648	100.0	79429	1429.7
Indeterminate grains	4	0.7	535	9.6	15	2.6	2996	53.9	5	0.8	834	15.0	3	0.5	368	6.6
Total Pollen and Spores	583	100.0	77958	1403.2	580	100.0	115857	2085.4	620	100.0	103419	1861.5	651	100.0	79797	1436.3
Pediastrum colonies	3	0.5	401	7.2	0	0.0	0	0.0	0	0.0	0	0.0	1	0.2	123	2.2
Nymphaeceae basal cells	96	16.5	12837	231.1	154	26.6	30762	553.7	67	10.8	11176	201.2	103	15.8	12625	227.3
Nymphaeceae sclerids	35	6.0	4680	84.2	12	2.1	2397	43.1	5	0.8	834	15.0	20	3.1	2452	44.1
Eucalyptus grains counted	121				81				97				132			
No. of *Eucalyptus* tablets	1				1				1				1			
Sample volume (cm^3)	1.0				1.0				1.0				1.0			
Accumulation rate (cm yr^{-1})	0.02				0.02				0.02				0.02			
Eucalyptus grains added	16180				16180				16180				16180			
Eucalyptus concentration (gr cm^{-3})	16180				16180				16180				16180			
Total Pollen Influx (gr cm^{-2} yr^{-1})	1403				2085				1862				1436			

Appendix H. Beaverhouse Lake Palynomorph Tabulation (continued).

Beaverhouse Lake, Mackinac County, Michigan																
Depth (cm below platform)	246.9				248.7				250.5				252.3			
Depth (cm below water/sediment interface)	36.9				38.7				40.5				42.3			
Age (yr BP)	1090				1190				1290				1400			
Taxa	Count (No.)	Percent (%)	Conc. (gr cm^{-3})	Influx (gr cm^{-2} yr^{-1})	Count (No.)	Percent (%)	Conc. (gr cm^{-3})	Influx (gr cm^{-2} yr^{-1})	Count (No.)	Percent (%)	Conc. (gr cm^{-3})	Influx (gr cm^{-2} yr^{-1})	Count (No.)	Percent (%)	Conc. (gr cm^{-3})	Influx (gr cm^{-2} yr^{-1})
Abies	4	0.8	809	14.6	1	0.2	99	1.8	4	0.8	789	14.2	3	0.6	422	7.6
Acer (undiff.)	1	0.2	202	3.6	4	0.9	395	7.1	4	0.8	789	14.2	5	1.0	703	12.7
A. pensylvanicum	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
A. rubrum	3	0.6	607	10.9	1	0.2	99	1.8	0	0.0	0	0.0	1	0.2	141	2.5
A. saccharum	3	0.6	607	10.9	3	0.7	296	5.3	4	0.8	789	14.2	2	0.4	281	5.1
A. spicatum	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Acer (total)	7	1.3	1416	25.5	8	1.5	789	14.2	8	1.5	1579	28.4	8	1.3	1126	20.3
Betula	123	25.5	24877	447.8	96	20.9	9471	170.5	120	25.2	23678	426.2	126	24.1	17728	319.1
Carpinus/Ostrya —type	2	0.4	405	7.3	4	0.9	395	7.1	3	0.6	592	10.7	3	0.6	422	7.6
Carya	1	0.2	202	3.6	0	0.0	0	0.0	4	0.8	789	14.2	1	0.2	141	2.5
Castanea dentata	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Celtis occidentalis	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Fagus grandifolia	16	3.0	3236	58.2	13	2.5	1283	23.1	14	2.6	2762	49.7	21	3.4	2955	53.2
Fraxinus (undiff.)	0	0.0	0	0.0	1	0.2	99	1.8	0	0.0	0	0.0	4	0.8	563	10.1
Fraxinus americana/pennsylvanica —type	1	0.2	202	3.6	0	0.0	0	0.0	0	0.0	0	0.0	2	0.4	281	5.1
Fraxinus nigra	2	0.4	405	7.3	0	0.0	0	0.0	1	0.2	197	3.6	1	0.2	141	2.5
Fraxinus (total)	3	0.6	607	10.9	1	0.2	99	1.8	1	0.2	197	3.6	7	1.1	985	17.7
Juglans (undiff.)	1	0.2	202	3.6	1	0.2	99	1.8	2	0.4	395	7.1	0	0.0	0	0.0
Juglans cinerea	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Juglans nigra	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Juglans (total)	1	0.2	202	3.6	1	0.2	99	1.8	2	0.4	395	7.1	0	0.0	0	0.0
Larix laricina	5	1.0	1011	18.2	6	1.3	592	10.7	4	0.8	789	14.2	6	1.1	844	15.2
Liquidambar styraciflua	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Picea (undiff.)	16	3.3	3236	58.2	10	2.2	987	17.8	14	2.9	2762	49.7	17	3.3	2392	43.1
Picea marina	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Picea glauca	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Picea (total)	16	3.0	3236	58.2	10	1.9	987	17.8	14	2.6	2762	49.7	17	2.8	2392	43.1
Pinus (undiff.)	74	15.4	14967	269.4	83	18.1	8189	147.4	62	13.0	12234	220.2	60	11.5	8442	152.0
Pinus banksiana/resinosa (Diploxylon)	44	8.2	8899	160.2	37	7.0	3650	65.7	47	8.7	9274	166.9	45	7.4	6331	114.0
Pinus strobus (Haploxylon)	79	16.4	15978	287.6	111	24.2	10951	197.1	92	19.3	18153	326.8	100	19.2	14070	253.3
Pinus (total)	197	36.8	39843	717.2	231	43.6	22790	410.2	201	37.0	39661	713.9	205	33.6	28843	519.2
Platanus occidentalis	0	0.0	0	0.0	0	0.0	0	0.0	1	0.2	197	3.6	0	0.0	0	0.0
Populus	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Prunus	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Quercus	30	6.2	6068	109.2	16	3.5	1579	28.4	23	4.8	4538	81.7	29	5.6	4080	73.4
Salix	1	0.2	202	3.6	1	0.2	99	1.8	1	0.2	197	3.6	0	0.0	0	0.0
Thuja occidentalis/Juniperus —type	21	4.4	4247	76.5	27	5.9	2664	47.9	23	4.8	4538	81.7	32	6.1	4502	81.0
Tilia americana	0	0.0	0	0.0	1	0.2	99	1.8	0	0.0	0	0.0	2	0.4	281	5.1
Tsuga canadensis	45	9.3	9101	163.8	33	7.2	3256	58.6	43	9.0	8485	152.7	50	9.6	7035	126.6
Ulmus	10	2.1	2023	36.4	10	2.2	987	17.8	10	2.1	1973	35.5	12	2.3	1688	30.4
ARBOREAL POLLEN (TOTAL)	482	89.9	97485	1754.7	459	86.6	45284	815.1	476	87.7	93923	1690.6	522	85.6	73443	1322.0

Appendix H. Beaverhouse Lake Palynomorph Tabulation (continued).

Beaverhouse Lake, Mackinac County, Michigan																
Depth (cm below platform)	246.9				248.7				250.5				252.3			
Depth (cm below water/sediment interface)	36.9				38.7				40.5				42.3			
Age (yr BP)	1090				1190				1290				1400			
Taxa	Count (No.)	Percent (%)	Conc. (gr cm^{-3})	Influx (gr cm^{-2} yr^{-1})	Count (No.)	Percent (%)	Conc. (gr cm^{-3})	Influx (gr cm^{-2} yr^{-1})	Count (No.)	Percent (%)	Conc. (gr cm^{-3})	Influx (gr cm^{-2} yr^{-1})	Count (No.)	Percent (%)	Conc. (gr cm^{-3})	Influx (gr cm^{-2} yr^{-1})
Alnus crispa	3	0.6	607	10.9	0	0.0	0	0.0	0	0.0	0	0.0	1	0.2	141	2.5
Alnus rugosa-type	9	1.7	1820	32.8	17	3.1	1677	30.2	10	1.8	1973	35.5	15	2.4	2110	38.0
Cephalanthus occidentalis	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Corylus	1	0.2	202	3.6	1	0.2	99	1.8	0	0.0	0	0.0	3	0.5	422	7.6
Ericaceae (tetrads)	0	0.0	0	0.0	0	0.0	0	0.0	1	0.2	197	3.6	0	0.0	0	0.0
Ilex/Nemopanthus —type	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Myrica —type	2	0.4	405	7.3	9	1.7	888	16.0	6	1.1	1184	21.3	13	2.1	1829	32.9
Moraceae	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Sambucus	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Total Shrubs	15	2.8	3034	54.6	27	5.1	2664	47.9	17	3.1	3354	60.4	32	5.2	4502	81.0
Vitis	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Epiphytes	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Ambrosia —type	3	0.6	607	10.9	4	0.7	395	7.1	6	1.1	1184	21.3	3	0.5	422	7.6
Artemisia	4	0.7	809	14.6	0	0.0	0	0.0	6	1.1	1184	21.3	4	0.6	563	10.1
Campanulaceae	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Caryophyllaceae	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Chenopodium —type	0	0.0	0	0.0	0	0.0	0	0.0	1	0.2	197	3.6	1	0.2	141	2.5
Cornus canadensis —type	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Cyperaceae	27	5.0	5461	98.3	37	6.8	3650	65.7	27	4.9	5328	95.9	35	5.6	4924	88.6
Labiatae	1	0.2	202	3.6	0	0.0	0	0.0	0	0.0	0	0.0	2	0.3	281	5.1
Menyanthes trifoliata	0	0.0	0	0.0	0	0.0	0	0.0	1	0.2	197	3.6	0	0.0	0	0.0
Petalostemum purpureum -type	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Poaceae	1	0.2	202	3.6	1	0.2	99	1.8	8	1.5	1579	28.4	10	1.6	1407	25.3
Polygonum	0	0.0	0	0.0	1	0.2	99	1.8	0	0.0	0	0.0	0	0.0	0	0.0
Potentilla —type	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Rosaceae	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Rhamnus	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Rubiaceae	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Rumex	1	0.2	202	3.6	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Saxifragaceae	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Thalictrum	0	0.0	0	0.0	0	0.0	0	0.0	1	0.2	197	3.6	0	0.0	0	0.0
Tubuliflorea	2	0.4	405	7.3	1	0.2	99	1.8	0	0.0	0	0.0	1	0.2	141	2.5
Umbelliferae	0.0	0.0	0	0.0	0.0	0.0	0	0.0	0.0	0.0	0	0.0	0.0	0.0	0	0.0
Ephedra —type	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Total NonArboreal Herbs	39	7.3	7888	142.0	44	8.3	4341	78.1	50	9.2	9866	177.6	56	9.2	7879	141.8
Total Terrestrial Pollen	536	100.0	108406	1951.3	530	100.0	52289	941.2	543	100.0	107143	1928.6	610	100.0	85824	1544.8
Adiantum/Dennstaedtia	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Botrychium	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Equisetum	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	1	0.2	141	2.5
Lycopodium annotinum	0	0.0	0	0.0	1	0.2	99	1.8	0	0.0	0	0.0	0	0.0	0	0.0
Lycopodium clavatum	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Lycopodium complanatum -type	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0

Appendix H. Beaverhouse Lake Palynomorph Tabulation (continued).

Beaverhouse Lake, Mackinac County, Michigan																
Depth (cm below platform)	246.9				248.7				250.5				252.3			
Depth (cm below water/sediment interface)	36.9				38.7				40.5				42.3			
Age (yr BP)	1090				1190				1290				1400			
Taxa	Count (No.)	Percent (%)	Conc. (gr cm^{-3})	Influx (gr cm^{-2} yr^{-1})	Count (No.)	Percent (%)	Conc. (gr cm^{-3})	Influx (gr cm^{-2} yr^{-1})	Count (No.)	Percent (%)	Conc. (gr cm^{-3})	Influx (gr cm^{-2} yr^{-1})	Count (No.)	Percent (%)	Conc. (gr cm^{-3})	Influx (gr cm^{-2} yr^{-1})
Lycopodium inundatum	1	0.2	202	3.6	0	0.0	0	0.0	1	0.2	197	3.6	0	0.0	0	0.0
Lycopodium lucidulum	1	0.2	202	3.6	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Lycopodium obscurum	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Lycopodium (undiff.)	1	0.2	202	3.6	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Lycopodium (total)	3	0.6	607	10.9	1	0.2	99	1.8	1	0.2	197	3.6	0	0.0	0	0.0
Monolete spores (undiff.)	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Osmunda cinnamomea	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Osmunda regalis -type	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Polypodium	0	0.0	0	0.0	3	0.6	296	5.3	1	0.2	197	3.6	4	0.6	563	10.1
Pteridium aquilinum	2	0.4	405	7.3	6	1.1	592	10.7	1	0.2	197	3.6	2	0.3	281	5.1
Trilete spores (undiff.)	0.0	0.0	0	0.0	1.0	0.2	99	1.8	0.0	0.0	0	0.0	0.0	0.0	0	0.0
Selaginella	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Total Ferns and Allies	5	0.9	1011	18.2	11	2.0	1085	19.5	3	0.5	592	10.7	7	1.1	985	17.7
Unknowns	2	0.4	405	7.3	3	0.6	296	5.3	3	0.5	592	10.7	4	0.6	563	10.1
Total Upland Pollen & Spores	543	100.0	109822	1976.8	544	100.0	53670	966.1	549	100.0	108327	1949.9	621	100.0	87372	1572.7
Brasenia schreberi	21	3.6	4247	76.5	31	5.3	3058	55.1	16	2.7	3157	56.8	30	4.4	4221	76.0
Caltha	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Drosera	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	2	0.3	281	5.1
Isoetes	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Myriophyllum exalbescens —type	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Nuphar	2	0.3	405	7.3	3	0.5	296	5.3	7	1.2	1381	24.9	7	1.0	985	17.7
Nymphea	7	1.2	1416	25.5	7	1.2	691	12.4	8	1.4	1579	28.4	2	0.3	281	5.1
Potamogeton	4	0.7	809	14.6	0	0.0	0	0.0	4	0.7	789	14.2	4	0.6	563	10.1
Sagittaria	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Sphagnum	6	1.0	1214	21.8	4	0.7	395	7.1	3	0.5	592	10.7	7	1.0	985	17.7
Typha latifolia	2	0.3	405	7.3	0	0.0	0	0.0	1	0.2	197	3.6	2	0.3	281	5.1
Sparganium —type	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Utricularia	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Total Aquatics	42	7.2	8495	152.9	45	7.6	4440	79.9	39	6.6	7695	138.5	54	8.0	7598	136.8
Total Determinable Pollen and Spores	585	100.0	118316	2129.7	589	100.0	58110	1046.0	588	100.0	116022	2088.4	675	100.0	94970	1709.5
Indeterminate grains	6	1.0	1214	21.8	19	3.1	1875	33.7	10	1.7	1973	35.5	9	1.3	1266	22.8
Total Pollen and Spores	591	100.0	119530	2151.5	608	100.0	59984	1079.7	598	100.0	117996	2123.9	684	100.0	96236	1732.2
Pediastrum colonies	0	0.0	0	0.0	0	0.0	0	0.0	3	0.5	592	10.7	0	0.0	0	0.0
Nymphaeceae basal cells	106	17.9	21439	385.9	176	28.9	17364	312.6	83	13.9	16377	294.8	160	23.4	22511	405.2
Nymphaeceae sclerids	19	3.2	3843	69.2	24	3.9	2368	42.6	27	4.5	5328	95.9	21	3.1	2955	53.2
Eucalyptus grains counted	80				164				82				115			
No. of *Eucalyptus* tablets	1				1				1				1			
Sample volume (cm^3)	1.0				1.0				1.0				1.0			
Accumulation rate (cm yr^{-1})	0.02				0.02				0.02				0.02			
Eucalyptus grains added	16180				16180				16180				16180			
Eucalyptus concentration (gr cm^{-3})	16180				16180				16180				16180			
Total Pollen Influx (gr cm^{-2} yr^{-1})	2152				1080				2124				1732			

Appendix H. Beaverhouse Lake Palynomorph Tabulation (continued).

Beaverhouse Lake, Mackinac County, Michigan																
Depth (cm below platform)	254.1				256.7				260.1				263.5			
Depth (cm below water/sediment interface)	44.1				46.7				50.1				53.5			
Age (yr BP)	1500				1600				1700				1800			
Taxa	Count (No.)	Percent (%)	Conc. (gr cm^{-3})	Influx (gr cm^{-2} yr^{-1})	Count (No.)	Percent (%)	Conc. (gr cm^{-3})	Influx (gr cm^{-2} yr^{-1})	Count (No.)	Percent (%)	Conc. (gr cm^{-3})	Influx (gr cm^{-2} yr^{-1})	Count (No.)	Percent (%)	Conc. (gr cm^{-3})	Influx (gr cm^{-2} yr^{-1})
Abies	3	0.6	382	6.9	3	0.6	558	19.0	1	0.2	207	7.1	4	0.8	1294	44.0
Acer (undiff.)	4	0.8	510	9.2	3	0.6	558	19.0	1	0.2	207	7.1	0	0.0	0	0.0
A. pensylvanicum	0	0.0	0	0.0	0	0.0	0	0.0	4	0.8	830	28.2	1	0.2	324	11.0
A. rubrum	0	0.0	0	0.0	1	0.2	186	6.3	0	0.0	0	0.0	4	0.8	1294	44.0
A. saccharum	5	1.0	637	11.5	3	0.6	558	19.0	9	1.9	1867	63.5	7	1.5	2265	77.0
A. spicatum	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Acer (total)	9	1.7	1147	20.6	7	1.2	1302	44.3	14	2.5	2904	98.7	12	2.3	3883	132.0
Betula	103	21.3	13122	236.2	112	21.4	20829	708.2	128	26.5	26552	902.8	106	22.2	34302	1166.3
Carpinus/Ostrya —type	1	0.2	127	2.3	4	0.8	744	25.3	5	1.0	1037	35.3	2	0.4	647	22.0
Carya	2	0.4	255	4.6	2	0.4	372	12.6	2	0.4	415	14.1	1	0.2	324	11.0
Castanea dentata	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Celtis occidentalis	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Fagus grandifolia	14	2.6	1784	32.1	17	2.9	3162	107.5	12	2.2	2489	84.6	14	2.7	4530	154.0
Fraxinus (undiff.)	0	0.0	0	0.0	3	0.6	558	19.0	1	0.2	207	7.1	3	0.6	971	33.0
Fraxinus americana/pennsylvanica —type	3	0.6	382	6.9	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Fraxinus nigra	2	0.4	255	4.6	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Fraxinus (total)	5	0.9	637	11.5	3	0.5	558	19.0	1	0.2	207	7.1	3	0.6	971	33.0
Juglans (undiff.)	0	0.0	0	0.0	0	0.0	0	0.0	1	0.2	207	7.1	2	0.4	647	22.0
Juglans cinerea	1	0.2	127	2.3	0	0.0	0	0.0	0	0.0	0	0.0	1	0.2	324	11.0
Juglans nigra	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Juglans (total)	1	0.2	127	2.3	0	0.0	0	0.0	1	0.2	207	7.1	3	0.6	971	33.0
Larix laricina	7	1.4	892	16.1	6	1.1	1116	37.9	9	1.9	1867	63.5	4	0.8	1294	44.0
Liquidambar styraciflua	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Picea (undiff.)	15	3.1	1911	34.4	15	2.9	2790	94.8	11	2.3	2282	77.6	16	3.4	5178	176.0
Picea marina	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Picea glauca	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Picea (total)	15	2.8	1911	34.4	15	2.6	2790	94.8	11	2.0	2282	77.6	16	3.0	5178	176.0
Pinus (undiff.)	64	13.3	8154	146.8	64	12.2	11903	404.7	56	11.6	11616	395.0	68	14.3	22005	748.2
Pinus banksiana/resinosa (Diploxylon)	47	8.8	5988	107.8	45	7.8	8369	284.5	31	5.6	6431	218.6	38	7.2	12297	418.1
Pinus strobus (Haploxylon)	97	20.1	12358	222.4	102	19.5	18970	645.0	106	21.9	21988	747.6	100	21.0	32360	1100.2
Pinus (total)	208	38.8	26500	477.0	211	36.4	39241	1334.2	193	34.8	40035	1361.2	206	39.0	66662	2266.5
Platanus occidentalis	0	0.0	0	0.0	0	0.0	0	0.0	1	0.2	207	7.1	0	0.0	0	0.0
Populus	1	0.2	127	2.3	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Prunus	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Quercus	31	6.4	3949	71.1	29	5.5	5393	183.4	20	4.1	4149	141.1	26	5.5	8414	286.1
Salix	0	0.0	0	0.0	1	0.2	186	6.3	0	0.0	0	0.0	0	0.0	0	0.0
Thuja occidentalis/Juniperus —type	29	6.0	3695	66.5	35	6.7	6509	221.3	19	3.9	3941	134.0	37	7.8	11973	407.1
Tilia americana	2	0.4	255	4.6	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Tsuga canadensis	39	8.1	4969	89.4	69	13.2	12832	436.3	53	11.0	10994	373.8	34	7.1	11002	374.1
Ulmus	13	2.7	1656	29.8	10	1.9	1860	63.2	13	2.7	2697	91.7	9	1.9	2912	99.0
ARBOREAL POLLEN (TOTAL)	483	90.1	61535	1107.6	524	90.3	97452	3313.4	483	87.2	100192	3406.5	477	90.3	154357	5248.1

Appendix H. Beaverhouse Lake Palynomorph Tabulation (continued).

Beaverhouse Lake, Mackinac County, Michigan																
Depth (cm below platform)	254.1				256.7				260.1				263.5			
Depth (cm below water/sediment interface)	44.1				46.7				50.1				53.5			
Age (yr BP)	1500				1600				1700				1800			
Taxa	Count (No.)	Percent (%)	Conc. (gr cm^{-3})	Influx (gr cm^{-2} yr^{-1})	Count (No.)	Percent (%)	Conc. (gr cm^{-3})	Influx (gr cm^{-2} yr^{-1})	Count (No.)	Percent (%)	Conc. (gr cm^{-3})	Influx (gr cm^{-2} yr^{-1})	Count (No.)	Percent (%)	Conc. (gr cm^{-3})	Influx (gr cm^{-2} yr^{-1})
Alnus crispa	0	0.0	0	0.0	1	0.2	186	6.3	1	0.2	207	7.1	1	0.2	324	11.0
Alnus rugosa-type	13	2.4	1656	29.8	6	1.0	1116	37.9	17	3.0	3526	119.9	10	1.9	3236	110.0
Cephalanthus occidentalis	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Corylus	2	0.4	255	4.6	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Ericaceae (tetrads)	0	0.0	0	0.0	2	0.3	372	12.6	0	0.0	0	0.0	1	0.2	324	11.0
Ilex/Nemopanthus —type	0	0.0	0	0.0	0	0.0	0	0.0	1	0.2	207	7.1	0	0.0	0	0.0
Myrica —type	3	0.5	382	6.9	6	1.0	1116	37.9	13	2.3	2697	91.7	10	1.9	3236	110.0
Moraceae	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Sambucus	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Total Shrubs	18	3.4	2293	41.3	15	2.6	2790	94.8	32	5.8	6638	225.7	22	4.2	7119	242.1
Vitis	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Epiphytes	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Ambrosia —type	2	0.4	255	4.6	4	0.7	744	25.3	3	0.5	622	21.2	2	0.4	647	22.0
Artemisia	2	0.4	255	4.6	0	0.0	0	0.0	0	0.0	0	0.0	2	0.4	647	22.0
Campanulaceae	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Caryophyllaceae	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Chenopodium —type	0	0.0	0	0.0	1	0.2	186	6.3	0	0.0	0	0.0	1	0.2	324	11.0
Cornus canadensis —type	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Cyperaceae	25	4.6	3185	57.3	29	5.0	5393	183.4	29	5.2	6016	204.5	19	3.6	6148	209.0
Labiatae	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Menyanthes trifoliata	0	0.0	0	0.0	1	0.2	186	6.3	0	0.0	0	0.0	0	0.0	0	0.0
Petalostemum purpureum -type	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Poaceae	3	0.5	382	6.9	2	0.3	372	12.6	3	0.5	622	21.2	4	0.7	1294	44.0
Polygonum	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Potentilla —type	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Rosaceae	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Rhamnus	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Rubiaceae	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Rumex	3	0.5	382	6.9	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Saxifragaceae	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Thalictrum	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Tubuliflorea	0	0.0	0	0.0	4	0.7	744	25.3	3	0.5	622	21.2	1	0.2	324	11.0
Umbelliferae	0.0	0.0	0	0.0	0.0	0.0	0	0.0	1	0.2	207	7.1	0.0	0.0	0	0.0
Ephedra —type	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Total NonArboreal Herbs	35	6.5	4459	80.3	41	7.1	7625	259.3	38	6.9	7883	268.0	29	5.5	9384	319.1
Total Terrestrial Pollen	536	100.0	68287	1229.2	580	100.0	107867	3667.5	554	100.0	114919	3907.3	528	100.0	170861	5809.3
Adiantum/Dennstaedtia	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Botrychium	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Equisetum	0	0.0	0	0.0	0	0.0	0	0.0	3	0.5	622	21.2	0	0.0	0	0.0
Lycopodium annotinum	1	0.2	127	2.3	0	0.0	0	0.0	0	0.0	0	0.0	1	0.2	324	11.0
Lycopodium clavatum	0	0.0	0	0.0	1	0.2	186	6.3	1	0.2	207	7.1	0	0.0	0	0.0
Lycopodium complanatum -type	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0

Appendix H. Beaverhouse Lake Palynomorph Tabulation (continued).

Beaverhouse Lake, Mackinac County, Michigan

Depth (cm below platform)	254.1				256.7				260.1				263.5			
Depth (cm below water/sediment interface)	44.1				46.7				50.1				53.5			
Age (yr BP)	1500				1600				1700				1800			
Taxa	Count (No.)	Percent (%)	Conc. (gr cm^{-3})	Influx (gr cm^{-2} yr^{-1})	Count (No.)	Percent (%)	Conc. (gr cm^{-3})	Influx (gr cm^{-2} yr^{-1})	Count (No.)	Percent (%)	Conc. (gr cm^{-3})	Influx (gr cm^{-2} yr^{-1})	Count (No.)	Percent (%)	Conc. (gr cm^{-3})	Influx (gr cm^{-2} yr^{-1})
Lycopodium inundatum	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Lycopodium lucidulum	1	0.2	127	2.3	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Lycopodium obscurum	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Lycopodium (undiff.)	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Lycopodium (total)	2	0.4	255	4.6	1	0.2	186	6.3	1	0.2	207	7.1	1	0.2	324	11.0
Monolete spores (undiff.)	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Osmunda cinnamomea	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Osmunda regalis -type	1	0.2	127	2.3	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Polypodium	3	0.5	382	6.9	2	0.3	372	12.6	2	0.4	415	14.1	1	0.2	324	11.0
Pteridium aquilinum	4	0.7	510	9.2	1	0.2	186	6.3	0	0.0	0	0.0	1	0.2	324	11.0
Trilete spores (undiff.)	0.0	0.0	0	0.0	0.0	0.0	0	0.0	0.0	0.0	0	0.0	0.0	0.0	0	0.0
Selaginella	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Total Ferns and Allies	10	1.8	1274	22.9	4	0.7	744	25.3	6	1.1	1245	42.3	3	0.6	971	33.0
Unknowns	1	0.2	127	2.3	0	0.0	0	0.0	2	0.4	415	14.1	3	0.6	971	33.0
Total Upland Pollen & Spores	547	100.0	69689	1254.4	584	100.0	108611	3692.8	562	100.0	116579	3963.7	534	100.0	172802	5875.3
Brasenia schreberi	42	6.9	5351	96.3	21	3.4	3906	132.8	11	1.8	2282	77.6	9	1.6	2912	99.0
Caltha	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Drosera	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Isoetes	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Myriophyllum exalbescens —type	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Nuphar	3	0.5	382	6.9	5	0.8	930	31.6	8	1.3	1659	56.4	1	0.2	324	11.0
Nymphea	7	1.2	892	16.1	5	0.8	930	31.6	9	1.5	1867	63.5	2	0.4	647	22.0
Potamogeton	3	0.5	382	6.9	2	0.3	372	12.6	0	0.0	0	0.0	0	0.0	0	0.0
Sagittaria	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Sphagnum	1	0.2	127	2.3	3	0.5	558	19.0	2	0.3	415	14.1	3	0.5	971	33.0
Typha latifolia	1	0.2	127	2.3	0	0.0	0	0.0	2	0.3	415	14.1	1	0.2	324	11.0
Sparganium —type	2	0.3	255	4.6	0	0.0	0	0.0	0	0.0	0	0.0	1	0.2	324	11.0
Utricularia	0	0.0	0	0.0	0	0.0	0	0.0	1	0.2	207	7.1	0	0.0	0	0.0
Total Aquatics	59	9.7	7517	135.3	36	5.8	6695	227.6	33	5.5	6845	232.7	17	3.1	5501	187.0
Total Determinable Pollen and Spores	606	100.0	77205	1389.7	620	100.0	115306	3920.4	595	100.0	123424	4196.4	551	100.0	178304	6062.3
Indeterminate grains	9	1.5	1147	20.6	4	0.6	744	25.3	8	1.3	1659	56.4	4	0.7	1294	44.0
Total Pollen and Spores	615	100.0	78352	1410.3	624	100.0	116050	3945.7	603	100.0	125084	4252.9	555	100.0	179598	6106.3
Pediastrum colonies	1	0.2	127	2.3	1	0.2	186	6.3	2	0.3	415	14.1	0	0.0	0	0.0
Nymphaeceae basal cells	100	16.3	12740	229.3	53	8.5	9857	335.1	195	32.3	40450	1375.3	98	17.7	31713	1078.2
Nymphaeceae sclerids	9	1.5	1147	20.6	30	4.8	5579	189.7	43	7.1	8920	303.3	14	2.5	4530	154.0
Eucalyptus grains counted	127				87				78				50			
No. of *Eucalyptus* tablets	1				1				1				1			
Sample volume (cm^3)	1.0				1.0				1.0				1.0			
Accumulation rate (cm yr^{-1})	0.02				0.03				0.03				0.03			
Eucalyptus grains added	16180				16180				16180				16180			
Eucalyptus concentration (gr cm^{-3})	16180				16180				16180				16180			
Total Pollen Influx (gr cm^{-2} yr^{-1})	1410				3946				4253				6106			

Appendix H. Beaverhouse Lake Palynomorph Tabulation (continued).

Beaverhouse Lake, Mackinac County, Michigan																
Depth (cm below platform)	266.9				270.3				273.8				277.2			
Depth (cm below water/sediment interface)	56.9				60.3				63.8				67.2			
Age (yr BP)	1900				2000				2100				2200			
Taxa	Count (No.)	Percent (%)	Conc. (gr cm⁻³)	Influx (gr cm⁻² yr⁻¹)	Count (No.)	Percent (%)	Conc. (gr cm⁻³)	Influx (gr cm⁻² yr⁻¹)	Count (No.)	Percent (%)	Conc. (gr cm⁻³)	Influx (gr cm⁻² yr⁻¹)	Count (No.)	Percent (%)	Conc. (gr cm⁻³)	Influx (gr cm⁻² yr⁻¹)
Abies	3	0.6	837	28.5	2	0.4	744	25.3	4	0.8	1659	56.4	4	0.9	1579	54
Acer (undiff.)	0	0.0	0	0.0	2	0.4	744	25.3	0	0.0	0	0.0	0	0.0	0	0
A. pensylvanicum	1	0.2	279	9.5	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0
A. rubrum	2	0.4	558	19.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0
A. saccharum	4	0.8	1116	37.9	10	1.9	3720	126.5	4	0.8	1659	56.4	5	1.2	1973	67
A. spicatum	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0
Acer (total)	7	1.3	1953	66.4	12	2.1	4463	151.8	4	0.8	1659	56.4	5	1.0	1973	67.1
Betula	73	15.4	20364	692.4	152	29.5	56537	1922.3	136	27.6	56423	1918.4	94	21.9	37096	1261
Carpinus/Ostrya —type	6	1.3	1674	56.9	4	0.8	1488	50.6	1	0.2	415	14.1	4	0.9	1579	54
Carya	1	0.2	279	9.5	0	0.0	0	0.0	2	0.4	830	28.2	4	0.9	1579	54
Castanea dentata	0	0.0	0	0.0	0	0.0	0	0.0	1	0.2	415	14.1	0	0.0	0	0
Celtis occidentalis	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Fagus grandifolia	13	2.5	3627	123.3	11	1.9	4091	139.1	9	1.7	3734	127.0	9	1.8	3552	120.8
Fraxinus (undiff.)	1	0.2	279	9.5	2	0.4	744	25.3	0	0.0	0	0.0	1	0.2	395	13
Fraxinus americana/pennsylvanica —type	0	0.0	0	0.0	1	0.2	372	12.6	2	0.4	830	28.2	0	0.0	0	0
Fraxinus nigra	0	0.0	0	0.0	1	0.2	372	12.6	0	0.0	0	0.0	0	0.0	0	0
Fraxinus (total)	1	0.2	279	9.5	4	0.7	1488	50.6	2	0.4	830	28.2	1	0.2	395	13.4
Juglans (undiff.)	1	0.2	279	9.5	1	0.2	372	12.6	0	0.0	0	0.0	1	0.2	395	13
Juglans cinerea	1	0.2	279	9.5	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0
Juglans nigra	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0
Juglans (total)	2	0.4	558	19.0	1	0.2	372	12.6	0	0.0	0	0.0	1	0.2	395	13.4
Larix laricina	7	1.5	1953	66.4	6	1.2	2232	75.9	6	1.2	2489	84.6	4	0.9	1579	54
Liquidambar styraciflua	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0
Picea (undiff.)	14	2.9	3906	132.8	14	2.7	5207	177.1	12	2.4	4978	169.3	12	2.8	4736	161
Picea marina	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0
Picea glauca	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0
Picea (total)	14	2.7	3906	132.8	14	2.5	5207	177.1	12	2.3	4978	169.3	12	2.4	4736	161.0
Pinus (undiff.)	48	10.1	13390	455.3	63	12.1	23247	790.4	67	13.6	27796	945.1	61	14.2	24073	818
Pinus banksiana/resinosa (Diploxylon)	63	12.1	17575	597.5	48	8.4	17854	607.0	48	9.1	19914	677.1	35	7.0	13812	469.6
Pinus strobus (Haploxylon)	149	31.4	41566	1413.2	114	22.1	42403	1441.7	120	24.4	49785	1692.7	93	21.6	36701	1248
Pinus (total)	260	50.0	72531	2466.1	225	39.5	83504	2839.1	235	44.7	97495	3314.8	189	37.8	74586	2535.9
Platanus occidentalis	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0
Populus	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0
Prunus	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0
Quercus	20	4.2	5579	189.7	27	5.2	10043	341.5	24	4.9	9957	338.5	33	7.7	13023	443
Salix	0	0.0	0	0.0	0	0.0	0	0.0	2	0.4	830	28.2	0	0.0	0	0
Thuja occidentalis/Juniperus —type	23	4.8	6416	218.2	11	2.1	4091	139.1	11	2.2	4564	155.2	26	6.0	10260	349
Tilia americana	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	1	0.2	395	13
Tsuga canadensis	39	8.2	10880	369.9	40	7.8	14878	505.9	36	7.3	14935	507.8	35	8.1	13812	470
Ulmus	6	1.3	1674	56.9	7	1.4	2604	88.5	7	1.4	2904	98.7	8	1.9	3157	107
ARBOREAL POLLEN (TOTAL)	475	91.3	132509	4505.3	516	90.7	191742	6519.2	492	93.5	204117	6940.0	430	86.0	169693	5769.6

Appendix H. Beaverhouse Lake Palynomorph Tabulation (continued).

Beaverhouse Lake, Mackinac County, Michigan																
Depth (cm below platform)	266.9				270.3				273.8				277.2			
Depth (cm below water/sediment interface)	56.9				60.3				63.8				67.2			
Age (yr BP)	1900				2000				2100				2200			
Taxa	Count (No.)	Percent (%)	Conc. (gr cm^{-3})	Influx (gr cm^{-2} yr^{-1})	Count (No.)	Percent (%)	Conc. (gr cm^{-3})	Influx (gr cm^{-2} yr^{-1})	Count (No.)	Percent (%)	Conc. (gr cm^{-3})	Influx (gr cm^{-2} yr^{-1})	Count (No.)	Percent (%)	Conc. (gr cm^{-3})	Influx (gr cm^{-2} yr^{-1})
Alnus crispa	1	0.2	279	9.5	0	0.0	0	0.0	1	0.2	415	14.1	4	0.8	1579	54
Alnus rugosa-type	9	1.7	2511	85.4	10	1.7	3720	126.5	6	1.1	2489	84.6	14	2.7	5525	188
Cephalanthus occidentalis	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0
Corylus	0	0.0	0	0.0	4	0.7	1488	50.6	1	0.2	415	14.1	5	1.0	1973	67
Ericaceae (tetrads)	0	0.0	0	0.0	1	0.2	372	12.6	0	0.0	0	0.0	1	0.2	395	13
Ilex/Nemopanthus —type	0	0.0	0	0.0	1	0.2	372	12.6	0	0.0	0	0.0	0	0.0	0	0
Myrica —type	8	1.5	2232	75.9	7	1.2	2604	88.5	5	0.9	2074	70.5	5	1.0	1973	67
Moraceae	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Sambucus	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0
Total Shrubs	18	3.5	5021	170.7	23	4.0	8555	290.9	13	2.5	5393	183.4	29	5.8	11444	389.1
Vitis	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0
Epiphytes	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0
Ambrosia —type	0	0.0	0	0.0	3	0.5	1116	37.9	1	0.2	415	14.1	7	1.4	2762	94
Artemisia	1	0.2	279	9.5	0	0.0	0	0.0	4	0.8	1659	56.4	0	0.0	0	0
Campanulaceae	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Caryophyllaceae	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Chenopodium —type	0	0.0	0	0.0	2	0.3	744	25.3	0	0.0	0	0.0	3	0.6	1184	40
Cornus canadensis —type	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0
Cyperaceae	22	4.2	6137	208.7	21	3.6	7811	265.6	12	2.3	4978	169.3	18	3.5	7103	242
Labiatae	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0
Menyanthes trifoliata	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0
Petalostemum purpureum -type	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0
Poaceae	3	0.6	837	28.5	4	0.7	1488	50.6	4	0.8	1659	56.4	12	2.3	4736	161
Polygonum	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0
Potentilla —type	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0
Rosaceae	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0
Rhamnus	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0
Rubiaceae	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0
Rumex	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0
Saxifragaceae	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0
Thalictrum	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0
Tubuliflorea	1	0.2	279	9.5	0	0.0	0	0.0	0	0.0	0	0.0	1	0.2	395	13
Umbelliferae	0.0	0.0	0	0.0	0.0	0.0	0	0.0	0.0	0.0	0	0.0	0.0	0.0	0	0.0
Ephedra —type	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0
Total NonArboreal Herbs	27	5.2	7532	256.1	30	5.3	11159	379.4	21	4.0	8712	296.2	41	8.2	16180	550.1
Total Terrestrial Pollen	520	100.0	145062	4932.1	569	100.0	211456	7189.5	526	100.0	218223	7419.6	500	100.0	197317	6708.8
Adiantum/Dennstaedtia	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Botrychium	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0
Equisetum	0	0.0	0	0.0	0	0.0	0	0.0	1	0.2	415	14.1	1	0.2	395	13
Lycopodium annotinum	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0
Lycopodium clavatum	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0
Lycopodium complanatum -type	0	0.0	0	0.0	1	0.2	372	12.6	0	0.0	0	0.0	0	0.0	0	0

Appendix H. Beaverhouse Lake Palynomorph Tabulation (continued).

Beaverhouse Lake, Mackinac County, Michigan																
Depth (cm below platform)	266.9				270.3				273.8				277.2			
Depth (cm below water/sediment interface)	56.9				60.3				63.8				67.2			
Age (yr BP)	1900				2000				2100				2200			
Taxa	Count (No.)	Percent (%)	Conc. (gr cm^{-3})	Influx (gr cm^{-2} yr^{-1})	Count (No.)	Percent (%)	Conc. (gr cm^{-3})	Influx (gr cm^{-2} yr^{-1})	Count (No.)	Percent (%)	Conc. (gr cm^{-3})	Influx (gr cm^{-2} yr^{-1})	Count (No.)	Percent (%)	Conc. (gr cm^{-3})	Influx (gr cm^{-2} yr^{-1})
Lycopodium inundatum	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0
Lycopodium lucidulum	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0
Lycopodium obscurum	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0
Lycopodium (undiff.)	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0
Lycopodium (total)	0	0.0	0	0.0	1	0.2	372	12.6	0	0.0	0	0.0	0	0.0	0	0.0
Monolete spores (undiff.)	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0
Osmunda cinnamomea	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0
Osmunda regalis -type	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0
Polypodium	2	0.4	558	19.0	0	0.0	0	0.0	2	0.4	830	28.2	0	0.0	0	0
Pteridium aquilinum	0	0.0	0	0.0	2	0.3	744	25.3	1	0.2	415	14.1	4	0.8	1579	54
Trilete spores (undiff.)	0.0	0.0	0	0.0	0	0.0	0	0.0	1.0	0.2	415	14.1	1	0.2	395	13
Selaginella	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0
Total Ferns and Allies	2	0.4	558	19.0	3	0.5	1116	37.9	5	0.9	2074	70.5	6	1.2	2368	80.5
Unknowns	1	0.2	279	9.5	6	1.0	2232	75.9	0	0.0	0	0.0	7	1.4	2762	94
Total Upland Pollen & Spores	523	100.0	145899	4960.6	578	100.0	214803	7303.3	531	100.0	220297	7490.1	513	100.0	202447	6883.2
Brasenia schreberi	2	0.4	558	19.0	5	0.8	1860	63.2	1	0.2	415	14.1	0	0.0	0	0
Caltha	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0
Drosera	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Isoetes	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0
Myriophyllum exalbescens —type	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0
Nuphar	3	0.6	837	28.5	1	0.2	372	12.6	5	0.9	2074	70.5	0	0.0	0	0
Nymphea	2	0.4	558	19.0	2	0.3	744	25.3	8	1.5	3319	112.8	7	1.3	2762	94
Potamogeton	1	0.2	279	9.5	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0
Sagittaria	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0
Sphagnum	1	0.2	279	9.5	0	0.0	0	0.0	2	0.4	830	28.2	1	0.2	395	13
Typha latifolia	1	0.2	279	9.5	1	0.2	372	12.6	0	0.0	0	0.0	0	0.0	0	0
Sparganium —type	0	0.0	0	0.0	2	0.3	744	25.3	0	0.0	0	0.0	0	0.0	0	0
Utricularia	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0
Total Aquatics	10	1.9	2790	94.8	11	1.9	4091	139.1	16	2.9	6638	225.7	8	1.5	3157	107.3
Total Determinable Pollen and Spores	533	100.0	148689	5055.4	589	100.0	218895	7442.4	547	100.0	226935	7715.8	521	100.0	205604	6990.5
Indeterminate grains	11	2.0	3069	104.3	5	0.8	1860	63.2	10	1.8	4149	141.1	14	2.6	5525	188
Total Pollen and Spores	544	100.0	151757	5159.7	594	100.0	220755	7505.7	557	100.0	231084	7856.8	535	100.0	211129	7178.4
Pediastrum colonies	14	2.6	3906	132.8	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Nymphaeceae basal cells	62	11.4	17296	588.1	0	0.0	0	0.0	87	15.6	36094	1227.2	0	0.0	0	0.0
Nymphaeceae sclerids	6	1.1	1674	56.9	0	0.0	0	0.0	22	3.9	9127	310.3	0	0.0	0	0.0
Eucalyptus grains counted	58				87				39				41			
No. of *Eucalyptus* tablets	1				1				1				1			
Sample volume (cm^3)	1.0				0.5				1.0				1.0			
Accumulation rate (cm yr^{-1})	0.03				0.03				0.03				0.03			
Eucalyptus grains added	16180				16180				16180				16180			
Eucalyptus concentration (gr cm^{-3})	16180				32360				16180				16180			
Total Pollen Influx (gr cm^{-2} yr^{-1})	5160				7506				7857				7178			

Appendix H. Beaverhouse Lake Palynomorph Tabulation (continued).

Beaverhouse Lake, Mackinac County, Michigan																
Depth (cm below platform)	280.6				284.0				287.4				290.8			
Depth (cm below water/sediment interface)	70.6				74.0				77.4				80.8			
Age (yr BP)	2300				2400				2500				2600			
Taxa	Count (No.)	Percent (%)	Conc. (gr cm^{-3})	Influx (gr cm^{-2} yr^{-1})	Count (No.)	Percent (%)	Conc. (gr cm^{-3})	Influx (gr cm^{-2} yr^{-1})	Count (No.)	Percent (%)	Conc. (gr cm^{-3})	Influx (gr cm^{-2} yr^{-1})	Count (No.)	Percent (%)	Conc. (gr cm^{-3})	Influx (gr cm^{-2} yr^{-1})
Abies	4	0.8	925	31.4	6	1.3	1618	55.0	2	0.4	327	11.1	0	0.0	0	0.0
Acer (undiff.)	4	0.8	925	31.4	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
A. pensylvanicum	0	0.0	0	0.0	2	0.4	539	18.3	1	0.2	163	5.6	1	0.2	449	15.3
A. rubrum	0	0.0	0	0.0	2	0.4	539	18.3	1	0.2	163	5.6	0	0.0	0	0.0
A. saccharum	4	0.8	925	31.4	0	0.0	0	0.0	8	1.6	1307	44.5	11	2.4	4944	168.1
A. spicatum	10	2.0	2311	78.6	8	1.8	2157	73.3	0	0.0	0	0.0	0	0.0	0	0.0
Acer (total)	18	3.2	4161	141.5	12	2.3	3236	110.0	10	1.8	1634	55.6	12	2.4	5393	183.4
Betula	104	20.6	24039	817.3	122	26.7	32899	1118.6	135	26.8	22064	750.2	139	30.3	62473	2124.1
Carpinus/Ostrya —type	3	0.6	693	23.6	3	0.7	809	27.5	7	1.4	1144	38.9	4	0.9	1798	61.1
Carya	0	0.0	0	0.0	0	0.0	0	0.0	4	0.8	654	22.2	0	0.0	0	0.0
Castanea dentata	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Celtis occidentalis	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Fagus grandifolia	9	1.6	2080	70.7	14	2.6	3775	128.4	12	2.2	1961	66.7	4	0.8	1798	61.1
Fraxinus (undiff.)	0	0.0	0	0.0	2	0.4	539	18.3	0	0.0	0	0.0	3	0.7	1348	45.8
Fraxinus americana/pennsylvanica —type	1	0.2	231	7.9	0	0.0	0	0.0	2	0.4	327	11.1	0	0.0	0	0.0
Fraxinus nigra	0	0.0	0	0.0	0	0.0	0	0.0	2	0.4	327	11.1	1	0.2	449	15.3
Fraxinus (total)	1	0.2	231	7.9	2	0.4	539	18.3	4	0.7	654	22.2	4	0.8	1798	61.1
Juglans (undiff.)	1	0.2	231	7.9	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Juglans cinerea	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Juglans nigra	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Juglans (total)	1	0.2	231	7.9	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Larix laricina	6	1.2	1387	47.2	8	1.8	2157	73.3	7	1.4	1144	38.9	4	0.9	1798	61.1
Liquidambar styraciflua	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Picea (undiff.)	11	2.2	2543	86.4	13	2.8	3506	119.2	7	1.4	1144	38.9	1	0.2	449	15.3
Picea marina	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Picea glauca	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Picea (total)	11	1.9	2543	86.4	13	2.4	3506	119.2	7	1.3	1144	38.9	1	0.2	449	15.3
Pinus (undiff.)	55	10.9	12713	432.2	36	7.9	9708	330.1	80	15.9	13075	444.5	80	17.5	35956	1222.5
Pinus banksiana/resinosa (Diploxylon)	66	11.7	15255	518.7	47	8.9	12674	430.9	57	10.3	9316	316.7	54	10.8	24270	825.2
Pinus strobus (Haploxylon)	127	25.2	29355	998.1	101	22.1	27236	926.0	128	25.4	20920	711.3	95	20.7	42697	1451.7
Pinus (total)	248	43.8	57323	1949.0	184	34.7	49619	1687.0	265	47.7	43310	1472.5	229	45.6	102923	3499.4
Platanus occidentalis	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Populus	0	0.0	0	0.0	3	0.7	809	27.5	2	0.4	327	11.1	0	0.0	0	0.0
Prunus	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Quercus	20	4.0	4623	157.2	24	5.3	6472	220.0	17	3.4	2778	94.5	16	3.5	7191	244.5
Salix	1	0.2	231	7.9	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Thuja occidentalis/Juniperus —type	25	5.0	5779	196.5	19	4.2	5124	174.2	11	2.2	1798	61.1	23	5.0	10337	351.5
Tilia americana	0	0.0	0	0.0	0	0.0	0	0.0	1	0.2	163	5.6	0	0.0	0	0.0
Tsuga canadensis	47	9.3	10864	369.4	38	8.3	10247	348.4	14	2.8	2288	77.8	18	3.9	8090	275.1
Ulmus	6	1.2	1387	47.2	9	2.0	2427	82.5	6	1.2	981	33.3	4	0.9	1798	61.1
ARBOREAL POLLEN (TOTAL)	504	89.0	116496	3960.9	457	86.1	123238	4190.1	504	90.8	82371	2800.6	458	91.2	205846	6998.7

Appendix H. Beaverhouse Lake Palynomorph Tabulation (continued).

Beaverhouse Lake, Mackinac County, Michigan																
Depth (cm below platform)	280.6				284.0				287.4				290.8			
Depth (cm below water/sediment interface)	70.6				74.0				77.4				80.8			
Age (yr BP)	2300				2400				2500				2600			
Taxa	Count (No.)	Percent (%)	Conc. (gr cm^{-3})	Influx (gr cm^{-2} yr^{-1})	Count (No.)	Percent (%)	Conc. (gr cm^{-3})	Influx (gr cm^{-2} yr^{-1})	Count (No.)	Percent (%)	Conc. (gr cm^{-3})	Influx (gr cm^{-2} yr^{-1})	Count (No.)	Percent (%)	Conc. (gr cm^{-3})	Influx (gr cm^{-2} yr^{-1})
Alnus crispa	1	0.2	231	7.9	3	0.6	809	27.5	2	0.4	327	11.1	0	0.0	0	0.0
Alnus rugosa-type	14	2.5	3236	110.0	17	3.2	4584	155.9	13	2.3	2125	72.2	9	1.8	4045	137.5
Cephalanthus occidentalis	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Corylus	2	0.4	462	15.7	0	0.0	0	0.0	2	0.4	327	11.1	0	0.0	0	0.0
Ericaceae (tetrads)	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Ilex/Nemopanthus —type	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Myrica —type	12	2.1	2774	94.3	19	3.5	5124	174.2	9	1.6	1471	50.0	7	1.4	3146	107.0
Moraceae	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Sambucus	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Total Shrubs	29	5.1	6703	227.9	39	7.3	10517	357.6	26	4.7	4249	144.5	16	3.2	7191	244.5
Vitis	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Epiphytes	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Ambrosia —type	2	0.4	462	15.7	2	0.4	539	18.3	2	0.4	327	11.1	1	0.2	449	15.3
Artemisia	4	0.7	925	31.4	0	0.0	0	0.0	1	0.2	163	5.6	0	0.0	0	0.0
Campanulaceae	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Caryophyllaceae	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Chenopodium —type	1	0.2	231	7.9	3	0.6	809	27.5	0	0.0	0	0.0	0	0.0	0	0.0
Cornus canadensis —type	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Cyperaceae	21	3.7	4854	165.0	19	3.5	5124	174.2	15	2.7	2452	83.4	26	5.1	11686	397.3
Labiatae	1	0.2	231	7.9	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Menyanthes trifoliata	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Petalostemum purpureum -type	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Poaceae	4	0.7	925	31.4	8	1.5	2157	73.3	7	1.3	1144	38.9	0	0.0	0	0.0
Polygonum	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Potentilla —type	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Rosaceae	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Rhamnus	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Rubiaceae	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Rumex	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Saxifragaceae	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Thalictrum	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Tubuliflorea	0	0.0	0	0.0	3	0.6	809	27.5	0	0.0	0	0.0	1	0.2	449	15.3
Umbelliferae	0.0	0.0	0	0.0	0.0	0.0	0	0.0	0.0	0.0	0	0.0	0.0	0.0	0	0.0
Ephedra —type	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Total NonArboreal Herbs	33	5.8	7628	259.3	35	6.6	9438	320.9	25	4.5	4086	138.9	28	5.6	12584	427.9
Total Terrestrial Pollen	566	100.0	130827	4448.1	531	100.0	143193	4868.6	555	100.0	90706	3084.0	502	100.0	225621	7671.1
Adiantum/Dennstaedtia	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Botrychium	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Equisetum	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Lycopodium annotinum	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	1	0.2	449	15.3
Lycopodium clavatum	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Lycopodium complanatum -type	0	0.0	0	0.0	2	0.4	539	18.3	0	0.0	0	0.0	0	0.0	0	0.0

Appendix H. Beaverhouse Lake Palynomorph Tabulation (continued).

Beaverhouse Lake, Mackinac County, Michigan

Depth (cm below platform)	280.6				284.0				287.4				290.8			
Depth (cm below water/sediment interface)	70.6				74.0				77.4				80.8			
Age (yr BP)	2300				2400				2500				2600			
	Count	Percent	Conc.	Influx	Count	Percent	Conc.	Influx	Count	Percent	Conc.	Influx	Count	Percent	Conc.	Influx
Taxa	(No.)	(%)	(gr cm^{-3})	(gr cm^{-2} yr^{-1})	(No.)	(%)	(gr cm^{-3})	(gr cm^{-2} yr^{-1})	(No.)	(%)	(gr cm^{-3})	(gr cm^{-2} yr^{-1})	(No.)	(%)	(gr cm^{-3})	(gr cm^{-2} yr^{-1})
Lycopodium inundatum	0	0.0	0	0.0	0	0.0	0	0.0	1	0.2	163	5.6	0	0.0	0	0.0
Lycopodium lucidulum	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Lycopodium obscurum	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Lycopodium (undiff.)	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Lycopodium (total)	0	0.0	0	0.0	2	0.4	539	18.3	1	0.2	163	5.6	1	0.2	449	15.3
Monolete spores (undiff.)	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Osmunda cinnamomea	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Osmunda regalis -type	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Polypodium	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Pteridium aquilinum	0	0.0	0	0.0	0	0.0	0	0.0	2	0.4	327	11.1	3	0.6	1348	45.8
Trilete spores (undiff.)	1.0	0.2	231	7.9	0.0	0.0	0	0.0	0	0.0	0	0.0	1.0	0.2	449	15.3
Selaginella	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Total Ferns and Allies	1	0.2	231	7.9	2	0.4	539	18.3	3	0.5	490	16.7	5	1.0	2247	76.4
Unknowns	1	0.2	231	7.9	6	1.1	1618	55.0	2	0.4	327	11.1	3	0.6	1348	45.8
Total Upland Pollen & Spores	568	100.0	131289	4463.8	539	100.0	145350	4941.9	560	100.0	91523	3111.8	510	100.0	229217	7793.4
Brasenia schreberi	13	2.2	3005	102.2	8	1.4	2157	73.3	19	3.1	3105	105.6	11	2.0	4944	168.1
Caltha	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Drosera	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Isoetes	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Myriophyllum exalbescens —type	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Nuphar	1	0.2	231	7.9	2	0.4	539	18.3	3	0.5	490	16.7	0	0.0	0	0.0
Nymphea	4	0.7	925	31.4	6	1.1	1618	55.0	28	4.6	4576	155.6	18	3.3	8090	275.1
Potamogeton	0	0.0	0	0.0	0	0.0	0	0.0	2	0.3	327	11.1	0	0.0	0	0.0
Sagittaria	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Sphagnum	5	0.8	1156	39.3	0	0.0	0	0.0	1	0.2	163	5.6	1	0.2	449	15.3
Typha latifolia	1	0.2	231	7.9	2	0.4	539	18.3	0	0.0	0	0.0	3	0.6	1348	45.8
Sparganium —type	0	0.0	0	0.0	0	0.0	0	0.0	1	0.2	163	5.6	0	0.0	0	0.0
Utricularia	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Total Aquatics	24	4.1	5547	188.6	18	3.2	4854	165.0	54	8.8	8825	300.1	33	6.1	14832	504.3
Total Determinable Pollen and Spores	592	100.0	136837	4652.4	557	100.0	150204	5106.9	614	100.0	100349	3411.9	543	100.0	244048	8297.6
Indeterminate grains	7	1.2	1618	55.0	11	1.9	2966	100.9	9	1.4	1471	50.0	13	2.3	5843	198.7
Total Pollen and Spores	599	100.0	138455	4707.5	568	100.0	153171	5207.8	623	100.0	101820	3461.9	556	100.0	249891	8496.3
Pediastrum colonies	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Nymphaeceae basal cells	110	18.4	25426	864.5	152	26.8	40989	1393.6	0	0.0	0	0.0	203	36.5	91237	3102.1
Nymphaeceae sclerids	28	4.7	6472	220.0	38	6.7	10247	348.4	0	0.0	0	0.0	27	4.9	12135	412.6
Eucalyptus grains counted	70				60				198				36			
No. of *Eucalyptus* tablets	1				1				1				1			
Sample volume (cm^{3})	1.0				1.0				0.5				1.0			
Accumulation rate (cm yr^{-1})	0.03				0.03				0.03				0.03			
Eucalyptus grains added	16180				16180				16180				16180			
Eucalyptus concentration (gr cm^{-3})	16180				16180				32360				16180			
Total Pollen Influx (gr cm^{-2} yr^{-1})	4707				5208				3462				8496			

Appendix H. Beaverhouse Lake Palynomorph Tabulation (continued).

Beaverhouse Lake, Mackinac County, Michigan																
Depth (cm below platform)	294.2				297.6				303.3				310.0			
Depth (cm below water/sediment interface)	84.2				87.6				93.3				100.0			
Age (yr BP)	2700				2800				2900				3000			
Taxa	Count (No.)	Percent (%)	Conc. (gr cm^{-3})	Influx (gr cm^{-2} yr^{-1})	Count (No.)	Percent (%)	Conc. (gr cm^{-3})	Influx (gr cm^{-2} yr^{-1})	Count (No.)	Percent (%)	Conc. (gr cm^{-3})	Influx (gr cm^{-2} yr^{-1})	Count (No.)	Percent (%)	Conc. (gr cm^{-3})	Influx (gr cm^{-2} yr^{-1})
Abies	1	0.2	228	7.7	4	0.8	1199	40.7	5	1.0	2311	251.9	3	0.7	796	86.7
Acer (undiff.)	0	0.0	0	0.0	3	0.6	899	30.6	1	0.2	462	50.4	0	0.0	0	0.0
A. pensylvanicum	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	1	0.2	265	28.9
A. rubrum	1	0.2	228	7.7	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
A. saccharum	4	0.8	912	31.0	10	2.1	2996	101.9	1	0.2	462	50.4	8	1.8	2122	231.3
A. spicatum	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	6	1.4	1591	173.5
Acer (total)	5	0.9	1139	38.7	13	2.5	3895	132.4	2	0.4	925	100.8	15	2.9	3979	433.7
Betula	109	22.2	24840	844.6	113	23.9	33858	1151.2	92	18.7	42530	4635.8	100	23.0	26525	2891.2
Carpinus/Ostrya —type	10	2.0	2279	77.5	3	0.6	899	30.6	5	1.0	2311	251.9	6	1.4	1591	173.5
Carya	3	0.6	684	23.2	0	0.0	0	0.0	0	0.0	0	0.0	6	1.4	1591	173.5
Castanea dentata	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Celtis occidentalis	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Fagus grandifolia	3	0.5	684	23.2	7	1.3	2097	71.3	2	0.4	925	100.8	4	0.8	1061	115.6
Fraxinus (undiff.)	0	0.0	0	0.0	0	0.0	0	0.0	2	0.4	925	100.8	0	0.0	0	0.0
Fraxinus americana/pennsylvanica —type	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Fraxinus nigra	0	0.0	0	0.0	1	0.2	300	10.2	0	0.0	0	0.0	0	0.0	0	0.0
Fraxinus (total)	0	0.0	0	0.0	1	0.2	300	10.2	2	0.4	925	100.8	0	0.0	0	0.0
Juglans (undiff.)	0	0.0	0	0.0	0	0.0	0	0.0	1	0.2	462	50.4	0	0.0	0	0.0
Juglans cinerea	0	0.0	0	0.0	1	0.2	300	10.2	0	0.0	0	0.0	0	0.0	0	0.0
Juglans nigra	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Juglans (total)	0	0.0	0	0.0	1	0.2	300	10.2	1	0.2	462	50.4	0	0.0	0	0.0
Larix laricina	2	0.4	456	15.5	4	0.8	1199	40.7	0	0.0	0	0.0	7	1.6	1857	202.4
Liquidambar styraciflua	0	0.0	0	0.0	1	0.2	300	10.2	0	0.0	0	0.0	0	0.0	0	0.0
Picea (undiff.)	7	1.4	1595	54.2	4	0.8	1199	40.7	5	1.0	2311	251.9	4	0.9	1061	115.6
Picea marina	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Picea glauca	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Picea (total)	7	1.3	1595	54.2	4	0.8	1199	40.7	5	0.9	2311	251.9	4	0.8	1061	115.6
Pinus (undiff.)	52	10.6	11850	402.9	54	11.4	16180	550.1	90	18.3	41606	4535.0	82	18.9	21750	2370.8
Pinus banksiana/resinosa (Diploxylon)	59	10.8	13445	457.1	56	10.8	16779	570.5	67	12.4	30973	3376.1	46	9.0	12201	1329.9
Pinus strobus (Haploxylon)	162	33.0	36918	1255.2	153	32.4	45843	1558.7	163	33.1	75353	8213.4	118	27.2	31299	3411.6
Pinus (total)	273	49.8	62213	2115.3	263	50.6	78803	2679.3	320	59.4	147931	16124.5	246	48.1	65250	7112.3
Platanus occidentalis	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Populus	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Prunus	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Quercus	39	7.9	8888	302.2	14	3.0	4195	142.6	23	4.7	10633	1159.0	17	3.9	4509	491.5
Salix	1	0.2	228	7.7	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Thuja occidentalis/Juniperus —type	28	5.7	6381	216.9	29	6.1	8689	295.4	10	2.0	4623	503.9	15	3.5	3979	433.7
Tilia americana	0	0.0	0	0.0	1	0.2	300	10.2	0	0.0	0	0.0	1	0.2	265	28.9
Tsuga canadensis	9	1.8	2051	69.7	10	2.1	2996	101.9	14	2.8	6472	705.4	7	1.6	1857	202.4
Ulmus	1	0.2	228	7.7	4	0.8	1199	40.7	12	2.4	5547	604.7	3	0.7	796	86.7
ARBOREAL POLLEN (TOTAL)	491	89.6	111893	3804.4	472	90.8	141425	4808.5	493	91.5	227907	24841.8	434	84.9	115117	12547.7

Appendix H. Beaverhouse Lake Palynomorph Tabulation (continued).

Beaverhouse Lake, Mackinac County, Michigan																
Depth (cm below platform)	294.2				297.6				303.3				310.0			
Depth (cm below water/sediment interface)	84.2				87.6				93.3				100.0			
Age (yr BP)	2700				2800				2900				3000			
Taxa	Count (No.)	Percent (%)	Conc. (gr cm^{-3})	Influx (gr cm^{-2} yr^{-1})	Count (No.)	Percent (%)	Conc. (gr cm^{-3})	Influx (gr cm^{-2} yr^{-1})	Count (No.)	Percent (%)	Conc. (gr cm^{-3})	Influx (gr cm^{-2} yr^{-1})	Count (No.)	Percent (%)	Conc. (gr cm^{-3})	Influx (gr cm^{-2} yr^{-1})
Alnus crispa	0	0.0	0	0.0	1	0.2	300	10.2	2	0.4	925	100.8	3	0.6	796	86.7
Alnus rugosa-type	10	1.8	2279	77.5	7	1.3	2097	71.3	6	1.1	2774	302.3	12	2.3	3183	346.9
Cephalanthus occidentalis	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Corylus	1	0.2	228	7.7	1	0.2	300	10.2	2	0.4	925	100.8	1	0.2	265	28.9
Ericaceae (tetrads)	0	0.0	0	0.0	0	0.0	0	0.0	1	0.2	462	50.4	0	0.0	0	0.0
Ilex/Nemopanthus —type	1	0.2	228	7.7	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Myrica —type	8	1.4	1823	62.0	11	2.0	3296	112.1	7	1.3	3236	352.7	7	1.3	1857	202.4
Moraceae	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Sambucus	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Total Shrubs	20	3.6	4558	155.0	20	3.8	5993	203.7	18	3.3	8321	907.0	23	4.5	6101	665.0
Vitis	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Epiphytes	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Ambrosia —type	4	0.7	912	31.0	6	1.1	1798	61.1	0	0.0	0	0.0	7	1.3	1857	202.4
Artemisia	2	0.4	456	15.5	1	0.2	300	10.2	0	0.0	0	0.0	1	0.2	265	28.9
Campanulaceae	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Caryophyllaceae	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Chenopodium —type	1	0.2	228	7.7	1	0.2	300	10.2	0	0.0	0	0.0	1	0.2	265	28.9
Cornus canadensis —type	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Cyperaceae	26	4.7	5925	201.5	16	3.0	4794	163.0	19	3.5	8783	957.4	32	6.1	8488	925.2
Labiatae	0	0.0	0	0.0	0	0.0	0	0.0	1	0.2	462	50.4	0	0.0	0	0.0
Menyanthes trifoliata	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	1	0.2	265	28.9
Petalostemum purpureum -type	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Poaceae	2	0.4	456	15.5	3	0.6	899	30.6	6	1.1	2774	302.3	12	2.3	3183	346.9
Polygonum	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Potentilla —type	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Rosaceae	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Rhamnus	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Rubiaceae	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Rumex	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Saxifragaceae	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Thalictrum	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Tubuliflorea	2	0.4	456	15.5	1	0.2	300	10.2	2	0.4	925	100.8	0	0.0	0	0.0
Umbelliferae	0.0	0.0	0	0.0	0.0	0.0	0	0.0	0.0	0.0	0	0.0	0.0	0.0	0	0.0
Ephedra —type	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Total NonArboreal Herbs	37	6.8	8432	286.7	28	5.4	8390	285.2	28	5.2	12944	1410.9	54	10.6	14323	1561.2
Total Terrestrial Pollen	548	100.0	124882	4246.0	520	100.0	155807	5297.5	539	100.0	249172	27159.7	511	100.0	135541	14773.9
Adiantum/Dennstaedtia	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Botrychium	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Equisetum	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Lycopodium annotinum	1	0.2	228	7.7	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Lycopodium clavatum	0	0.0	0	0.0	3	0.6	899	30.6	0	0.0	0	0.0	0	0.0	0	0.0
Lycopodium complanatum -type	2	0.4	456	15.5	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0

Appendix H. Beaverhouse Lake Palynomorph Tabulation (continued).

Beaverhouse Lake, Mackinac County, Michigan																
Depth (cm below platform)	294.2				297.6				303.3				310.0			
Depth (cm below water/sediment interface)	84.2				87.6				93.3				100.0			
Age (yr BP)	2700				2800				2900				3000			
Taxa	Count (No.)	Percent (%)	Conc. (gr cm⁻³)	Influx (gr cm⁻² yr⁻¹)	Count (No.)	Percent (%)	Conc. (gr cm⁻³)	Influx (gr cm⁻² yr⁻¹)	Count (No.)	Percent (%)	Conc. (gr cm⁻³)	Influx (gr cm⁻² yr⁻¹)	Count (No.)	Percent (%)	Conc. (gr cm⁻³)	Influx (gr cm⁻² yr⁻¹)
Lycopodium inundatum	1	0.2	228	7.7	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Lycopodium lucidulum	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Lycopodium obscurum	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Lycopodium (undiff.)	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Lycopodium (total)	4	0.7	912	31.0	3	0.6	899	30.6	0	0.0	0	0.0	0	0.0	0	0.0
Monolete spores (undiff.)	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Osmunda cinnamomea	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Osmunda regalis -type	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Polypodium	0	0.0	0	0.0	3	0.6	899	30.6	2	0.4	925	100.8	1	0.2	265	28.9
Pteridium aquilinum	1	0.2	228	7.7	4	0.7	1199	40.7	0	0.0	0	0.0	7	1.3	1857	202.4
Trilete spores (undiff.)	1.0	0.2	228	7.7	3.0	0.6	899	30.6	1.0	0.2	462	50.4	1	0.2	265	28.9
Selaginella	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Total Ferns and Allies	6	1.1	1367	46.5	13	2.4	3895	132.4	3	0.6	1387	151.2	9	1.7	2387	260.2
Unknowns	0	0.0	0	0.0	4	0.7	1199	40.7	1	0.2	462	50.4	1	0.2	265	28.9
Total Upland Pollen & Spores	554	100.0	126250	4292.5	537	100.0	160901	5470.6	543	100.0	251021	27361.3	521	100.0	138193	15063.0
Brasenia schreberi	19	3.1	4330	147.2	16	2.7	4794	163.0	17	2.9	7859	856.6	10	1.8	2652	289.1
Caltha	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Drosera	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Isoetes	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Myriophyllum exalbescens —type	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Nuphar	3	0.5	684	23.2	4	0.7	1199	40.7	3	0.5	1387	151.2	3	0.5	796	86.7
Nymphea	23	3.8	5241	178.2	14	2.4	4195	142.6	7	1.2	3236	352.7	11	2.0	2918	318.0
Potamogeton	0	0.0	0	0.0	0	0.0	0	0.0	1	0.2	462	50.4	0	0.0	0	0.0
Sagittaria	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Sphagnum	5	0.8	1139	38.7	10	1.7	2996	101.9	6	1.0	2774	302.3	8	1.4	2122	231.3
Typha latifolia	0	0.0	0	0.0	1	0.2	300	10.2	0	0.0	0	0.0	0	0.0	0	0.0
Sparganium —type	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Utricularia	0	0.0	0	0.0	0	0.0	0	0.0	1	0.2	462	50.4	0	0.0	0	0.0
Total Aquatics	50	8.3	11394	387.4	45	7.7	13483	458.4	35	6.1	16180	1763.6	32	5.8	8488	925.2
Total Determinable Pollen and Spores	604	100.0	137644	4679.9	582	100.0	174384	5929.1	578	100.0	267201	29124.9	553	100.0	146681	15988.2
Indeterminate grains	5	0.8	1139	38.7	13	2.2	3895	132.4	7	1.2	3236	352.7	8	1.4	2122	231.3
Total Pollen and Spores	609	100.0	138783	4718.6	595	100.0	178280	6061.5	585	100.0	270437	29477.6	561	100.0	148803	16219.5
Pediastrum colonies	10	1.6	2279	77.5	0	0.0	0	0.0	1	0.2	462	50.4	0	0.0	0	0.0
Nymphaeceae basal cells	116	19.0	26435	898.8	160	26.9	47941	1630.0	99	16.9	45766	4988.5	0	0.0	0	0.0
Nymphaeceae sclerids	24	3.9	5469	186.0	33	5.5	9888	336.2	13	2.2	6010	655.1	0	0.0	0	0.0
Eucalyptus grains counted	71				54				35				122			
No. of *Eucalyptus* tablets	1				1				1				1			
Sample volume (cm³)	1.0				1.0				1.0				0.5			
Accumulation rate (cm yr⁻¹)	0.03				0.03				0.11				0.11			
Eucalyptus grains added	16180				16180				16180				16180			
Eucalyptus concentration (gr cm⁻³)	16180				16180				16180				32360			
Total Pollen Influx (gr cm⁻² yr⁻¹)	4719				6062				29478				16220			

Appendix H. Beaverhouse Lake Palynomorph Tabulation (continued).

Beaverhouse Lake, Mackinac County, Michigan

Depth (cm below platform)	325.0				335.9				346.7				354.6			
Depth (cm below water/sediment interface)	115.0				125.9				136.7				144.6			
Age (yr BP)	3100				3200				3300				3400			
Taxa	Count (No.)	Percent (%)	Conc. (gr cm^{-3})	Influx (gr cm^{-2} yr^{-1})	Count (No.)	Percent (%)	Conc. (gr cm^{-3})	Influx (gr cm^{-2} yr^{-1})	Count (No.)	Percent (%)	Conc. (gr cm^{-3})	Influx (gr cm^{-2} yr^{-1})	Count (No.)	Percent (%)	Conc. (gr cm^{-3})	Influx (gr cm^{-2} yr^{-1})
Abies	1	0.2	186	20.3	2	0.4	578	63.0	4	0.7	996	108.5	1	0.2	197	12.8
Acer (undiff.)	2	0.4	372	40.5	2	0.4	578	63.0	0	0.0	0	0.0	1	0.2	197	12.8
A. pensylvanicum	1	0.2	186	20.3	0	0.0	0	0.0	1	0.2	249	27.1	1	0.2	197	12.8
A. rubrum	2	0.4	372	40.5	0	0.0	0	0.0	1	0.2	249	27.1	1	0.2	197	12.8
A. saccharum	6	1.2	1116	121.6	1	0.2	289	31.5	5	0.9	1245	135.7	2	0.4	395	25.7
A. spicatum	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Acer (total)	11	1.9	2046	223.0	3	0.5	867	94.5	7	1.1	1742	189.9	5	0.9	987	64.1
Betula	108	21.3	20086	2189.3	112	23.9	32360	3527.2	107	19.3	26635	2903.2	78	16.5	15391	1000.4
Carpinus/Ostrya —type	2	0.4	372	40.5	1	0.2	289	31.5	8	1.4	1991	217.1	5	1.1	987	64.1
Carya	4	0.8	744	81.1	3	0.6	867	94.5	1	0.2	249	27.1	1	0.2	197	12.8
Castanea dentata	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Celtis occidentalis	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Fagus grandifolia	6	1.0	1116	121.6	2	0.4	578	63.0	8	1.3	1991	217.1	3	0.5	592	38.5
Fraxinus (undiff.)	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Fraxinus americana/pennsylvanica —type	3	0.6	558	60.8	0	0.0	0	0.0	1	0.2	249	27.1	0	0.0	0	0.0
Fraxinus nigra	0	0.0	0	0.0	0	0.0	0	0.0	1	0.2	249	27.1	0	0.0	0	0.0
Fraxinus (total)	3	0.5	558	60.8	0	0.0	0	0.0	2	0.3	498	54.3	0	0.0	0	0.0
Juglans (undiff.)	0	0.0	0	0.0	1	0.2	289	31.5	1	0.2	249	27.1	0	0.0	0	0.0
Juglans cinerea	0	0.0	0	0.0	0	0.0	0	0.0	1	0.2	249	27.1	2	0.4	395	25.7
Juglans nigra	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Juglans (total)	0	0.0	0	0.0	1	0.2	289	31.5	2	0.3	498	54.3	2	0.4	395	25.7
Larix laricina	8	1.6	1488	162.2	0	0.0	0	0.0	5	0.9	1245	135.7	3	0.6	592	38.5
Liquidambar styraciflua	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Picea (undiff.)	10	2.0	1860	202.7	9	1.9	2600	283.4	0	0.0	0	0.0	3	0.6	592	38.5
Picea marina	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Picea glauca	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Picea (total)	10	1.7	1860	202.7	9	1.6	2600	283.4	0	0.0	0	0.0	3	0.5	592	38.5
Pinus (undiff.)	78	15.4	14506	1581.2	62	13.2	17914	1952.6	76	13.7	18918	2062.1	81	17.2	15983	1038.9
Pinus banksiana/resinosa (Diploxylon)	63	10.7	11717	1277.1	47	8.5	13580	1480.2	50	7.9	12446	1356.6	82	14.6	16180	1051.7
Pinus strobus (Haploxylon)	139	27.4	25851	2817.7	142	30.3	41028	4472.0	199	36.0	49536	5399.4	139	29.4	27427	1782.8
Pinus (total)	280	47.6	52074	5676.0	251	45.6	72521	7904.8	325	51.6	80900	8818.1	302	53.6	59590	3873.3
Platanus occidentalis	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Populus	4	0.8	744	81.1	0	0.0	0	0.0	0	0.0	0	0.0	1	0.2	197	12.8
Prunus	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Quercus	25	4.9	4649	506.8	30	6.4	8668	944.8	46	8.3	11450	1248.1	35	7.4	6906	448.9
Salix	1	0.2	186	20.3	0	0.0	0	0.0	0	0.0	0	0.0	1	0.2	197	12.8
Thuja occidentalis/Juniperus —type	19	3.7	3534	385.2	29	6.2	8379	913.3	27	4.9	6721	732.6	18	3.8	3552	230.9
Tilia americana	0	0.0	0	0.0	2	0.4	578	63.0	0	0.0	0	0.0	1	0.2	197	12.8
Tsuga canadensis	19	3.7	3534	385.2	8	1.7	2311	251.9	7	1.3	1742	189.9	8	1.7	1579	102.6
Ulmus	6	1.2	1116	121.6	15	3.2	4334	472.4	4	0.7	996	108.5	5	1.1	987	64.1
ARBOREAL POLLEN (TOTAL)	507	86.2	94290	10277.6	468	84.9	135219	14738.8	553	87.8	137654	15004.3	472	83.8	93134	6053.7

Appendix H. Beaverhouse Lake Palynomorph Tabulation (continued).

Beaverhouse Lake, Mackinac County, Michigan																
Depth (cm below platform)	325.0				335.9				346.7				354.6			
Depth (cm below water/sediment interface)	115.0				125.9				136.7				144.6			
Age (yr BP)	3100				3200				3300				3400			
Taxa	Count (No.)	Percent (%)	Conc. (gr cm^{-3})	Influx (gr cm^{-2} yr^{-1})	Count (No.)	Percent (%)	Conc. (gr cm^{-3})	Influx (gr cm^{-2} yr^{-1})	Count (No.)	Percent (%)	Conc. (gr cm^{-3})	Influx (gr cm^{-2} yr^{-1})	Count (No.)	Percent (%)	Conc. (gr cm^{-3})	Influx (gr cm^{-2} yr^{-1})
Alnus crispa	0	0.0	0	0.0	1	0.2	289	31.5	0	0.0	0	0.0	2	0.3	395	25.7
Alnus rugosa-type	11	1.9	2046	223.0	9	1.6	2600	283.4	3	0.5	747	81.4	9	1.6	1776	115.4
Cephalanthus occidentalis	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Corylus	1	0.2	186	20.3	2	0.4	578	63.0	2	0.3	498	54.3	2	0.3	395	25.7
Ericaceae (tetrads)	3	0.5	558	60.8	2	0.4	578	63.0	0	0.0	0	0.0	3	0.5	592	38.5
Ilex/Nemopanthus —type	0	0.0	0	0.0	2	0.4	578	63.0	0	0.0	0	0.0	0	0.0	0	0.0
Myrica —type	10	1.7	1860	202.7	13	2.3	3756	409.4	9	1.4	2240	244.2	14	2.4	2762	179.6
Moraceae	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Sambucus	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Total Shrubs	25	4.3	4649	506.8	29	5.3	8379	913.3	14	2.2	3485	379.9	30	5.3	5920	384.8
Vitis	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Epiphytes	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Ambrosia —type	4	0.7	744	81.1	6	1.1	1734	189.0	3	0.5	747	81.4	5	0.9	987	64.1
Artemisia	3	0.5	558	60.8	2	0.4	578	63.0	5	0.8	1245	135.7	0	0.0	0	0.0
Campanulaceae	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Caryophyllaceae	0	0.0	0	0.0	1	0.2	289	31.5	0	0.0	0	0.0	0	0.0	0	0.0
Chenopodium —type	0	0.0	0	0.0	2	0.4	578	63.0	0	0.0	0	0.0	2	0.3	395	25.7
Cornus canadensis —type	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Cyperaceae	45	7.6	8369	912.2	33	5.9	9535	1039.3	48	7.5	11948	1302.4	44	7.6	8682	564.3
Labiatae	0	0.0	0	0.0	1	0.2	289	31.5	0	0.0	0	0.0	0	0.0	0	0.0
Menyanthes trifoliata	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	1	0.2	197	12.8
Petalostemum purpureum -type	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Poaceae	0	0.0	0	0.0	6	1.1	1734	189.0	5	0.8	1245	135.7	4	0.7	789	51.3
Polygonum	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Potentilla —type	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Rosaceae	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	1	0.2	197	12.8
Rhamnus	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Rubiaceae	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Rumex	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Saxifragaceae	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Thalictrum	3	0.5	558	60.8	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Tubuliflorea	1	0.2	186	20.3	3	0.5	867	94.5	2	0.3	498	54.3	4	0.7	789	51.3
Umbelliferae	0.0	0.0	0	0.0	0.0	0.0	0	0.0	0.0	0.0	0	0.0	0.0	0.0	0	0.0
Ephedra —type	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Total NonArboreal Herbs	56	9.5	10415	1135.2	54	9.8	15602	1700.6	63	10.0	15682	1709.4	61	10.8	12036	782.4
Total Terrestrial Pollen	588	100.0	109354	11919.6	551	100.0	159200	17352.8	630	100.0	156822	17093.5	563	100.0	111090	7220.8
Adiantum/Dennstaedtia	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Botrychium	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Equisetum	0	0.0	0	0.0	0	0.0	0	0.0	2	0.3	498	54.3	1	0.2	197	12.8
Lycopodium annotinum	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Lycopodium clavatum	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Lycopodium complanatum -type	0	0.0	0	0.0	1	0.2	289	31.5	0	0.0	0	0.0	0	0.0	0	0.0

Appendix H. Beaverhouse Lake Palynomorph Tabulation (continued).

Beaverhouse Lake, Mackinac County, Michigan																
Depth (cm below platform)	325.0				335.9				346.7				354.6			
Depth (cm below water/sediment interface)	115.0				125.9				136.7				144.6			
Age (yr BP)	3100				3200				3300				3400			
Taxa	Count (No.)	Percent (%)	Conc. (gr cm^{-3})	Influx (gr cm^{-2} yr^{-1})	Count (No.)	Percent (%)	Conc. (gr cm^{-3})	Influx (gr cm^{-2} yr^{-1})	Count (No.)	Percent (%)	Conc. (gr cm^{-3})	Influx (gr cm^{-2} yr^{-1})	Count (No.)	Percent (%)	Conc. (gr cm^{-3})	Influx (gr cm^{-2} yr^{-1})
Lycopodium inundatum	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Lycopodium lucidulum	0	0.0	0	0.0	1	0.2	289	31.5	0	0.0	0	0.0	0	0.0	0	0.0
Lycopodium obscurum	0	0.0	0	0.0	1	0.2	289	31.5	0	0.0	0	0.0	0	0.0	0	0.0
Lycopodium (undiff.)	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Lycopodium (total)	0	0.0	0	0.0	3	0.5	867	94.5	0	0.0	0	0.0	0	0.0	0	0.0
Monolete spores (undiff.)	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Osmunda cinnamomea	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Osmunda regalis -type	1	0.2	186	20.3	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Polypodium	2	0.3	372	40.5	2	0.4	578	63.0	0	0.0	0	0.0	6	1.0	1184	77.0
Pteridium aquilinum	0	0.0	0	0.0	2	0.4	578	63.0	3	0.5	747	81.4	4	0.7	789	51.3
Trilete spores (undiff.)	0.0	0.0	0	0.0	0.0	0.0	0	0.0	0.0	0.0	0	0.0	2.0	0.3	395	25.7
Selaginella	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Total Ferns and Allies	3	0.5	558	60.8	7	1.3	2023	220.5	5	0.8	1245	135.7	13	2.2	2565	166.7
Unknowns	1	0.2	186	20.3	1	0.2	289	31.5	1	0.2	249	27.1	2	0.3	395	25.7
Total Upland Pollen & Spores	592	100.0	110098	12000.7	559	100.0	161511	17604.7	636	100.0	158315	17256.3	578	100.0	114049	7413.2
Brasenia schreberi	15	2.3	2790	304.1	13	2.2	3756	409.4	22	3.2	5476	596.9	4	0.7	789	51.3
Caltha	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Drosera	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Isoetes	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Myriophyllum exalbescens —type	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Nuphar	7	1.1	1302	141.9	2	0.3	578	63.0	4	0.6	996	108.5	0	0.0	0	0.0
Nymphea	11	1.7	2046	223.0	9	1.5	2600	283.4	13	1.9	3236	352.7	1	0.2	197	12.8
Potamogeton	2	0.3	372	40.5	2	0.3	578	63.0	1	0.1	249	27.1	0	0.0	0	0.0
Sagittaria	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Sphagnum	12	1.9	2232	243.3	15	2.5	4334	472.4	3	0.4	747	81.4	26	4.3	5130	333.5
Typha latifolia	2	0.3	372	40.5	0	0.0	0	0.0	2	0.3	498	54.3	0	0.0	0	0.0
Sparganium —type	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	2	0.3	395	25.7
Utricularia	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Total Aquatics	49	7.6	9113	993.3	41	6.8	11846	1291.2	45	6.6	11202	1221.0	33	5.4	6511	423.2
Total Determinable Pollen and Spores	641	100.0	119211	12994.0	600	100.0	173357	18895.9	681	100.0	169517	18477.3	611	100.0	120561	7836.4
Indeterminate grains	5	0.8	930	101.4	6	1.0	1734	189.0	4	0.6	996	108.5	7	1.1	1381	89.8
Total Pollen and Spores	646	100.0	120141	13095.4	606	100.0	175091	19084.9	685	100.0	170512	18585.8	618	100.0	121942	7926.2
Pediastrum colonies	0	0.0	0	0.0	5	0.8	1445	157.5	2	0.3	498	54.3	0	0.0	0	0.0
Nymphaeceae basal cells	69	10.7	12832	1398.7	108	17.8	31204	3401.3	77	11.2	19167	2089.2	52	8.4	10260	666.9
Nymphaeceae sclerids	16	2.5	2976	324.3	15	2.5	4334	472.4	13	1.9	3236	352.7	7	1.1	1381	89.8
Eucalyptus grains counted	87				56				65				82			
No. of *Eucalyptus* tablets	1				1				1				1			
Sample volume (cm^3)	1.0				1.0				1.0				1.0			
Accumulation rate (cm yr^{-1})	0.11				0.11				0.11				0.07			
Eucalyptus grains added	16180				16180				16180				16180			
Eucalyptus concentration (gr cm^{-3})	16180				16180				16180				16180			
Total Pollen Influx (gr cm^{-2} yr^{-1})	13095				19085				18586				7926			

Appendix H. Beaverhouse Lake Palynomorph Tabulation (continued).

Beaverhouse Lake, Mackinac County, Michigan

Depth (cm below platform)	364.3				367.6				374.1				380.7			
Depth (cm below water/sediment interface)	154.3				157.6				164.1				170.7			
Age (yr BP)	3550				3600				3700				3800			
Taxa	Count (No.)	Percent (%)	Conc. (gr cm^{-3})	Influx (gr cm^{-2} yr^{-1})	Count (No.)	Percent (%)	Conc. (gr cm^{-3})	Influx (gr cm^{-2} yr^{-1})	Count (No.)	Percent (%)	Conc. (gr cm^{-3})	Influx (gr cm^{-2} yr^{-1})	Count (No.)	Percent (%)	Conc. (gr cm^{-3})	Influx (gr cm^{-2} yr^{-1})
Abies	3	0.7	564	36.7	2	0.4	212	13.7	0	0.0	0	0.0	1	0.2	165	10.7
Acer (undiff.)	0	0.0	0	0.0	0	0.0	0	0.0	1	0.2	132	8.6	0	0.0	0	0.0
A. pensylvanicum	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
A. rubrum	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
A. saccharum	0	0.0	0	0.0	5	1.0	529	34.4	3	0.7	395	25.7	0	0.0	0	0.0
A. spicatum	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Acer (total)	0	0.0	0	0.0	5	0.9	529	34.4	4	0.8	526	34.2	0	0.0	0	0.0
Betula	61	15.1	11477	746.0	79	16.5	8354	543.0	74	18.0	9734	632.7	64	15.2	10567	686.8
Carpinus/Ostrya —type	4	1.0	753	48.9	5	1.0	529	34.4	3	0.7	395	25.7	0	0.0	0	0.0
Carya	0	0.0	0	0.0	0	0.0	0	0.0	1	0.2	132	8.6	0	0.0	0	0.0
Castanea dentata	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Celtis occidentalis	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Fagus grandifolia	3	0.6	564	36.7	0	0.0	0	0.0	5	1.0	658	42.8	3	0.6	495	32.2
Fraxinus (undiff.)	0	0.0	0	0.0	0	0.0	0	0.0	3	0.7	395	25.7	3	0.7	495	32.2
Fraxinus americana/pennsylvanica —type	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Fraxinus nigra	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Fraxinus (total)	0	0.0	0	0.0	0	0.0	0	0.0	3	0.6	395	25.7	3	0.6	495	32.2
Juglans (undiff.)	0	0.0	0	0.0	0	0.0	0	0.0	3	0.7	395	25.7	0	0.0	0	0.0
Juglans cinerea	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Juglans nigra	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Juglans (total)	0	0.0	0	0.0	0	0.0	0	0.0	3	0.6	395	25.7	0	0.0	0	0.0
Larix laricina	3	0.7	564	36.7	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Liquidambar styraciflua	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Picea (undiff.)	4	1.0	753	48.9	2	0.4	212	13.7	3	0.7	395	25.7	7	1.7	1156	75.1
Picea marina	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Picea glauca	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Picea (total)	4	0.8	753	48.9	2	0.4	212	13.7	3	0.6	395	25.7	7	1.4	1156	75.1
Pinus (undiff.)	104	25.7	19567	1271.8	160	33.5	16920	1099.8	93	22.6	12234	795.2	115	27.3	18987	1234.1
Pinus banksiana/resinosa (Diploxylon)	63	12.3	11853	770.4	64	11.8	6768	439.9	47	9.3	6183	401.9	56	11.0	9246	601.0
Pinus strobus (Haploxylon)	99	24.4	18626	1210.7	104	21.8	10998	714.9	104	25.2	13681	889.2	119	28.3	19647	1277.1
Pinus (total)	266	51.8	50045	3252.9	328	60.3	34687	2254.6	244	48.1	32097	2086.3	290	57.1	47880	3112.2
Platanus occidentalis	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	1	0.2	165	10.7
Populus	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	3	0.7	495	32.2
Prunus	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Quercus	32	7.9	6020	391.3	23	4.8	2432	158.1	28	6.8	3683	239.4	19	4.5	3137	203.9
Salix	0	0.0	0	0.0	2	0.4	212	13.7	4	1.0	526	34.2	1	0.2	165	10.7
Thuja occidentalis/Juniperus —type	5	1.2	941	61.1	12	2.5	1269	82.5	9	2.2	1184	77.0	11	2.6	1816	118.0
Tilia americana	1	0.2	188	12.2	2	0.4	212	13.7	1	0.2	132	8.6	0	0.0	0	0.0
Tsuga canadensis	18	4.4	3387	220.1	12	2.5	1269	82.5	20	4.9	2631	171.0	14	3.3	2311	150.2
Ulmus	5	1.2	941	61.1	6	1.3	635	41.2	10	2.4	1315	85.5	4	1.0	660	42.9
ARBOREAL POLLEN (TOTAL)	405	78.8	76197	4952.8	478	87.9	50549	3285.7	412	81.3	54196	3522.8	421	82.9	69508	4518.0

Appendix H. Beaverhouse Lake Palynomorph Tabulation (continued).

Beaverhouse Lake, Mackinac County, Michigan

Depth (cm below platform)	364.3				367.6				374.1				380.7			
Depth (cm below water/sediment interface)	154.3				157.6				164.1				170.7			
Age (yr BP)	3550				3600				3700				3800			
Taxa	Count (No.)	Percent (%)	Conc. (gr cm^{-3})	Influx (gr cm^{-2} yr^{-1})	Count (No.)	Percent (%)	Conc. (gr cm^{-3})	Influx (gr cm^{-2} yr^{-1})	Count (No.)	Percent (%)	Conc. (gr cm^{-3})	Influx (gr cm^{-2} yr^{-1})	Count (No.)	Percent (%)	Conc. (gr cm^{-3})	Influx (gr cm^{-2} yr^{-1})
Alnus crispa	3	0.5	564	36.7	2	0.4	212	13.7	0	0.0	0	0.0	3	0.6	495	32.2
Alnus rugosa-type	17	3.1	3198	207.9	17	3.0	1798	116.9	15	2.8	1973	128.3	10	1.9	1651	107.3
Cephalanthus occidentalis	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Corylus	1	0.2	188	12.2	0	0.0	0	0.0	0	0.0	0	0.0	1	0.2	165	10.7
Ericaceae (tetrads)	5	0.9	941	61.1	5	0.9	529	34.4	9	1.7	1184	77.0	7	1.3	1156	75.1
Ilex/Nemopanthus —type	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Myrica —type	25	4.6	4703	305.7	9	1.6	952	61.9	18	3.4	2368	153.9	23	4.4	3797	246.8
Moraceae	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Sambucus	3	0.5	564	36.7	0	0.0	0	0.0	0	0.0	0	0.0	1	0.2	165	10.7
Total Shrubs	54	10.5	10160	660.4	33	6.1	3490	226.8	42	8.3	5525	359.1	45	8.9	7430	482.9
Vitis	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Epiphytes	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Ambrosia —type	4	0.7	753	48.9	9	1.6	952	61.9	0	0.0	0	0.0	8	1.5	1321	85.9
Artemisia	3	0.5	564	36.7	3	0.5	317	20.6	6	1.1	789	51.3	0	0.0	0	0.0
Campanulaceae	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Caryophyllaceae	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Chenopodium —type	3	0.5	564	36.7	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Cornus canadensis —type	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Cyperaceae	32	5.9	6020	391.3	15	2.7	1586	103.1	34	6.4	4473	290.7	28	5.4	4623	300.5
Labiatae	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Menyanthes trifoliata	3	0.5	564	36.7	0	0.0	0	0.0	3	0.6	395	25.7	1	0.2	165	10.7
Petalostemum purpureum -type	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Poaceae	4	0.7	753	48.9	3	0.5	317	20.6	3	0.6	395	25.7	0	0.0	0	0.0
Polygonum	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Potentilla —type	1	0.2	188	12.2	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Rosaceae	1	0.2	188	12.2	0	0.0	0	0.0	1	0.2	132	8.6	1	0.2	165	10.7
Rhamnus	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Rubiaceae	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Rumex	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Saxifragaceae	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Thalictrum	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Tubuliflorea	4	0.7	753	48.9	3	0.5	317	20.6	6	1.1	789	51.3	4	0.8	660	42.9
Umbelliferae	0.0	0.0	0	0.0	0.0	0.0	0	0.0	0.0	0.0	0	0.0	0.0	0.0	0	0.0
Ephedra —type	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Total NonArboreal Herbs	55	10.7	10348	672.6	33	6.1	3490	226.8	53	10.5	6972	453.2	42	8.3	6934	450.7
Total Terrestrial Pollen	514	100.0	96704	6285.7	544	100.0	57529	3739.4	507	100.0	66693	4335.1	508	100.0	83872	5451.7
Adiantum/Dennstaedtia	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Botrychium	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Equisetum	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Lycopodium annotinum	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Lycopodium clavatum	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Lycopodium complanatum -type	1	0.2	188	12.2	2	0.4	212	13.7	0	0.0	0	0.0	0	0.0	0	0.0

Appendix H. Beaverhouse Lake Palynomorph Tabulation (continued).

Beaverhouse Lake, Mackinac County, Michigan																
Depth (cm below platform)	364.3				367.6				374.1				380.7			
Depth (cm below water/sediment interface)	154.3				157.6				164.1				170.7			
Age (yr BP)	3550				3600				3700				3800			
Taxa	Count (No.)	Percent (%)	Conc. (gr cm^{-3})	Influx (gr cm^{-2} yr^{-1})	Count (No.)	Percent (%)	Conc. (gr cm^{-3})	Influx (gr cm^{-2} yr^{-1})	Count (No.)	Percent (%)	Conc. (gr cm^{-3})	Influx (gr cm^{-2} yr^{-1})	Count (No.)	Percent (%)	Conc. (gr cm^{-3})	Influx (gr cm^{-2} yr^{-1})
Lycopodium inundatum	0	0.0	0	0.0	0	0.0	0	0.0	1	0.2	132	8.6	0	0.0	0	0.0
Lycopodium lucidulum	3	0.5	564	36.7	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Lycopodium obscurum	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Lycopodium (undiff.)	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Lycopodium (total)	4	0.7	753	48.9	2	0.4	212	13.7	1	0.2	132	8.6	0	0.0	0	0.0
Monolete spores (undiff.)	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Osmunda cinnamomea	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Osmunda regalis -type	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Polypodium	5	0.9	941	61.1	0	0.0	0	0.0	8	1.5	1052	68.4	4	0.8	660	42.9
Pteridium aquilinum	10	1.8	1881	122.3	9	1.6	952	61.9	11	2.1	1447	94.1	4	0.8	660	42.9
Trilete spores (undiff.)	10	1.8	1881	122.3	6.0	1.1	635	41.2	1.0	0.2	132	8.6	4.0	0.8	660	42.9
Selaginella	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Total Ferns and Allies	29	5.3	5456	354.6	17	3.0	1798	116.9	21	4.0	2762	179.6	12	2.3	1981	128.8
Unknowns	3	0.5	564	36.7	2	0.4	212	13.7	1	0.2	132	8.6	3	0.6	495	32.2
Total Upland Pollen & Spores	546	100.0	102724	6677.1	563	100.0	59538	3870.0	529	100.0	69587	4523.2	523	100.0	86348	5612.6
Brasenia schreberi	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Caltha	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Drosera	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Isoetes	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Myriophyllum exalbescens —type	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Nuphar	1	0.2	188	12.2	2	0.3	212	13.7	0	0.0	0	0.0	0	0.0	0	0.0
Nymphea	0	0.0	0	0.0	2	0.3	212	13.7	1	0.2	132	8.6	0	0.0	0	0.0
Potamogeton	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Sagittaria	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Sphagnum	38	6.5	7149	464.7	50	8.0	5288	343.7	82	13.3	10787	701.1	69	11.6	11392	740.5
Typha latifolia	3	0.5	564	36.7	5	0.8	529	34.4	4	0.6	526	34.2	3	0.5	495	32.2
Sparganium —type	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Utricularia	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Total Aquatics	42	7.1	7902	513.6	59	9.5	6239	405.6	87	14.1	11444	743.9	72	12.1	11887	772.7
Total Determinable Pollen and Spores	588	100.0	110626	7190.7	622	100.0	65778	4275.5	616	100.0	81032	5267.1	595	100.0	98236	6385.3
Indeterminate grains	17	2.8	3198	207.9	11	1.7	1163	75.6	9	1.4	1184	77.0	11	1.8	1816	118.0
Total Pollen and Spores	605	100.0	113824	7398.6	633	100.0	66941	4351.2	625	100.0	82215	5344.0	606	100.0	100052	6503.4
Pediastrum colonies	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Nymphaeaceae basal cells	9	1.5	1693	110.1	3	0.5	317	20.6	5	0.8	658	42.8	7	1.2	1156	75.1
Nymphaeaceae sclerids	1	0.2	188	12.2	2	0.3	212	13.7	0	0.0	0	0.0	1	0.2	165	10.7
Eucalyptus grains counted	86				153				123				98			
No. of *Eucalyptus* tablets	1				1				1				1			
Sample volume (cm^{3})	1.0				1.0				1.0				1.0			
Accumulation rate (cm yr^{-1})	0.07				0.07				0.07				0.07			
Eucalyptus grains added	16180				16180				16180				16180			
Eucalyptus concentration (gr cm^{-3})	16180				16180				16180				16180			
Total Pollen Influx (gr cm^{-2} yr^{-1})	7399				4351				5344				6503			

Appendix H. Beaverhouse Lake Palynomorph Tabulation (continued).

Beaverhouse Lake, Mackinac County, Michigan																
Depth (cm below platform)	387.2				393.7				397.5				400.5			
Depth (cm below water/sediment interface)	177.2				183.7				187.5				190.5			
Age (yr BP)	3900				4000				4100				4200			
Taxa	Count (No.)	Percent (%)	Conc. (gr cm^{-3})	Influx (gr cm^{-2} yr^{-1})	Count (No.)	Percent (%)	Conc. (gr cm^{-3})	Influx (gr cm^{-2} yr^{-1})	Count (No.)	Percent (%)	Conc. (gr cm^{-3})	Influx (gr cm^{-2} yr^{-1})	Count (No.)	Percent (%)	Conc. (gr cm^{-3})	Influx (gr cm^{-2} yr^{-1})
Abies	4	0.9	622	40.5	0	0.0	0	0.0	4	0.8	490	15.2	0	0.0	0	0.0
Acer (undiff.)	0	0.0	0	0.0	0	0.0	0	0.0	2	0.4	245	7.6	0	0.0	0	0.0
A. pensylvanicum	1	0.2	156	10.1	0	0.0	0	0.0	1	0.2	123	3.8	0	0.0	0	0.0
A. rubrum	3	0.7	467	30.3	0	0.0	0	0.0	1	0.2	123	3.8	0	0.0	0	0.0
A. saccharum	1	0.2	156	10.1	9	1.8	1464	95.1	2	0.4	245	7.6	2	0.4	251	7.8
A. spicatum	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Acer (total)	5	0.9	778	50.6	9	1.6	1464	95.1	6	1.0	735	22.8	2	0.3	251	7.8
Betula	71	16.1	11046	718.0	63	12.9	10245	665.9	88	17.6	10787	334.4	22	4.3	2759	85.5
Carpinus/Ostrya —type	4	0.9	622	40.5	10	2.0	1626	105.7	3	0.6	368	11.4	3	0.6	376	11.7
Carya	0	0.0	0	0.0	0	0.0	0	0.0	1	0.2	123	3.8	0	0.0	0	0.0
Castanea dentata	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Celtis occidentalis	1	0.2	156	10.1	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Fagus grandifolia	3	0.6	467	30.3	3	0.5	488	31.7	3	0.5	368	11.4	0	0.0	0	0.0
Fraxinus (undiff.)	4	0.9	622	40.5	0	0.0	0	0.0	3	0.6	368	11.4	3	0.6	376	11.7
Fraxinus americana/pennsylvanica —type	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Fraxinus nigra	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Fraxinus (total)	4	0.7	622	40.5	0	0.0	0	0.0	3	0.5	368	11.4	3	0.5	376	11.7
Juglans (undiff.)	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Juglans cinerea	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Juglans nigra	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Juglans (total)	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Larix laricina	0	0.0	0	0.0	4	0.8	650	42.3	3	0.6	368	11.4	2	0.4	251	7.8
Liquidambar styraciflua	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Picea (undiff.)	12	2.7	1867	121.4	7	1.4	1138	74.0	2	0.4	245	7.6	0	0.0	0	0.0
Picea marina	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Picea glauca	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Picea (total)	12	2.2	1867	121.4	7	1.2	1138	74.0	2	0.3	245	7.6	0	0.0	0	0.0
Pinus (undiff.)	110	24.9	17113	1112.4	104	21.2	16912	1099.3	75	15.0	9193	285.0	105	20.3	13170	408.3
Pinus banksiana/resinosa (Diploxylon)	48	8.9	7468	485.4	48	8.5	7805	507.4	90	14.8	11032	342.0	49	7.9	6146	190.5
Pinus strobus (Haploxylon)	110	24.9	17113	1112.4	158	32.2	25693	1670.0	152	30.4	18632	577.6	294	56.9	36875	1143.1
Pinus (total)	268	49.8	41695	2710.2	310	54.7	50410	3276.7	317	52.1	38857	1204.6	448	72.3	56191	1741.9
Platanus occidentalis	0	0.0	0	0.0	1	0.2	163	10.6	0	0.0	0	0.0	0	0.0	0	0.0
Populus	0	0.0	0	0.0	4	0.8	650	42.3	0	0.0	0	0.0	2	0.4	251	7.8
Prunus	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Quercus	23	5.2	3578	232.6	8	1.6	1301	84.6	21	4.2	2574	79.8	22	4.3	2759	85.5
Salix	1	0.2	156	10.1	1	0.2	163	10.6	1	0.2	123	3.8	0	0.0	0	0.0
Thuja occidentalis/Juniperus —type	23	5.2	3578	232.6	4	0.8	650	42.3	15	3.0	1839	57.0	3	0.6	376	11.7
Tilia americana	0	0.0	0	0.0	0	0.0	0	0.0	1	0.2	123	3.8	0	0.0	0	0.0
Tsuga canadensis	17	3.8	2645	171.9	60	12.2	9757	634.2	27	5.4	3310	102.6	10	1.9	1254	38.9
Ulmus	6	1.4	933	60.7	6	1.2	976	63.4	5	1.0	613	19.0	0	0.0	0	0.0
ARBOREAL POLLEN (TOTAL)	442	82.2	68765	4469.7	490	86.4	79680	5179.2	500	82.2	61288	1899.9	517	83.4	64845	2010.2

Appendix H. Beaverhouse Lake Palynomorph Tabulation (continued).

Beaverhouse Lake, Mackinac County, Michigan																
Depth (cm below platform)	387.2				393.7				397.5				400.5			
Depth (cm below water/sediment interface)	177.2				183.7				187.5				190.5			
Age (yr BP)	3900				4000				4100				4200			
Taxa	Count (No.)	Percent (%)	Conc. (gr cm^{-3})	Influx (gr cm^{-2} yr^{-1})	Count (No.)	Percent (%)	Conc. (gr cm^{-3})	Influx (gr cm^{-2} yr^{-1})	Count (No.)	Percent (%)	Conc. (gr cm^{-3})	Influx (gr cm^{-2} yr^{-1})	Count (No.)	Percent (%)	Conc. (gr cm^{-3})	Influx (gr cm^{-2} yr^{-1})
Alnus crispa	0	0.0	0	0.0	0	0.0	0	0.0	1	0.2	123	3.8	5	0.8	627	19.4
Alnus rugosa-type	9	1.6	1400	91.0	4	0.7	650	42.3	10	1.6	1226	38.0	14	2.2	1756	54.4
Cephalanthus occidentalis	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Corylus	3	0.5	467	30.3	1	0.2	163	10.6	2	0.3	245	7.6	0	0.0	0	0.0
Ericaceae (tetrads)	3	0.5	467	30.3	1	0.2	163	10.6	3	0.5	368	11.4	0	0.0	0	0.0
Ilex/Nemopanthus —type	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Myrica —type	25	4.6	3889	252.8	1	0.2	163	10.6	14	2.3	1716	53.2	2	0.3	251	7.8
Moraceae	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Sambucus	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Total Shrubs	40	7.4	6223	404.5	7	1.2	1138	74.0	30	4.9	3677	114.0	21	3.4	2634	81.7
Vitis	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Epiphytes	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Ambrosia —type	6	1.1	933	60.7	1	0.2	163	10.6	4	0.6	490	15.2	7	1.1	878	27.2
Artemisia	6	1.1	933	60.7	3	0.5	488	31.7	3	0.5	368	11.4	2	0.3	251	7.8
Campanulaceae	0	0.0	0	0.0	0	0.0	0	0.0	1	0.2	123	3.8	0	0.0	0	0.0
Caryophyllaceae	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Chenopodium —type	0	0.0	0	0.0	3	0.5	488	31.7	2	0.3	245	7.6	0	0.0	0	0.0
Cornus canadensis —type	0	0.0	0	0.0	0	0.0	0	0.0	1	0.2	123	3.8	0	0.0	0	0.0
Cyperaceae	39	7.1	6068	394.4	57	10.0	9269	602.5	61	9.9	7477	231.8	53	8.5	6648	206.1
Labiatae	0	0.0	0	0.0	1	0.2	163	10.6	0	0.0	0	0.0	0	0.0	0	0.0
Menyanthes trifoliata	0	0.0	0	0.0	0	0.0	0	0.0	2	0.3	245	7.6	0	0.0	0	0.0
Petalostemum purpureum -type	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Poaceae	4	0.7	622	40.5	4	0.7	650	42.3	1	0.2	123	3.8	0	0.0	0	0.0
Polygonum	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Potentilla —type	0	0.0	0	0.0	0	0.0	0	0.0	1	0.2	123	3.8	20	3.2	2509	77.8
Rosaceae	1	0.2	156	10.1	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Rhamnus	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Rubiaceae	0	0.0	0	0.0	0	0.0	0	0.0	1	0.2	123	3.8	0	0.0	0	0.0
Rumex	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Saxifragaceae	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Thalictrum	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Tubuliflorea	0	0.0	0	0.0	1	0.2	163	10.6	1	0.2	123	3.8	0	0.0	0	0.0
Umbelliferae	0.0	0.0	0	0.0	0.0	0.0	0	0.0	0.0	0.0	0	0.0	0.0	0.0	0	0.0
Ephedra —type	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Total NonArboreal Herbs	56	10.4	8712	566.3	70	12.3	11383	739.9	78	12.8	9561	296.4	82	13.2	10285	318.8
Total Terrestrial Pollen	538	100.0	83700	5440.5	567	100.0	92202	5993.1	608	100.0	74526	2310.3	620	100.0	77764	2410.7
Adiantum/Dennstaedtia	3	0.5	467	30.3	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Botrychium	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Equisetum	0	0.0	0	0.0	1	0.2	163	10.6	0	0.0	0	0.0	0	0.0	0	0.0
Lycopodium annotinum	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Lycopodium clavatum	0	0.0	0	0.0	0	0.0	0	0.0	1	0.2	123	3.8	0	0.0	0	0.0
Lycopodium complanatum -type	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0

Appendix H. Beaverhouse Lake Palynomorph Tabulation (continued).

Beaverhouse Lake, Mackinac County, Michigan																
Depth (cm below platform)	387.2				393.7				397.5				400.5			
Depth (cm below water/sediment interface)	177.2				183.7				187.5				190.5			
Age (yr BP)	3900				4000				4100				4200			
Taxa	Count (No.)	Percent (%)	Conc. (gr cm^{3})	Influx (gr cm^{2} yr^{1})	Count (No.)	Percent (%)	Conc. (gr cm^{3})	Influx (gr cm^{2} yr^{1})	Count (No.)	Percent (%)	Conc. (gr cm^{3})	Influx (gr cm^{2} yr^{1})	Count (No.)	Percent (%)	Conc. (gr cm^{3})	Influx (gr cm^{2} yr^{1})
Lycopodium inundatum	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Lycopodium lucidulum	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Lycopodium obscurum	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Lycopodium (undiff.)	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Lycopodium (total)	0	0.0	0	0.0	0	0.0	0	0.0	1	0.2	123	3.8	0	0.0	0	0.0
Monolete spores (undiff.)	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Osmunda cinnamomea	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Osmunda regalis -type	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Polypodium	0	0.0	0	0.0	1	0.2	163	10.6	2	0.3	245	7.6	0	0.0	0	0.0
Pteridium aquilinum	1	0.2	156	10.1	1	0.2	163	10.6	3	0.5	368	11.4	0	0.0	0	0.0
Trilete spores (undiff.)	6.0	1.1	933	60.7	0	0.0	0	0.0	0.0	0.0	0	0.0	3.0	0.5	376	11.7
Selaginella	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Total Ferns and Allies	10	1.8	1556	101.1	3	0.5	488	31.7	6	1.0	735	22.8	3	0.5	376	11.7
Unknowns	1	0.2	156	10.1	1	0.2	163	10.6	4	0.6	490	15.2	0	0.0	0	0.0
Total Upland Pollen & Spores	549	100.0	85412	5551.8	571	100.0	92852	6035.4	618	100.0	75752	2348.3	623	100.0	78141	2422.4
Brasenia schreberi	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Caltha	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Drosera	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Isoetes	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Myriophyllum exalbescens —type	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Nuphar	1	0.2	156	10.1	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Nymphea	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Potamogeton	0	0.0	0	0.0	3	0.5	488	31.7	2	0.3	245	7.6	0	0.0	0	0.0
Sagittaria	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Sphagnum	46	7.7	7157	465.2	7	1.2	1138	74.0	38	5.8	4658	144.4	0	0.0	0	0.0
Typha latifolia	3	0.5	467	30.3	3	0.5	488	31.7	1	0.2	123	3.8	0	0.0	0	0.0
Sparganium —type	0	0.0	0	0.0	0	0.0	0	0.0	1	0.2	123	3.8	0	0.0	0	0.0
Utricularia	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Total Aquatics	50	8.3	7779	505.6	13	2.2	2114	137.4	42	6.4	5148	159.6	0	0.0	0	0.0
Total Determinable Pollen and Spores	599	100.0	93191	6057.4	584	100.0	94966	6172.8	660	100.0	80900	2507.9	623	100.0	78141	2422.4
Indeterminate grains	9	1.5	1400	91.0	20	3.3	3252	211.4	11	1.6	1348	41.8	5	0.8	627	19.4
Total Pollen and Spores	608	100.0	94591	6148.4	604	100.0	98218	6384.2	671	100.0	82248	2549.7	628	100.0	78768	2441.8
Pediastrum colonies	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Nymphaeceae basal cells	1	0.2	156	10.1	0	0.0	0	0.0	4	0.6	490	15.2	0	0.0	0	0.0
Nymphaeceae sclerids	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Eucalyptus grains counted	104				199				132				129			
No. of *Eucalyptus* tablets	1				1				1				1			
Sample volume (cm^{3})	1.0				0.5				1.0				1.0			
Accumulation rate (cm yr^{1})	0.07				0.07				0.03				0.03			
Eucalyptus grains added	16180				16180				16180				16180			
Eucalyptus concentration (gr cm^{3})	16180				32360				16180				16180			
Total Pollen Influx (gr cm^{2} yr^{1})	6148				6384				2550				2442			

Appendix H. Beaverhouse Lake Palynomorph Tabulation (continued).

Beaverhouse Lake, Mackinac County, Michigan																
Depth (cm below platform)	403.6				406.6				409.7				412.8			
Depth (cm below water/sediment interface)	193.6				196.6				199.7				202.8			
Age (yr BP)	4300				4400				4500				4600			
Taxa	Count (No.)	Percent (% TTP)	Conc. (gr cm^{-3})	Influx (gr cm^{-2} yr^{-1})	Count (No.)	Percent (%)	Conc. (gr cm^{-3})	Influx (gr cm^{-2} yr^{-1})	Count (No.)	Percent (%)	Conc. (gr cm^{-3})	Influx (gr cm^{-2} yr^{-1})	Count (No.)	Percent (%)	Conc. (gr cm^{-3})	Influx (gr cm^{-2} yr^{-1})
Abies	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Acer (undiff.)	0	0.0	0	0.0	2	0.4	247	7.7	1	0.2	133	4.1	0	0.0	0	0.0
A. pensylvanicum	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
A. rubrum	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
A. saccharum	4	1.0	446	13.8	2	0.4	247	7.7	1	0.2	133	4.1	0	0.0	0	0.0
A. spicatum	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Acer (total)	4	0.8	446	13.8	4	0.7	494	15.3	2	0.4	265	8.2	0	0.0	0	0.0
Betula	28	6.7	3124	96.9	12	2.4	1482	45.9	7	1.7	928	28.8	27	6.1	9497	294.4
Carpinus/Ostrya —type	6	1.4	670	20.8	9	1.8	1112	34.5	0	0.0	0	0.0	0	0.0	0	0.0
Carya	0	0.0	0	0.0	0	0.0	0	0.0	4	1.0	530	16.4	0	0.0	0	0.0
Castanea dentata	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Celtis occidentalis	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Fagus grandifolia	3	0.6	335	10.4	0	0.0	0	0.0	0	0.0	0	0.0	2	0.3	703	21.8
Fraxinus (undiff.)	1	0.2	112	3.5	7	1.4	865	26.8	1	0.2	133	4.1	1	0.2	352	10.9
Fraxinus americana/pennsylvanica —type	0	0.0	0	0.0	1	0.2	124	3.8	0	0.0	0	0.0	1	0.2	352	10.9
Fraxinus nigra	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Fraxinus (total)	1	0.2	112	3.5	8	1.4	988	30.6	1	0.2	133	4.1	2	0.3	703	21.8
Juglans (undiff.)	0	0.0	0	0.0	1	0.2	124	3.8	0	0.0	0	0.0	0	0.0	0	0.0
Juglans cinerea	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Juglans nigra	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Juglans (total)	0	0.0	0	0.0	1	0.2	124	3.8	0	0.0	0	0.0	0	0.0	0	0.0
Larix laricina	0	0.0	0	0.0	0	0.0	0	0.0	1	0.2	133	4.1	3	0.7	1055	32.7
Liquidambar styraciflua	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Picea (undiff.)	0	0.0	0	0.0	1	0.2	124	3.8	3	0.7	398	12.3	0	0.0	0	0.0
Picea marina	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Picea glauca	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Picea (total)	0	0.0	0	0.0	1	0.2	124	3.8	3	0.5	398	12.3	0	0.0	0	0.0
Pinus (undiff.)	125	29.8	13948	432.4	94	19.1	11610	359.9	103	24.7	13660	423.5	86	19.4	30250	937.7
Pinus banksiana/resinosa (Diploxylon)	77	15.1	8592	266.4	121	21.7	14945	463.3	96	17.4	12732	394.7	88	14.1	30953	959.5
Pinus strobus (Haploxylon)	112	26.7	12498	387.4	161	32.7	19885	616.4	136	32.6	18037	559.1	192	43.3	67534	2093.6
Pinus (total)	314	61.6	35038	1086.2	376	67.4	46440	1439.6	335	60.7	44429	1377.3	366	58.6	128737	3990.8
Platanus occidentalis	1	0.2	112	3.5	1	0.2	124	3.8	3	0.7	398	12.3	3	0.7	1055	32.7
Populus	0	0.0	0	0.0	1	0.2	124	3.8	0	0.0	0	0.0	0	0.0	0	0.0
Prunus	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Quercus	22	5.3	2455	76.1	24	4.9	2964	91.9	20	4.8	2652	82.2	18	4.1	6331	196.3
Salix	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	2	0.5	703	21.8
Thuja occidentalis/Juniperus —type	17	4.1	1897	58.8	22	4.5	2717	84.2	14	3.4	1857	57.6	10	2.3	3517	109.0
Tilia americana	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	1	0.2	352	10.9
Tsuga canadensis	15	3.6	1674	51.9	30	6.1	3705	114.9	17	4.1	2255	69.9	7	1.6	2462	76.3
Ulmus	8	1.9	893	27.7	4	0.8	494	15.3	10	2.4	1326	41.1	2	0.5	703	21.8
ARBOREAL POLLEN (TOTAL)	419	82.2	46755	1449.4	493	88.4	60891	1887.6	417	75.5	55304	1714.4	443	70.9	155820	4830.4

Appendix H. Beaverhouse Lake Palynomorph Tabulation (continued).

Beaverhouse Lake, Mackinac County, Michigan																
Depth (cm below platform)	403.6				406.6				409.7				412.8			
Depth (cm below water/sediment interface)	193.6				196.6				199.7				202.8			
Age (yr BP)	4300				4400				4500				4600			
Taxa	Count (No.)	Percent (% TTP)	Conc. (gr cm^{-3})	Influx (gr cm^{-2} yr^{-1})	Count (No.)	Percent (%)	Conc. (gr cm^{-3})	Influx (gr cm^{-2} yr^{-1})	Count (No.)	Percent (%)	Conc. (gr cm^{-3})	Influx (gr cm^{-2} yr^{-1})	Count (No.)	Percent (%)	Conc. (gr cm^{-3})	Influx (gr cm^{-2} yr^{-1})
Alnus crispa	1	0.2	112	3.5	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Alnus rugosa-type	6	1.2	670	20.8	5	0.9	618	19.1	6	1.0	796	24.7	6	1.0	2110	65.4
Cephalanthus occidentalis	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Corylus	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Ericaceae (tetrads)	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Ilex/Nemopanthus —type	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Myrica —type	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	1	0.2	352	10.9
Moraceae	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Sambucus	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Total Shrubs	7	1.4	781	24.2	5	0.9	618	19.1	6	1.1	796	24.7	7	1.1	2462	76.3
Vitis	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Epiphytes	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Ambrosia —type	7	1.4	781	24.2	0	0.0	0	0.0	4	0.7	530	16.4	1	0.2	352	10.9
Artemisia	3	0.6	335	10.4	3	0.5	371	11.5	0	0.0	0	0.0	2	0.3	703	21.8
Campanulaceae	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Caryophyllaceae	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Chenopodium —type	0	0.0	0	0.0	1	0.2	124	3.8	0	0.0	0	0.0	4	0.6	1407	43.6
Cornus canadensis —type	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Cyperaceae	58	11.2	6472	200.6	52	9.3	6423	199.1	120	20.9	15915	493.4	124	19.7	43616	1352.1
Labiatae	1	0.2	112	3.5	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Menyanthes trifoliata	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	1	0.2	352	10.9
Petalostemum purpureum -type	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Poaceae	1	0.2	112	3.5	1	0.2	124	3.8	0	0.0	0	0.0	1	0.2	352	10.9
Polygonum	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Potentilla —type	4	0.8	446	13.8	3	0.5	371	11.5	0	0.0	0	0.0	35	5.6	12311	381.6
Rosaceae	6	1.2	670	20.8	0	0.0	0	0.0	4	0.7	530	16.4	4	0.6	1407	43.6
Rhamnus	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Rubiaceae	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Rumex	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Saxifragaceae	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Thalictrum	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Tubuliflorea	4	0.8	446	13.8	0	0.0	0	0.0	1	0.2	133	4.1	3	0.5	1055	32.7
Umbelliferae	0.0	0.0	0	0.0	0.0	0.0	0	0.0	0.0	0.0	0	0.0	0.0	0.0	0	0.0
Ephedra —type	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Total NonArboreal Herbs	84	16.5	9373	290.6	60	10.8	7411	229.7	129	23.4	17108	530.4	175	28.0	61554	1908.2
Total Terrestrial Pollen	510	100.0	56909	1764.2	558	100.0	68919	2136.5	552	100.0	73208	2269.4	625	100.0	219837	6814.9
Adiantum/Dennstaedtia	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Botrychium	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Equisetum	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Lycopodium annotinum	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Lycopodium clavatum	3	0.6	335	10.4	2	0.4	247	7.7	0	0.0	0	0.0	0	0.0	0	0.0
Lycopodium complanatum -type	1	0.2	112	3.5	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0

Appendix H. Beaverhouse Lake Palynomorph Tabulation (continued).

Beaverhouse Lake, Mackinac County, Michigan																
Depth (cm below platform)	403.6				406.6				409.7				412.8			
Depth (cm below water/sediment interface)	193.6				196.6				199.7				202.8			
Age (yr BP)	4300				4400				4500				4600			
Taxa	Count (No.)	Percent (% TTP)	Conc. (gr cm^{-3})	Influx (gr cm^{-2} yr^{-1})	Count (No.)	Percent (%)	Conc. (gr cm^{-3})	Influx (gr cm^{-2} yr^{-1})	Count (No.)	Percent (%)	Conc. (gr cm^{-3})	Influx (gr cm^{-2} yr^{-1})	Count (No.)	Percent (%)	Conc. (gr cm^{-3})	Influx (gr cm^{-2} yr^{-1})
Lycopodium inundatum	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Lycopodium lucidulum	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Lycopodium obscurum	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Lycopodium (undiff.)	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	1	0.2	352	10.9
Lycopodium (total)	4	0.8	446	13.8	2	0.4	247	7.7	0	0.0	0	0.0	1	0.2	352	10.9
Monolete spores (undiff.)	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Osmunda cinnamomea	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Osmunda regalis -type	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Polypodium	0	0.0	0	0.0	1	0.2	124	3.8	1	0.2	133	4.1	0	0.0	0	0.0
Pteridium aquilinum	0	0.0	0	0.0	0	0.0	0	0.0	9	1.6	1194	37.0	2	0.3	703	21.8
Trilete spores (undiff.)	1.0	0.2	112	3.5	0.0	0.0	0	0.0	1.0	0.2	133	4.1	0.0	0.0	0	0.0
Selaginella	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Total Ferns and Allies	5	1.0	558	17.3	3	0.5	371	11.5	11	1.9	1459	45.2	3	0.5	1055	32.7
Unknowns	1	0.2	112	3.5	1	0.2	124	3.8	10	1.7	1326	41.1	2	0.3	703	21.8
Total Upland Pollen & Spores	516	100.0	57578	1784.9	562	100.0	69413	2151.8	573	100.0	75993	2355.8	630	100.0	221596	6869.5
Brasenia schreberi	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Caltha	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Drosera	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Isoetes	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Myriophyllum exalbescens —type	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Nuphar	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Nymphea	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Potamogeton	0	0.0	0	0.0	1	0.2	124	3.8	0	0.0	0	0.0	0	0.0	0	0.0
Sagittaria	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Sphagnum	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Typha latifolia	1	0.2	112	3.5	1	0.2	124	3.8	3	0.5	398	12.3	0	0.0	0	0.0
Sparganium —type	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Utricularia	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Total Aquatics	1	0.2	112	3.5	2	0.4	247	7.7	3	0.5	398	12.3	0	0.0	0	0.0
Total Determinable Pollen and Spores	517	100.0	57690	1788.4	564	100.0	69660	2159.5	576	100.0	76391	2368.1	630	100.0	221596	6869.5
Indeterminate grains	8	1.5	893	27.7	6	1.1	741	23.0	16	2.7	2122	65.8	11	1.7	3869	119.9
Total Pollen and Spores	525	100.0	58583	1816.1	570	100.0	70402	2182.4	592	100.0	78513	2433.9	641	100.0	225465	6989.4
Pediastrum colonies	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Nymphaeceae basal cells	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Nymphaeceae sclerids	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Eucalyptus grains counted	145				131				122				46			
No. of *Eucalyptus* tablets	1				1				1				1			
Sample volume (cm^3)	1.0				1.0				1.0				1.0			
Accumulation rate (cm yr^{-1})	0.03				0.03				0.03				0.03			
Eucalyptus grains added	16180				16180				16180				16180			
Eucalyptus concentration (gr cm^{-3})	16180				16180				16180				16180			
Total Pollen Influx (gr cm^{-2} yr^{-1})	1816				2182				2434				6989			

Appendix H. Beaverhouse Lake Palynomorph Tabulation (continued).

Beaverhouse Lake, Mackinac County, Michigan																
Depth (cm below platform)	415.8				418.9				422.0				425.0			
Depth (cm below water/sediment interface)	205.8				208.9				212.0				215.0			
Age (yr BP)	4700				4800				4900				5000			
Taxa	Count (No.)	Percent (%)	Conc. (gr cm^{-3})	Influx (gr cm^{-2} yr^{-1})	Count (No.)	Percent (%)	Conc. (gr cm^{-3})	Influx (gr cm^{-2} yr^{-1})	Count (No.)	Percent (%)	Conc. (gr cm^{-3})	Influx (gr cm^{-2} yr^{-1})	Count (No.)	Percent (%)	Conc. (gr cm^{-3})	Influx (gr cm^{-2} yr^{-1})
Abies	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Acer (undiff.)	0	0.0	0	0.0	0	0.0	0	0.0	1	0.2	120	3.7	2	0.4	236	7.3
A. pensylvanicum	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
A. rubrum	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	3	0.6	354	11.0
A. saccharum	3	0.6	181	5.6	2	0.4	305	9.5	1	0.2	120	3.7	2	0.4	236	7.3
A. spicatum	1	0.2	60	1.9	0	0.0	0	0.0	0	0.0	0	0.0	2	0.4	236	7.3
Acer (total)	4	0.6	241	7.5	2	0.3	305	9.5	2	0.3	240	7.4	9	1.5	1063	33.0
Betula	22	4.6	1328	41.2	13	2.4	1984	61.5	14	2.7	1678	52.0	23	4.4	2716	84.2
Carpinus/Ostrya —type	5	1.1	302	9.4	0	0.0	0	0.0	2	0.4	240	7.4	5	1.0	591	18.3
Carya	0	0.0	0	0.0	2	0.4	305	9.5	0	0.0	0	0.0	2	0.4	236	7.3
Castanea dentata	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Celtis occidentalis	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Fagus grandifolia	3	0.5	181	5.6	0	0.0	0	0.0	1	0.2	120	3.7	2	0.3	236	7.3
Fraxinus (undiff.)	3	0.6	181	5.6	0	0.0	0	0.0	2	0.4	240	7.4	6	1.1	709	22.0
Fraxinus americana/pennsylvanica —type	0	0.0	0	0.0	2	0.4	305	9.5	0	0.0	0	0.0	2	0.4	236	7.3
Fraxinus nigra	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Fraxinus (total)	3	0.5	181	5.6	2	0.3	305	9.5	2	0.3	240	7.4	8	1.4	945	29.3
Juglans (undiff.)	2	0.4	121	3.7	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Juglans cinerea	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Juglans nigra	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Juglans (total)	2	0.3	121	3.7	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Larix laricina	1	0.2	60	1.9	2	0.4	305	9.5	0	0.0	0	0.0	2	0.4	236	7.3
Liquidambar styraciflua	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Picea (undiff.)	6	1.3	362	11.2	2	0.4	305	9.5	0	0.0	0	0.0	6	1.1	709	22.0
Picea marina	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Picea glauca	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Picea (total)	6	0.9	362	11.2	2	0.3	305	9.5	0	0.0	0	0.0	6	1.0	709	22.0
Pinus (undiff.)	105	22.2	6339	196.5	97	18.2	14806	459.0	98	18.6	11745	364.1	69	13.2	8149	252.6
Pinus banksiana/resinosa (Diploxylon)	104	16.1	6279	194.6	118	18.5	18012	558.4	110	17.7	13184	408.7	114	19.6	13464	417.4
Pinus strobus (Haploxylon)	180	38.0	10867	336.9	231	43.3	35260	1093.1	255	48.3	30562	947.4	211	40.3	24920	772.5
Pinus (total)	389	60.4	23485	728.0	446	69.8	68078	2110.4	463	74.7	55491	1720.2	394	67.8	46532	1442.5
Platanus occidentalis	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Populus	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	10	1.9	1181	36.6
Prunus	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Quercus	13	2.7	785	24.3	18	3.4	2748	85.2	22	4.2	2637	81.7	31	5.9	3661	113.5
Salix	0	0.0	0	0.0	0	0.0	0	0.0	3	0.6	360	11.1	0	0.0	0	0.0
Thuja occidentalis/Juniperus —type	10	2.1	604	18.7	18	3.4	2748	85.2	8	1.5	959	29.7	3	0.6	354	11.0
Tilia americana	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	2	0.4	236	7.3
Tsuga canadensis	10	2.1	604	18.7	23	4.3	3511	108.8	6	1.1	719	22.3	21	4.0	2480	76.9
Ulmus	6	1.3	362	11.2	5	0.9	763	23.7	5	0.9	599	18.6	5	1.0	591	18.3
ARBOREAL POLLEN (TOTAL)	474	73.6	28617	887.1	533	83.4	81358	2522.1	528	85.2	63282	1961.7	523	90.0	61767	1914.8

Appendix H. Beaverhouse Lake Palynomorph Tabulation (continued).

Beaverhouse Lake, Mackinac County, Michigan																
Depth (cm below platform)	415.8				418.9				422.0				425.0			
Depth (cm below water/sediment interface)	205.8				208.9				212.0				215.0			
Age (yr BP)	4700				4800				4900				5000			
Taxa	Count (No.)	Percent (%)	Conc. (gr cm^{-3})	Influx (gr cm^{-2} yr^{-1})	Count (No.)	Percent (%)	Conc. (gr cm^{-3})	Influx (gr cm^{-2} yr^{-1})	Count (No.)	Percent (%)	Conc. (gr cm^{-3})	Influx (gr cm^{-2} yr^{-1})	Count (No.)	Percent (%)	Conc. (gr cm^{-3})	Influx (gr cm^{-2} yr^{-1})
Alnus crispa	2	0.3	121	3.7	2	0.3	305	9.5	0	0.0	0	0.0	0	0.0	0	0.0
Alnus rugosa-type	22	3.4	1328	41.2	2	0.3	305	9.5	5	0.8	599	18.6	3	0.5	354	11.0
Cephalanthus occidentalis	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Corylus	2	0.3	121	3.7	0	0.0	0	0.0	2	0.3	240	7.4	0	0.0	0	0.0
Ericaceae (tetrads)	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Ilex/Nemopanthus —type	1	0.2	60	1.9	0	0.0	0	0.0	1	0.2	120	3.7	0	0.0	0	0.0
Myrica —type	1	0.2	60	1.9	0	0.0	0	0.0	1	0.2	120	3.7	0	0.0	0	0.0
Moraceae	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Sambucus	1	0.2	60	1.9	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Total Shrubs	29	4.5	1751	54.3	4	0.6	611	18.9	9	1.5	1079	33.4	3	0.5	354	11.0
Vitis	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Epiphytes	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Ambrosia —type	4	0.6	241	7.5	0	0.0	0	0.0	1	0.2	120	3.7	2	0.3	236	7.3
Artemisia	3	0.5	181	5.6	2	0.3	305	9.5	0	0.0	0	0.0	0	0.0	0	0.0
Campanulaceae	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Caryophyllaceae	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Chenopodium —type	4	0.6	241	7.5	2	0.3	305	9.5	0	0.0	0	0.0	0	0.0	0	0.0
Cornus canadensis —type	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Cyperaceae	90	13.8	5434	168.4	98	15.1	14959	463.7	73	11.7	8749	271.2	34	5.5	4015	124.5
Labiatae	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	2	0.3	236	7.3
Menyanthes trifoliata	3	0.5	181	5.6	0	0.0	0	0.0	3	0.5	360	11.1	14	2.3	1653	51.3
Petalostemum purpureum -type	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Poaceae	1	0.2	60	1.9	0	0.0	0	0.0	4	0.6	479	14.9	3	0.5	354	11.0
Polygonum	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Potentilla —type	27	4.1	1630	50.5	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Rosaceae	0	0.0	0	0.0	0	0.0	0	0.0	1	0.2	120	3.7	0	0.0	0	0.0
Rhamnus	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Rubiaceae	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Rumex	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Saxifragaceae	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Thalictrum	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Tubuliflorea	3	0.5	181	5.6	0	0.0	0	0.0	1	0.2	120	3.7	0	0.0	0	0.0
Umbelliferae	6.0	0.9	362	11.2	0.0	0.0	0	0.0	0.0	0.0	0	0.0	0.0	0.0	0	0.0
Ephedra —type	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Total NonArboreal Herbs	135	21.0	8150	252.7	102	16.0	15569	482.7	83	13.4	9948	308.4	55	9.5	6496	201.4
Total Terrestrial Pollen	644	100.0	38880	1205.3	639	100.0	97538	3023.7	620	100.0	74308	2303.6	581	100.0	68617	2127.1
Adiantum/Dennstaedtia	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Botrychium	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Equisetum	0	0.0	0	0.0	2	0.3	305	9.5	2	0.3	240	7.4	2	0.3	236	7.3
Lycopodium annotinum	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Lycopodium clavatum	2	0.3	121	3.7	0	0.0	0	0.0	1	0.2	120	3.7	0	0.0	0	0.0
Lycopodium complanatum -type	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0

Appendix H. Beaverhouse Lake Palynomorph Tabulation (continued).

Beaverhouse Lake, Mackinac County, Michigan																
Depth (cm below platform)	415.8				418.9				422.0				425.0			
Depth (cm below water/sediment interface)	205.8				208.9				212.0				215.0			
Age (yr BP)	4700				4800				4900				5000			
Taxa	Count (No.)	Percent (%)	Conc. (gr cm⁻³)	Influx (gr cm⁻² yr⁻¹)	Count (No.)	Percent (%)	Conc. (gr cm⁻³)	Influx (gr cm⁻² yr⁻¹)	Count (No.)	Percent (%)	Conc. (gr cm⁻³)	Influx (gr cm⁻² yr⁻¹)	Count (No.)	Percent (%)	Conc. (gr cm⁻³)	Influx (gr cm⁻² yr⁻¹)
Lycopodium inundatum	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Lycopodium lucidulum	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Lycopodium obscurum	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Lycopodium (undiff.)	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Lycopodium (total)	2	0.3	121	3.7	0	0.0	0	0.0	1	0.2	120	3.7	0	0.0	0	0.0
Monolete spores (undiff.)	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Osmunda cinnamomea	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Osmunda regalis -type	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Polypodium	2	0.3	121	3.7	0	0.0	0	0.0	0	0.0	0	0.0	6	1.0	709	22.0
Pteridium aquilinum	3	0.5	181	5.6	4	0.6	611	18.9	0	0.0	0	0.0	21	3.4	2480	76.9
Trilete spores (undiff.)	0.0	0.0	0	0.0	0.0	0.0	0	0.0	0.0	0.0	0	0.0	3.0	0.5	354	11.0
Selaginella	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Total Ferns and Allies	7	1.1	423	13.1	6	0.9	916	28.4	3	0.5	360	11.1	32	5.2	3779	117.2
Unknowns	1	0.2	60	1.9	2	0.3	305	9.5	2	0.3	240	7.4	6	1.0	709	22.0
Total Upland Pollen & Spores	652	100.0	39363	1220.3	647	100.0	98759	3061.5	625	100.0	74907	2322.1	619	100.0	73105	2266.3
Brasenia schreberi	0	0.0	0	0.0	0	0.0	0	0.0	1	0.2	120	3.7	0	0.0	0	0.0
Caltha	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Drosera	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Isoetes	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Myriophyllum exalbescens —type	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Nuphar	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Nymphea	0	0.0	0	0.0	0	0.0	0	0.0	1	0.2	120	3.7	0	0.0	0	0.0
Potamogeton	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Sagittaria	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Sphagnum	1	0.2	60	1.9	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Typha latifolia	1	0.2	60	1.9	32	4.7	4885	151.4	0	0.0	0	0.0	0	0.0	0	0.0
Sparganium —type	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	3	0.5	354	11.0
Utricularia	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Total Aquatics	2	0.3	121	3.7	32	4.7	4885	151.4	2	0.3	240	7.4	3	0.5	354	11.0
Total Determinable Pollen and Spores	654	100.0	39484	1224.0	679	100.0	103644	3213.0	627	100.0	75147	2329.6	622	100.0	73460	2277.2
Indeterminate grains	11	1.7	664	20.6	18	2.6	2748	85.2	6	0.9	719	22.3	16	2.5	1890	58.6
Total Pollen and Spores	665	100.0	40148	1244.6	697	100.0	106391	3298.1	633	100.0	75866	2351.9	638	100.0	75349	2335.8
Pediastrum colonies	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Nymphaeceae basal cells	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Nymphaeceae sclerids	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Eucalyptus grains counted	268				106				135				274			
No. of *Eucalyptus* tablets	1				1				1				1			
Sample volume (cm³)	1.0				1.0				1.0				0.5			
Accumulation rate (cm yr⁻¹)	0.03				0.03				0.03				0.03			
Eucalyptus grains added	16180				16180				16180				16180			
Eucalyptus concentration (gr cm⁻³)	16180				16180				16180				32360			
Total Pollen Influx (gr cm⁻² yr⁻¹)	1245				3298				2352				2336			

Appendix H. Beaverhouse Lake Palynomorph Tabulation (continued).

Beaverhouse Lake, Mackinac County, Michigan

Taxa	Count (No.)	Percent (%)	Conc. (gr cm^{-3})	Influx (gr cm^{-2} yr^{-1})	Count (No.)	Percent (%)	Conc. (gr cm^{-3})	Influx (gr cm^{-2} yr^{-1})	Count (No.)	Percent (%)	Conc. (gr cm^{-3})	Influx (gr cm^{-2} yr^{-1})	Count (No.)	Percent (%)	Conc. (gr cm^{-3})	Influx (gr cm^{-2} yr^{-1})
Depth (cm below platform)	428.1				431.2				435.0				437.5			
Depth (cm below water/sediment interface)	218.1				221.2				225.0				227.5			
Age (yr BP)	5100				5200				5320				5410			
Abies	4	0.8	799	24.8	1	0.2	305	9.5	4	0.7	2135	66.2	1	0.2	558	17.3
Acer (undiff.)	1	0.2	200	6.2	1	0.2	305	9.5	0	0.0	0	0.0	1	0.2	558	17.3
A. pensylvanicum	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
A. rubrum	0	0.0	0	0.0	0	0.0	0	0.0	2	0.3	1067	33.1	1	0.2	558	17.3
A. saccharum	5	1.0	999	31.0	2	0.4	611	18.9	0	0.0	0	0.0	3	0.6	1674	51.9
A. spicatum	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Acer (total)	6	1.1	1199	37.2	3	0.6	916	28.4	2	0.3	1067	33.1	5	0.9	2790	86.5
Betula	38	7.5	7591	235.3	8	1.7	2442	75.7	20	3.5	10674	330.9	28	5.4	15622	484.3
Carpinus/Ostrya —type	5	1.0	999	31.0	1	0.2	305	9.5	4	0.7	2135	66.2	5	1.0	2790	86.5
Carya	0	0.0	0	0.0	0	0.0	0	0.0	7	1.2	3736	115.8	0	0.0	0	0.0
Castanea dentata	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Celtis occidentalis	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Fagus grandifolia	1	0.2	200	6.2	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Fraxinus (undiff.)	0	0.0	0	0.0	1	0.2	305	9.5	0	0.0	0	0.0	0	0.0	0	0.0
Fraxinus americana/pennsylvanica —type	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	1	0.2	558	17.3
Fraxinus nigra	1	0.2	200	6.2	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Fraxinus (total)	1	0.2	200	6.2	1	0.2	305	9.5	0	0.0	0	0.0	1	0.2	558	17.3
Juglans (undiff.)	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Juglans cinerea	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Juglans nigra	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Juglans (total)	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Larix laricina	1	0.2	200	6.2	3	0.6	916	28.4	0	0.0	0	0.0	2	0.4	1116	34.6
Liquidambar styraciflua	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Picea (undiff.)	0	0.0	0	0.0	3	0.6	916	28.4	4	0.7	2135	66.2	4	0.8	2232	69.2
Picea marina	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Picea glauca	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Picea (total)	0	0.0	0	0.0	3	0.6	916	28.4	4	0.7	2135	66.2	4	0.7	2232	69.2
Pinus (undiff.)	132	26.0	26367	817.4	164	34.2	50066	1552.1	193	33.7	103001	3193.0	141	27.1	78668	2438.7
Pinus banksiana/resinosa (Diploxylon)	121	23.0	24170	749.3	87	16.9	26560	823.3	146	24.1	77918	2415.5	142	25.5	79226	2456.0
Pinus strobus (Haploxylon)	140	27.6	27965	866.9	145	30.2	44266	1372.2	159	27.7	84856	2630.5	138	26.5	76994	2386.8
Pinus (total)	393	74.6	78503	2433.6	396	76.7	120892	3747.7	498	82.3	265775	8239.0	421	75.7	234889	7281.6
Platanus occidentalis	0	0.0	0	0.0	1	0.2	305	9.5	0	0.0	0	0.0	0	0.0	0	0.0
Populus	0	0.0	0	0.0	1	0.2	305	9.5	0	0.0	0	0.0	0	0.0	0	0.0
Prunus	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Quercus	18	3.6	3596	111.5	24	5.0	7327	227.1	9	1.6	4803	148.9	19	3.6	10601	328.6
Salix	7	1.4	1398	43.3	10	2.1	3053	94.6	0	0.0	0	0.0	2	0.4	1116	34.6
Thuja occidentalis/Juniperus —type	21	4.1	4195	130.0	11	2.3	3358	104.1	0	0.0	0	0.0	0	0.0	0	0.0
Tilia americana	0	0.0	0	0.0	1	0.2	305	9.5	0	0.0	0	0.0	0	0.0	0	0.0
Tsuga canadensis	6	1.2	1199	37.2	13	2.7	3969	123.0	20	3.5	10674	330.9	20	3.8	11159	345.9
Ulmus	6	1.2	1199	37.2	3	0.6	916	28.4	5	0.9	2668	82.7	13	2.5	7253	224.8
ARBOREAL POLLEN (TOTAL)	507	96.2	101275	3139.5	480	93.0	146536	4542.6	573	94.7	305802	9479.8	521	93.7	290682	9011.1

Appendix H. Beaverhouse Lake Palynomorph Tabulation (continued).

Beaverhouse Lake, Mackinac County, Michigan																
Depth (cm below platform)	428.1				431.2				435.0				437.5			
Depth (cm below water/sediment interface)	218.1				221.2				225.0				227.5			
Age (yr BP)	5100				5200				5320				5410			
Taxa	Count (No.)	Percent (%)	Conc. (gr cm^{-3})	Influx (gr cm^{-2} yr^{-1})	Count (No.)	Percent (%)	Conc. (gr cm^{-3})	Influx (gr cm^{-2} yr^{-1})	Count (No.)	Percent (%)	Conc. (gr cm^{-3})	Influx (gr cm^{-2} yr^{-1})	Count (No.)	Percent (%)	Conc. (gr cm^{-3})	Influx (gr cm^{-2} yr^{-1})
Alnus crispa	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Alnus rugosa-type	0	0.0	0	0.0	2	0.4	611	18.9	0	0.0	0	0.0	1	0.2	558	17.3
Cephalanthus occidentalis	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Corylus	1	0.2	200	6.2	0	0.0	0	0.0	2	0.3	1067	33.1	0	0.0	0	0.0
Ericaceae (tetrads)	0	0.0	0	0.0	0	0.0	0	0.0	2	0.3	1067	33.1	0	0.0	0	0.0
Ilex/Nemopanthus —type	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Myrica —type	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	1	0.2	558	17.3
Moraceae	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Sambucus	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Total Shrubs	1	0.2	200	6.2	2	0.4	611	18.9	4	0.7	2135	66.2	2	0.4	1116	34.6
Vitis	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Epiphytes	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Ambrosia —type	1	0.2	200	6.2	7	1.2	2137	66.2	7	1.1	3736	115.8	5	0.8	2790	86.5
Artemisia	0	0.0	0	0.0	1	0.2	305	9.5	4	0.6	2135	66.2	2	0.3	1116	34.6
Campanulaceae	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Caryophyllaceae	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Chenopodium —type	0	0.0	0	0.0	3	0.5	916	28.4	2	0.3	1067	33.1	3	0.5	1674	51.9
Cornus canadensis —type	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Cyperaceae	5	0.9	999	31.0	14	2.5	4274	132.5	9	1.4	4803	148.9	14	2.4	7811	242.1
Labiatae	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	1	0.2	558	17.3
Menyanthes trifoliata	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Petalostemum purpureum -type	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Poaceae	6	1.1	1199	37.2	5	0.9	1526	47.3	2	0.3	1067	33.1	6	1.0	3348	103.8
Polygonum	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Potentilla —type	0	0.0	0	0.0	0	0.0	0	0.0	2	0.3	1067	33.1	0	0.0	0	0.0
Rosaceae	7	1.3	1398	43.3	2	0.4	611	18.9	2	0.3	1067	33.1	2	0.3	1116	34.6
Rhamnus	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Rubiaceae	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Rumex	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Saxifragaceae	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Thalictrum	0	0.0	0	0.0	1	0.2	305	9.5	0	0.0	0	0.0	0	0.0	0	0.0
Tubuliflorea	0	0.0	0	0.0	1	0.2	305	9.5	0	0.0	0	0.0	0	0.0	0	0.0
Umbelliferae	0.0	0.0	0	0.0	0.0	0.0	0	0.0	0.0	0.0	0	0.0	0.0	0.0	0	0.0
Ephedra —type	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Total NonArboreal Herbs	19	3.6	3795	117.7	34	6.6	10380	321.8	28	4.6	14943	463.2	33	5.9	18412	570.8
Total Terrestrial Pollen	527	100.0	105270	3263.4	516	100.0	157526	4883.3	605	100.0	322879	10009.3	556	100.0	310210	9616.5
Adiantum/Dennstaedtia	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Botrychium	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Equisetum	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Lycopodium annotinum	0	0.0	0	0.0	1	0.2	305	9.5	0	0.0	0	0.0	0	0.0	0	0.0
Lycopodium clavatum	0	0.0	0	0.0	1	0.2	305	9.5	0	0.0	0	0.0	0	0.0	0	0.0
Lycopodium complanatum -type	0	0.0	0	0.0	1	0.2	305	9.5	0	0.0	0	0.0	4	0.7	2232	69.2

Appendix H. Beaverhouse Lake Palynomorph Tabulation (continued).

Beaverhouse Lake, Mackinac County, Michigan																
Depth (cm below platform)	428.1				431.2				435.0				437.5			
Depth (cm below water/sediment interface)	218.1				221.2				225.0				227.5			
Age (yr BP)	5100				5200				5320				5410			
Taxa	Count (No.)	Percent (%)	Conc. (gr cm^{-3})	Influx (gr cm^{-2} yr^{-1})	Count (No.)	Percent (%)	Conc. (gr cm^{-3})	Influx (gr cm^{-2} yr^{-1})	Count (No.)	Percent (%)	Conc. (gr cm^{-3})	Influx (gr cm^{-2} yr^{-1})	Count (No.)	Percent (%)	Conc. (gr cm^{-3})	Influx (gr cm^{-2} yr^{-1})
Lycopodium inundatum	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Lycopodium lucidulum	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Lycopodium obscurum	0	0.0	0	0.0	0	0.0	0	0.0	2	0.3	1067	33.1	0	0.0	0	0.0
Lycopodium (undiff.)	0	0.0	0	0.0	1	0.2	305	9.5	0	0.0	0	0.0	0	0.0	0	0.0
Lycopodium (total)	0	0.0	0	0.0	4	0.7	1221	37.9	2	0.3	1067	33.1	4	0.7	2232	69.2
Monolete spores (undiff.)	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Osmunda cinnamomea	1	0.2	200	6.2	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Osmunda regalis -type	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Polypodium	7	1.3	1398	43.3	22	3.9	6716	208.2	2	0.3	1067	33.1	2	0.3	1116	34.6
Pteridium aquilinum	1	0.2	200	6.2	18	3.2	5495	170.3	16	2.6	8539	264.7	26	4.4	14506	449.7
Trilete spores (undiff.)	0	0.0	0	0.0	0.0	0.0	0	0.0	0.0	0.0	0	0.0	0	0.0	0	0.0
Selaginella	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Total Ferns and Allies	9	1.7	1798	55.7	44	7.8	13432	416.4	20	3.2	10674	330.9	32	5.4	17854	553.5
Unknowns	1	0.2	200	6.2	4	0.7	1221	37.9	2	0.3	1067	33.1	2	0.3	1116	34.6
Total Upland Pollen & Spores	537	100.0	107267	3325.3	564	100.0	172180	5337.6	627	100.0	334621	10373.2	590	100.0	329179	10204.6
Brasenia schreberi	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	2	0.3	1116	34.6
Caltha	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Drosera	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Isoetes	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Myriophyllum exalbescens —type	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Nuphar	0	0.0	0	0.0	3	0.5	916	28.4	0	0.0	0	0.0	0	0.0	0	0.0
Nymphea	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Potamogeton	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Sagittaria	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Sphagnum	1	0.2	200	6.2	3	0.5	916	28.4	7	1.1	3736	115.8	2	0.3	1116	34.6
Typha latifolia	5	0.9	999	31.0	4	0.7	1221	37.9	0	0.0	0	0.0	2	0.3	1116	34.6
Sparganium —type	1	0.2	200	6.2	0	0.0	0	0.0	2	0.3	1067	33.1	0	0.0	0	0.0
Utricularia	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Total Aquatics	7	1.3	1398	43.3	10	1.7	3053	94.6	9	1.4	4803	148.9	6	1.0	3348	103.8
Total Determinable Pollen and Spores	544	100.0	108666	3368.6	574	100.0	175232	5432.2	636	100.0	339424	10522.1	596	100.0	332527	10308.3
Indeterminate grains	10	1.8	1998	61.9	16	2.7	4885	151.4	4	0.6	2135	66.2	5	0.8	2790	86.5
Total Pollen and Spores	554	100.0	110663	3430.6	590	100.0	180117	5583.6	640	100.0	341558	10588.3	601	100.0	335317	10394.8
Pediastrum colonies	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Nymphaeceae basal cells	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Nymphaeceae sclerids	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Eucalyptus grains counted	81				53				30				58			
No. of *Eucalyptus* tablets	1				1				1				1			
Sample volume (cm^{3})	1.0				1.0				1.0				0.5			
Accumulation rate (cm yr^{-1})	0.03				0.03				0.03				0.03			
Eucalyptus grains added	16180				16180				16180				16180			
Eucalyptus concentration (gr cm^{-3})	16180				16180				16180				32360			
Total Pollen Influx (gr cm^{-2} yr^{-1})	3431				5584				10588				10395			

Appendix H. Beaverhouse Lake Palynomorph Tabulation (continued).

Beaverhouse Lake, Mackinac County, Michigan				
Depth (cm below platform)	439.0			
Depth (cm below water/sediment interface)	229.0			
Age (yr BP)	5460			
Taxa	Count (No.)	Percent (%)	Conc. (gr cm^{3})	Influx (gr cm^{2} yr^{1})
Abies	0	0.0	0	0.0
Acer (undiff.)	0	0.0	0	0.0
A. pensylvanicum	0	0.0	0	0.0
A. rubrum	0	0.0	0	0.0
A. saccharum	0	0.0	0	0.0
A. spicatum	0	0.0	0	0.0
Acer (total)	0	0.0	0	0.0
Betula	21	4.6	10296	319.2
Carpinus/Ostrya —type	1	0.2	490	15.2
Carya	3	0.7	1471	45.6
Castanea dentata	0	0.0	0	0.0
Celtis occidentalis	0	0.0	0	0.0
Fagus grandifolia	1	0.2	490	15.2
Fraxinus (undiff.)	0	0.0	0	0.0
Fraxinus americana/pennsylvanica —type	0	0.0	0	0.0
Fraxinus nigra	1	0.2	490	15.2
Fraxinus (total)	1	0.2	490	15.2
Juglans (undiff.)	0	0.0	0	0.0
Juglans cinerea	0	0.0	0	0.0
Juglans nigra	0	0.0	0	0.0
Juglans (total)	0	0.0	0	0.0
Larix laricina	3	0.7	1471	45.6
Liquidambar styraciflua	0	0.0	0	0.0
Picea (undiff.)	0	0.0	0	0.0
Picea marina	0	0.0	0	0.0
Picea glauca	0	0.0	0	0.0
Picea (total)	0	0.0	0	0.0
Pinus (undiff.)	181	39.3	88745	2751.1
Pinus banksiana/resinosa (Diploxylon)	83	16.6	40695	1261.5
Pinus strobus (Haploxylon)	121	26.3	59327	1839.1
Pinus (total)	385	76.8	188767	5851.8
Platanus occidentalis	0	0.0	0	0.0
Populus	3	0.7	1471	45.6
Prunus	0	0.0	0	0.0
Quercus	16	3.5	7845	243.2
Salix	5	1.1	2452	76.0
Thuja occidentalis/Juniperus —type	10	2.2	4903	152.0
Tilia americana	1	0.2	490	15.2
Tsuga canadensis	7	1.5	3432	106.4
Ulmus	3	0.7	1471	45.6
ARBOREAL POLLEN (TOTAL)	460	91.8	225539	6991.7

Appendix H. Beaverhouse Lake Palynomorph Tabulation (continued).

Beaverhouse Lake, Mackinac County, Michigan				
Depth (cm below platform)	439.0			
Depth (cm below water/sediment interface)	229.0			
Age (yr BP)	5460			
Taxa	Count (No.)	Percent (%)	Conc. (gr cm^{3})	Influx (gr cm^{2} yr^{1})
Alnus crispa	0	0.0	0	0.0
Alnus rugosa-type	3	0.6	1471	45.6
Cephalanthus occidentalis	0	0.0	0	0.0
Corylus	1	0.2	490	15.2
Ericaceae (tetrads)	1	0.2	490	15.2
Ilex/Nemopanthus —type	0	0.0	0	0.0
Myrica —type	0	0.0	0	0.0
Moraceae	0	0.0	0	0.0
Sambucus	0	0.0	0	0.0
Total Shrubs	5	1.0	2452	76.0
Vitis	0	0.0	0	0.0
Epiphytes	0	0.0	0	0.0
Ambrosia —type	1	0.2	490	15.2
Artemisia	8	1.5	3922	121.6
Campanulaceae	0	0.0	0	0.0
Caryophyllaceae	0	0.0	0	0.0
Chenopodium —type	0	0.0	0	0.0
Cornus canadensis —type	0	0.0	0	0.0
Cyperaceae	19	3.6	9316	288.8
Labiatae	0	0.0	0	0.0
Menyanthes trifoliata	1	0.2	490	15.2
Petalostemum purpureum -type	0	0.0	0	0.0
Poaceae	3	0.6	1471	45.6
Polygonum	0	0.0	0	0.0
Potentilla —type	0	0.0	0	0.0
Rosaceae	3	0.6	1471	45.6
Rhamnus	0	0.0	0	0.0
Rubiaceae	0	0.0	0	0.0
Rumex	0	0.0	0	0.0
Saxifragaceae	0	0.0	0	0.0
Thalictrum	0	0.0	0	0.0
Tubuliflorea	1	0.2	490	15.2
Umbelliferae	0.0	0.0	0	0.0
Ephedra —type	0	0.0	0	0.0
Total NonArboreal Herbs	36	7.2	17651	547.2
Total Terrestrial Pollen	501	100.0	245642	7614.9
Adiantum/Dennstaedtia	0	0.0	0	0.0
Botrychium	0	0.0	0	0.0
Equisetum	0	0.0	0	0.0
Lycopodium annotinum	0	0.0	0	0.0
Lycopodium clavatum	3	0.6	1471	45.6
Lycopodium complanatum -type	5	0.9	2452	76.0

Appendix H. Beaverhouse Lake Palynomorph Tabulation (continued).

Beaverhouse Lake, Mackinac County, Michigan				
Depth (cm below platform)	439.0			
Depth (cm below water/sediment interface)	229.0			
Age (yr BP)	5460			
Taxa	Count (No.)	Percent (%)	Conc. (gr cm^{-3})	Influx (gr cm^{-2} yr^{-1})
Lycopodium inundatum	0	0.0	0	0.0
Lycopodium lucidulum	0	0.0	0	0.0
Lycopodium obscurum	0	0.0	0	0.0
Lycopodium (undiff.)	0	0.0	0	0.0
Lycopodium (total)	8	1.5	3922	121.6
Monolete spores (undiff.)	0	0.0	0	0.0
Osmunda cinnamomea	0	0.0	0	0.0
Osmunda regalis -type	0	0.0	0	0.0
Polypodium	5	0.9	2452	76.0
Pteridium aquilinum	12	2.3	5884	182.4
Trilete spores (undiff.)	0	0.0	0	0.0
Selaginella	0	0.0	0	0.0
Total Ferns and Allies	25	4.7	12258	380.0
Unknowns	5	0.9	2452	76.0
Total Upland Pollen & Spores	531	100.0	260351	8070.9
Brasenia schreberi	0	0.0	0	0.0
Caltha	0	0.0	0	0.0
Drosera	0	0.0	0	0.0
Isoetes	0	0.0	0	0.0
Myriophyllum exalbescens —type	0	0.0	0	0.0
Nuphar	0	0.0	0	0.0
Nymphea	0	0.0	0	0.0
Potamogeton	0	0.0	0	0.0
Sagittaria	0	0.0	0	0.0
Sphagnum	1	0.2	490	15.2
Typha latifolia	5	0.9	2452	76.0
Sparganium —type	0	0.0	0	0.0
Utricularia	0	0.0	0	0.0
Total Aquatics	6	1.1	2942	91.2
Total Determinable Pollen and Spores	537	100.0	263293	8162.1
Indeterminate grains	12	2.2	5884	182.4
Total Pollen and Spores	549	100.0	269176	8344.5
Pediastrum colonies	0	0.0	0	0.0
Nymphaeceae basal cells	0	0.0	0	0.0
Nymphaeceae sclerids	0	0.0	0	0.0
Eucalyptus grains counted	33			
No. of *Eucalyptus* tablets	1			
Sample volume (cm^{3})	1.0			
Accumulation rate (cm yr^{-1})	0.03			
Eucalyptus grains added	16180			
Eucalyptus concentration (gr cm^{-3})	16180			
Total Pollen Influx (gr cm^{-2} yr^{-1})	8344			

Appendix I. Greylock Bog palynomorph tabulation

Greylock Bog, Mackinac County, Michigan

Depth (cm below surface)	0.0				37.0				66.8				96.6			
Age (^{14}C yr B.P.)	-40				550				1030				1510			
Taxa	Count (No.)	Percent (%)	Conc. (gr cm^{-3})	Influx (gr cm^{-2}yr^{-1})	Count (No.)	Percent (%)	Conc. (gr cm^{-3})	Influx (gr cm^{-2}yr^{-1})	Count (No.)	Percent (%)	Conc. (gr cm^{-3})	Influx (gr cm^{-2}yr^{-1})	Count (No.)	Percent (%)	Conc. (gr cm^{-3})	Influx (gr cm^{-2}yr^{-1})
Abies	10	1.7	658	40.8	12	2.2	1027	63.7	1	0.2	37	2.3	2	0.4	132	8.2
Acer (undiff.)	1	0.2	66	4.1	1	0.2	86	5.3	1	0.2	37	2.3	1	0.2	66	4.1
A. pensylvanicum	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	1	0.2	66	4.1
A. rubrum	0	0.0	0	0.0	0	0.0	0	0.0	1	0.2	37	2.3	0	0.0	0	0.0
A. saccharum	6	1.0	395	24.5	4	0.7	342	21.2	5	1.0	186	11.5	1	0.2	66	4.1
A. spicatum	0	0.0	0	0.0	1	0.2	86	5.3	0	0.0	0	0.0	0	0.0	0	0.0
Acer (total)	7	1.2	460	28.5	6	1.1	514	31.8	7	1.4	260	16.1	3	0.6	198	12.3
Betula	39	6.6	2565	159.0	20	3.6	1712	106.2	36	7.0	1336	82.8	40	7.7	2642	163.8
Carpinus/Ostrya -type	2	0.3	132	8.2	0	0.0	0	0.0	4	0.8	148	9.2	0	0.0	0	0.0
Carya	2	0.3	132	8.2	1	0.2	86	5.3	4	0.8	148	9.2	1	0.2	66	4.1
Fagus	3	0.5	197	12.2	2	0.4	171	10.6	3	0.6	111	6.9	5	1.0	330	20.5
Fraxinus undiff.	1	0.2	66	4.1	1	0.2	86	5.3	0	0.0	0	0.0	0	0.0	0	0.0
Fraxinus nigra	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Fraxinus (total)	1	0.2	66	4.1	1	0.2	86	5.3	0	0.0	0	0.0	0	0.0	0	0.0
Juglans (undiff.)	2	0.3	132	8.2	1	0.2	86	5.3	1	0.2	37	2.3	0	0.0	0	0.0
Juglans cinerea	1	0.2	66	4.1	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Juglans (total)	3	0.5	197	12.2	1	0.2	86	5.3	1	0.2	37	2.3	0	0.0	0	0.0
Larix laricina	14	2.4	921	57.1	23	4.2	1969	122.1	20	3.9	742	46.0	25	4.8	1651	102.4
Picea (undiff.)	60	10.2	3946	244.7	58	10.5	4965	307.8	42	8.2	1559	96.6	45	8.7	2972	184.3
Picea (total)	60	10.2	3946	244.7	58	10.5	4965	307.8	42	8.2	1559	96.6	45	8.7	2972	184.3
Pinus (undiff.)	63	10.7	4144	256.9	64	11.6	5479	339.7	119	23.1	4416	273.8	126	24.2	8321	515.9
Pinus banksiana/resinosa (Diploxylon)	164	27.9	10787	668.8	98	17.8	8390	520.2	78	15.1	2895	179.5	64	12.3	4227	262.0
Pinus strobus (Haploxylon)	68	11.6	4473	277.3	109	19.7	9331	578.5	78	15.1	2895	179.5	115	22.1	7595	470.9
Pinus (total)	295	50.3	19403	1203.0	271	49.1	23200	1438.4	275	53.4	10205	632.7	305	58.7	20142	1248.8
Populus	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Quercus	26	4.4	1710	106.0	10	1.8	856	53.1	13	2.5	482	29.9	7	1.3	462	28.7
Salix	4	0.7	263	16.3	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Thuja occidentalis/Juniperus -type	18	3.1	1184	73.4	19	3.4	1627	100.8	11	2.1	408	25.3	11	2.1	726	45.0
Tilia americana	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Tsuga canadensis	4	0.7	263	16.3	47	8.5	4024	249.5	42	8.2	1559	96.6	54	10.4	3566	221.1
Ulmus	0	0.0	0	0.0	3	0.5	257	15.9	4	0.8	148	9.2	1	0.2	66	4.1
ARBOREAL POLLEN (TOTAL)	488	83.1	32097	1990.0	474	85.9	40578	2515.9	463	89.9	17182	1065.3	499	96.0	32954	2043.2
Alnus crispa	1	0.2	66	4.1	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Alnus rugosa -type	2	0.3	132	8.2	0	0.0	0	0.0	3	0.6	111	6.9	2	0.4	132	8.2
Corylus	1	0.2	66	4.1	0	0.0	0	0.0	2	0.4	74	4.6	0	0.0	0	0.0
Ericaceae (Tetrads)	2	0.3	132	8.2	0	0.0	0	0.0	2	0.4	74	4.6	0	0.0	0	0.0
Myrica -type	0	0.0	0	0.0	0	0.0	0	0.0	1	0.2	37	2.3	1	0.2	66	4.1
Total Shrubs	6	1.0	395	24.5	0	0.0	0	0.0	8	1.6	297	18.4	3	0.6	198	12.3
Ambrosia -type	24	4.1	1579	97.9	1	0.2	86	5.3	5	1.0	186	11.5	2	0.4	132	8.2
Artemisia	1	0.2	66	4.1	1	0.2	86	5.3	1	0.2	37	2.3	0	0.0	0	0.0

Appendix I. Greylock Bog palynomorph tabulation (continued)

Greylock Bog, Mackinac County, Michigan

Depth (cm below surface)	126.2				137.9				161.2				173.0			
Age (^{14}C yr B.P.)	2000				2200				2600				2810			
Taxa	Count (No.)	Percent (%)	Conc. (gr cm^{-3})	Influx (gr cm^{-2}yr^{-1})	Count (No.)	Percent (%)	Conc. (gr cm^{-3})	Influx (gr cm^{-2}yr^{-1})	Count (No.)	Percent (%)	Conc. (gr cm^{-3})	Influx (gr cm^{-2}yr^{-1})	Count (No.)	Percent (%)	Conc. (gr cm^{-3})	Influx (gr cm^{-2}yr^{-1})
Abies	2	0.3	420	24.5	10	2.0	1839	107.4	4	0.8	530	31.0	7	1.4	765	40.6
Acer (undiff.)	2	0.3	420	24.5	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
A. pensylvanicum	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	1	0.2	109	5.8
A. rubrum	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	1	0.2	109	5.8
A. saccharum	5	0.8	1051	61.4	1	0.2	184	10.7	4	0.8	530	31.0	3	0.6	328	17.4
A. spicatum	1	0.2	210	12.3	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Acer (total)	8	1.3	1681	98.2	1	0.2	184	10.7	4	0.8	530	31.0	5	1.0	547	29.0
Betula	74	12.5	15550	908.1	82	16.1	15077	880.5	95	18.2	12599	735.8	50	9.8	5466	289.7
Carpinus/Ostrya -type	3	0.5	630	36.8	3	0.6	552	32.2	1	0.2	133	7.7	2	0.4	219	11.6
Carya	1	0.2	210	12.3	1	0.2	184	10.7	0	0.0	0	0.0	0	0.0	0	0.0
Fagus	8	1.3	1681	98.2	4	0.8	735	43.0	8	1.5	1061	62.0	0	0.0	0	0.0
Fraxinus undiff.	1	0.2	210	12.3	2	0.4	368	21.5	1	0.2	133	7.7	3	0.6	328	17.4
Fraxinus nigra	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	1	0.2	109	5.8
Fraxinus (total)	1	0.2	210	12.3	2	0.4	368	21.5	1	0.2	133	7.7	4	0.8	437	23.2
Juglans (undiff.)	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Juglans cinerea	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	1	0.2	109	5.8
Juglans (total)	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	1	0.2	109	5.8
Larix laricina	7	1.2	1471	85.9	28	5.5	5148	300.7	13	2.5	1724	100.7	15	3.0	1640	86.9
Picea (undiff.)	30	5.1	6304	368.1	29	5.7	5332	311.4	8	1.5	1061	62.0	12	2.4	1312	69.5
Picea (total)	30	5.1	6304	368.1	29	5.7	5332	311.4	8	1.5	1061	62.0	12	2.4	1312	69.5
Pinus (undiff.)	183	30.8	38454	2245.7	60	11.8	11032	644.3	91	17.5	12069	704.8	115	22.6	12572	666.3
Pinus banksiana/resinosa (Diploxylon)	43	7.2	9036	527.7	45	8.9	8274	483.2	60	11.5	7957	464.7	61	12.0	6669	353.4
Pinus strobus (Haploxylon)	102	17.2	21433	1251.7	127	25.0	23351	1363.7	142	27.3	18832	1099.8	122	24.0	13338	706.9
Pinus (total)	328	55.2	68923	4025.1	232	45.7	42656	2491.1	293	56.2	38859	2269.3	298	58.7	32579	1726.7
Populus	0	0.0	0	0.0	6	1.2	1103	64.4	5	1.0	663	38.7	8	1.6	875	46.4
Quercus	22	3.7	4623	270.0	21	4.1	3861	225.5	29	5.6	3846	224.6	19	3.7	2077	110.1
Salix	0	0.0	0	0.0	1	0.2	184	10.7	0	0.0	0	0.0	3	0.6	328	17.4
Thuja occidentalis/Juniperus -type	9	1.5	1891	110.4	29	5.7	5332	311.4	13	2.5	1724	100.7	22	4.3	2405	127.5
Tilia americana	0	0.0	0	0.0	0	0.0	0	0.0	1	0.2	133	7.7	0	0.0	0	0.0
Tsuga canadensis	53	8.9	11137	650.4	17	3.3	3126	182.5	13	2.5	1724	100.7	14	2.8	1531	81.1
Ulmus	4	0.7	841	49.1	5	1.0	919	53.7	3	0.6	398	23.2	3	0.6	328	17.4
ARBOREAL POLLEN (TOTAL)	550	92.6	115571	6749.4	471	92.7	86600	5057.4	491	94.2	65118	3802.9	463	91.1	50617	2682.7
Alnus crispa	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	1	0.2	109	5.8
Alnus rugosa -type	0	0.0	0	0.0	3	0.6	552	32.2	8	1.5	1061	62.0	3	0.6	328	17.4
Corylus	0	0.0	0	0.0	1	0.2	184	10.7	0	0.0	0	0.0	0	0.0	0	0.0
Ericaceae (Tetrads)	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Myrica -type	1	0.2	210	12.3	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Total Shrubs	1	0.2	210	12.3	4	0.8	735	43.0	8	1.5	1061	62.0	4	0.8	437	23.2
Ambrosia -type	4	0.7	841	49.1	5	1.0	919	53.7	2	0.4	265	15.5	6	1.2	656	34.8
Artemisia	5	0.8	1051	61.4	2	0.4	368	21.5	1	0.2	133	7.7	1	0.2	109	5.8

Appendix I. Greylock Bog palynomorph tabulation (continued)

Greylock Bog, Mackinac County, Michigan

Depth (cm below surface)	195.0			
Age (^{14}C yr B.P.)	3220			
Taxa	Count (No.)	Percent (%)	Conc. (gr cm^{-3})	Influx (gr cm^{-2}yr^{-1})
Abies	2	0.4	15	0.8
Acer (undiff.)	0	0.0	0	0.0
A. pensylvanicum	0	0.0	0	0.0
A. rubrum	1	0.2	7	0.4
A. saccharum	4	0.8	29	1.6
A. spicatum	0	0.0	0	0.0
Acer (total)	5	1.0	37	1.9
Betula	41	8.1	301	16.0
Carpinus/Ostrya -type	4	0.8	29	1.6
Carya	0	0.0	0	0.0
Fagus	6	1.2	44	2.3
Fraxinus undiff.	1	0.2	7	0.4
Fraxinus nigra	0	0.0	0	0.0
Fraxinus (total)	1	0.2	7	0.4
Juglans (undiff.)	0	0.0	0	0.0
Juglans cinerea	1	0.2	7	0.4
Juglans (total)	1	0.2	7	0.4
Larix laricina	13	2.6	95	5.1
Picea (undiff.)	16	3.2	117	6.2
Picea (total)	16	3.2	117	6.2
Pinus (undiff.)	128	25.3	940	49.8
Pinus banksiana/resinosa (Diploxylon)	47	9.3	345	18.3
Pinus strobus (Haploxylon)	124	24.6	910	48.2
Pinus (total)	299	59.2	2195	116.3
Populus	6	1.2	44	2.3
Quercus	11	2.2	81	4.3
Salix	1	0.2	7	0.4
Thuja occidentalis/Juniperus -type	24	4.8	176	9.3
Tilia americana	0	0.0	0	0.0
Tsuga canadensis	23	4.6	169	8.9
Ulmus	4	0.8	29	1.6
ARBOREAL POLLEN (TOTAL)	457	90.5	3355	177.8
Alnus crispa	1	0.2	7	0.4
Alnus rugosa -type	2	0.4	15	0.8
Corylus	0	0.0	0	0.0
Ericaceae (Tetrads)	1	0.2	7	0.4
Myrica -type	0	0.0	0	0.0
Total Shrubs	4	0.8	29	1.6
Ambrosia -type	7	1.4	51	2.7
Artemisia	1	0.2	7	0.4

Appendix I. Greylock Bog palynomorph tabulation (continued)

Greylock Bog, Mackinac County, Michigan

Depth (cm below surface)	0.0				37.0				66.8				96.6			
Age (^{14}C yr B.P.)	-40				550				1030				1510			
	Count	Percent	Conc.	Influx	Count	Percent	Conc.	Influx	Count	Percent	Conc.	Influx	Count	Percent	Conc.	Influx
Chenopodium -type	4	0.7	263	16.3	0	0.0	0	0.0	1	0.2	37	2.3	1	0.2	66	4.1
Cyperaceae	50	8.5	3289	203.9	76	13.8	6506	403.4	33	6.4	1225	75.9	12	2.3	792	49.1
Menyanthes trifoliata	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Poaceae	5	0.9	329	20.4	0	0.0	0	0.0	2	0.4	74	4.6	1	0.2	66	4.1
Tubuliflorae	9	1.5	592	36.7	0	0.0	0	0.0	2	0.4	74	4.6	2	0.4	132	8.2
Umbelliferae	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Total NonArboreal Herbs	93	15.8	6117	379.2	78	14.1	6677	414.0	44	8.5	1633	101.2	18	3.5	1189	73.7
Total Terrestrial Pollen	587	100.0	38608	2393.7	552	100.0	47256	2929.9	515	100.0	19112	1184.9	520	100.0	34341	2129.2
Equisetum	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Lycopodium annotinum	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Lycopodium complanatum/tri	0	0.0	0	0.0	0	0.0	0	0.0	1	0.1	37	2.3	0	0.0	0	0.0
Lycopodium lucidulum	1	0.2	66	4.1	0	0.0	0	0.0	1	0.1	37	2.3	0	0.0	0	0.0
Lycopodium obscurum	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Lycopodium (undiff.)	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Lycopodium (total)	1	0.2	66	4.1	0	0.0	0	0.0	2	0.2	74	4.6	0	0.0	0	0.0
Osmunda cinnamomea	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	1	0.1	66	4.1
Osmunda regalis -type	0	0.0	0	0.0	3	0.3	257	15.9	15	1.4	557	34.5	62	5.6	4095	253.9
Polypodium	1	0.2	66	4.1	0	0.0	0	0.0	0	0.0	0	0.0	2	0.2	132	8.2
Pteridium aquilinum	4	0.7	263	16.3	2	0.2	171	10.6	2	0.2	74	4.6	3	0.3	198	12.3
Trilete spores (undiff.)	5.0	0.8	329	20.4	0.0	0.0	0	0.0	3.0	0.3	111	6.9	2.0	0.2	132	8.2
Selaginella	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	1	0.1	66	4.1
Total Ferns and Allies	11	1.8	723	44.9	5	0.5	428	26.5	22	2.1	816	50.6	71	6.4	4689	290.7
Unknowns	3	0.5	197	12.2	0	0.0	0	0.0	2	0.2	74	4.6	1	0.1	66	4.1
Total Upland Pollen and Spores	601	100.0	39529	2450.8	1109	100.0	94940	5886.3	1054	100.0	39114	2425.1	1112	100.0	73437	4553.1
Nuphar	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Nymphea	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Potamogeton	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Sphagnum	78	11.5	5130	318.1	81	6.8	6934	429.9	55	5.0	2041	126.5	34	3.0	2245	139.2
Typha latifolia	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Sparganium -type	1	0.1	66	4.1	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Total Aquatics	79	11.6	5196	322.2	81	6.8	6934	429.9	55	5.0	2041	126.5	34	3.0	2245	139.2
Total Determinable Pollen and Spores	680	100.0	44725	2773.0	1190	100.0	101874	6316.2	1109	100.0	41155	2551.6	1146	100.0	75683	4692.3
Indeterminate Grains	10	1.4	658	40.8	1	0.1	86	5.3	8	0.7	297	18.4	15	1.3	991	61.4
Total Pollen and Spores	690	100.0	45383	2813.7	1191	100.0	101960	6321.5	1117	100.0	41452	2570.0	1161	100.0	76673	4753.8
Pediastrum colonies	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Nymphaeceae basal cells	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Nymphaeceae sclerids	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Eucalyptus grains counted	246				189				436				245			
No. of *Eucalyptus* tablets	1				1				1				1			
Sample volume (cm^3)	1.00				1.00				1.00				1.00			
Accumulation rate (cm yr^{-1})	0.0620				0.0620				0.0620				0.0620			

Appendix I. Greylock Bog palynomorph tabulation (continued)

Greylock Bog, Mackinac County, Michigan

Depth (cm below surface)	126.2				137.9				161.2				173.0			
Age (^{14}C yr B.P.)	2000				2200				2600				2810			
	Count	Percent	Conc.	Influx	Count	Percent	Conc.	Influx	Count	Percent	Conc.	Influx	Count	Percent	Conc.	Influx
Chenopodium -type	0	0.0	0	0.0	1	0.2	184	10.7	0	0.0	0	0.0	1	0.2	109	5.8
Cyperaceae	32	5.4	6724	392.7	18	3.5	3310	193.3	12	2.3	1591	92.9	20	3.9	2186	115.9
Menyanthes trifoliata	0	0.0	0	0.0	1	0.2	184	10.7	0	0.0	0	0.0	0	0.0	0	0.0
Poaceae	0	0.0	0	0.0	3	0.6	552	32.2	6	1.2	796	46.5	11	2.2	1203	63.7
Tubuliflorae	1	0.2	210	12.3	3	0.6	552	32.2	1	0.2	133	7.7	2	0.4	219	11.6
Umbelliferae	1	0.2	210	12.3	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Total NonArboreal Herbs	43	7.2	9036	527.7	33	6.5	6068	354.3	22	4.2	2918	170.4	41	8.1	4482	237.6
Total Terrestrial Pollen	594	100.0	124817	7289.3	508	100.0	93403	5454.7	521	100.0	69097	4035.2	508	100.0	55537	2943.4
Equisetum	0	0.0	0	0.0	3	0.3	552	32.2	1	0.1	133	7.7	0	0.0	0	0.0
Lycopodium annotinum	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Lycopodium complanatum/tri	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	1	0.1	109	5.8
Lycopodium lucidulum	3	0.3	630	36.8	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Lycopodium obscurum	1	0.1	210	12.3	0	0.0	0	0.0	0	0.0	0	0.0	3	0.3	328	17.4
Lycopodium (undiff.)	1	0.1	210	12.3	0	0.0	0	0.0	0	0.0	0	0.0	2	0.2	219	11.6
Lycopodium (total)	5	0.4	1051	61.4	0	0.0	0	0.0	0	0.0	0	0.0	6	0.6	656	34.8
Osmunda cinnamomea	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Osmunda regalis -type	0	0.0	0	0.0	0	0.0	0	0.0	1	0.1	133	7.7	0	0.0	0	0.0
Polypodium	2	0.2	420	24.5	2	0.2	368	21.5	2	0.2	265	15.5	2	0.2	219	11.6
Pteridium aquilinum	1	0.1	210	12.3	0	0.0	0	0.0	2	0.2	265	15.5	5	0.5	547	29.0
Trilete spores (undiff.)	0.0	0.0	0	0.0	0.0	0.0	0	0.0	0.0	0.0	0	0.0	0.0	0.0	0	0.0
Selaginella	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	2	0.2	219	11.6
Total Ferns and Allies	8	0.7	1681	98.2	5	0.5	919	53.7	6	0.6	796	46.5	15	1.5	1640	86.9
Unknowns	1	0.1	210	12.3	1	0.1	184	10.7	1	0.1	133	7.7	1	0.1	109	5.8
Total Upland Pollen and Spores	1197	100.0	251525	14689.1	1022	100.0	187909	10973.9	1049	100.0	139121	8124.7	1032	100.0	112823	5979.6
Nuphar	1	0.1	210	12.3	0	0.0	0	0.0	0	0.0	0	0.0	9	0.9	984	52.1
Nymphea	1	0.1	210	12.3	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Potamogeton	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	1	0.1	109	5.8
Sphagnum	2	0.2	420	24.5	2	0.2	368	21.5	0	0.0	0	0.0	0	0.0	0	0.0
Typha latifolia	0	0.0	0	0.0	0	0.0	0	0.0	1	0.1	133	7.7	1	0.1	109	5.8
Sparganium -type	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Total Aquatics	4	0.3	841	49.1	2	0.2	368	21.5	1	0.1	133	7.7	11	1.1	1203	63.7
Total Determinable Pollen and Spores	1201	100.0	252366	14738.2	1024	100.0	188276	10995.3	1050	100.0	139254	8132.4	1043	100.0	114025	6043.3
Indeterminate Grains	10	0.8	2101	122.7	5	0.5	919	53.7	9	0.8	1194	69.7	7	0.7	765	40.6
Total Pollen and Spores	1211	100.0	254467	14860.9	1029	100.0	189196	11049.0	1059	100.0	140448	8202.1	1050	100.0	114791	6083.9
Pediastrum colonies	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Nymphaeceae basal cells	0	0.0	0	0.0	3	0.3	552	32.2	2	0.2	265	15.5	141	13.4	15415	817.0
Nymphaeceae sclerids	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	3	0.3	328	17.4
Eucalyptus grains counted	77				88				122				148			
No. of *Eucalyptus* tablets	1				1				1				1			
Sample volume (cm^3)	1.00				1.00				1.00				1.00			
Accumulation rate (cm yr^{-1})	0.0584				0.0584				0.0584				0.0530			

Appendix I. Greylock Bog palynomorph tabulation (continued)

Greylock Bog, Mackinac County, Michigan				
Depth (cm below surface)	195.0			
Age (^{14}C yr B.P.)	3220			
	Count	Percent	Conc.	Influx
Chenopodium -type	0	0.0	0	0.0
Cyperaceae	22	4.4	162	8.6
Menyanthes trifoliata	0	0.0	0	0.0
Poaceae	11	2.2	81	4.3
Tubuliflorae	3	0.6	22	1.2
Umbelliferae	0	0.0	0	0.0
Total NonArboreal Herbs	44	8.7	323	17.1
Total Terrestrial Pollen	505	100.0	3707	196.5
Equisetum	0	0.0	0	0.0
Lycopodium annotinum	1	0.1	7	0.4
Lycopodium complanatum/tri	0	0.0	0	0.0
Lycopodium lucidulum	0	0.0	0	0.0
Lycopodium obscurum	0	0.0	0	0.0
Lycopodium (undiff.)	1	0.1	7	0.4
Lycopodium (total)	2	0.2	15	0.8
Osmunda cinnamomea	0	0.0	0	0.0
Osmunda regalis -type	4	0.4	29	1.6
Polypodium	3	0.3	22	1.2
Pteridium aquilinum	9	0.9	66	3.5
Trilete spores (undiff.)	1.0	0.1	7	0.4
Selaginella	0	0.0	0	0.0
Total Ferns and Allies	19	1.8	139	7.4
Unknowns	1	0.1	7	0.4
Total Upland Pollen and Spores	1030	100.0	7561	400.8
Nuphar	0	0.0	0	0.0
Nymphea	0	0.0	0	0.0
Potamogeton	0	0.0	0	0.0
Sphagnum	13	1.2	95	5.1
Typha latifolia	0	0.0	0	0.0
Sparganium -type	0	0.0	0	0.0
Total Aquatics	13	1.2	95	5.1
Total Determinable Pollen and Spores	1043	100.0	7657	405.8
Indeterminate Grains	16	1.5	117	6.2
Total Pollen and Spores	1059	100.0	7774	412.0
Pediastrum colonies	0	0.0	0	0.0
Nymphaeceae basal cells	3	0.3	22	1.2
Nymphaeceae sclerids	0	0.0	0	0.0
Eucalyptus grains counted	1102			
No. of *Eucalyptus* tablets	1			
Sample volume (cm^3)	2.00			
Accumulation rate (cm yr^{-1})	0.0530			

Appendix I. Greylock Bog palynomorph tabulation (continued)

Greylock Bog, Mackinac County, Michigan																
Depth (cm below surface)	0.0				37.0				66.8				96.6			
Age (^{14}C yr B.P.)	-40				550				1030				1510			
	Count	Percent	Conc.	Influx	Count	Percent	Conc.	Influx	Count	Percent	Conc.	Influx	Count	Percent	Conc.	Influx
Eucalyptus grains added	16180				16180				16180				16180			
Eucalyptus concentration (gr cm^{-3})	16180				16180				16180				16180			
Total Pollen Influx (gr cm^{-2} yr^{-1})	2814				6322				2570				4754			

Appendix I. Greylock Bog palynomorph tabulation (continued)

Greylock Bog, Mackinac County, Michigan																
Depth (cm below surface)	126.2				137.9				161.2				173.0			
Age (^{14}C yr B.P.)	2000				2200				2600				2810			
	Count	Percent	Conc.	Influx	Count	Percent	Conc.	Influx	Count	Percent	Conc.	Influx	Count	Percent	Conc.	Influx
Eucalyptus grains added	16180				16180				16180				16180			
Eucalyptus concentration (gr cm^{-3})	16180				16180				16180				16180			
Total Pollen Influx (gr cm^{-2} yr^{-1})	14861				11049				8202				6084			

Appendix I. Greylock Bog palynomorph tabulation (continued)

Greylock Bog, Mackinac County, Michigan				
Depth (cm below surface)	195.0			
Age (^{14}C yr B.P.)	3220			
	Count	Percent	Conc.	Influx
Eucalyptus grains added	16180			
Eucalyptus concentration (gr cm^{-3})	8090			
Total Pollen Influx (gr cm^{-2} yr^{-1})	412			

US2 Bog, Mackinac County, Michigan

Depth (cm below surface)	2.5				47.3				89.1			
Age (yr B.P.)	-14				514				1010			
Taxa	Count (No.)	Percent (%)	Conc. (gr cm^{-3})	Influx (gr cm^{-2} yr^{-1})	Count (No.)	Percent (%)	Conc. (gr cm^{-3})	Influx (gr cm^{-2} yr^{-1})	Count (No.)	Percent (%)	Conc. (gr cm^{-3})	Influx (gr cm^{-2} yr^{-1})
Abies	2	0.4	63	5.3	4	0.7	285	24.2	7	1.1	1595	135.4
Acer (undiff.)	0	0.0	0	0.0	0	0.0	0	0.0	1	0.2	228	19.3
A. pensylvanicum	0	0.0	0	0.0	2	0.4	143	12.1	2	0.3	456	38.7
A. rubrum	2	0.4	63	5.3	1	0.2	71	6.1	0	0.0	0	0.0
A. saccharum	3	0.6	94	8.0	3	0.6	214	18.2	7	1.1	1595	135.4
Acer (total)	5	0.9	157	13.4	6	1.1	428	36.3	10	1.6	2279	193.5
Betula	27	5.0	850	72.2	61	11.3	4348	369.1	76	12.0	17319	1470.4
Carpinus/Ostrya -type	4	0.7	126	10.7	2	0.4	143	12.1	5	0.8	1139	96.7
Carya	1	0.2	31	2.7	1	0.2	71	6.1	4	0.6	912	77.4
Celtis occidentalis	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Fagus	0	0.0	0	0.0	5	0.9	356	30.3	9	1.4	2051	174.1
Fraxinus (undiff.)	1	0.2	31	2.7	0	0.0	0	0.0	1	0.2	228	19.3
Fraxinus (total)	1	0.2	31	2.7	0	0.0	0	0.0	1	0.2	228	19.3
Juglans (total)	2	0.4	63	5.3	1	0.2	71	6.1	1	0.2	228	19.3
Larix laricina	2	0.4	63	5.3	26	4.8	1853	157.3	17	2.7	3874	328.9
Picea (undiff.)	21	3.9	661	56.1	39	7.2	2780	236.0	59	9.3	13445	1141.5
Picea (total)	21	3.9	661	56.1	39	7.2	2780	236.0	59	9.3	13445	1141.5
Pinus (undiff.)	54	10.1	1700	144.3	59	11.0	4205	357.0	62	9.8	14129	1199.6
Pinus banksiana/resinosa (Diploxylon)	69	12.8	2172	184.4	74	13.8	5275	447.8	73	11.5	16636	1412.4
Pinus strobus (Haploxylon)	39	7.3	1228	104.2	63	11.7	4490	381.2	119	18.8	27119	2302.4
Pinus (total)	162	30.2	5100	433.0	196	36.4	13970	1186.1	254	40.1	57883	4914.3
Platanus occidentalis	0	0.0	0	0.0	2	0.4	143	12.1	1	0.2	228	19.3
Populus	7	1.3	220	18.7	5	0.9	356	30.3	2	0.3	456	38.7
Quercus	28	5.2	881	74.8	28	5.2	1996	169.4	28	4.4	6381	541.7
Salix	1	0.2	31	2.7	7	1.3	499	42.4	1	0.2	228	19.3
Thuja occidentalis/Juniperus -type	110	20.5	3463	294.0	30	5.6	2138	181.5	38	6.0	8660	735.2
Tilia americana	0	0.0	0	0.0	1	0.2	71	6.1	0	0.0	0	0.0
Tsuga canadensis	4	0.7	126	10.7	32	5.9	2281	193.6	52	8.2	11850	1006.1
Ulmus	5	0.9	157	13.4	2	0.4	143	12.1	4	0.6	912	77.4
ARBOREAL POLLEN (TOTAL)	382	71.1	12025	1020.9	448	83.3	31932	2711.1	569	89.7	129668	11008.8
Alnus crispa	1	0.2	31	2.7	0	0.0	0	0.0	2	0.3	456	38.7
Alnus rugosa -type	3	0.6	94	8.0	3	0.6	214	18.2	5	0.8	1139	96.7
Corylus	2	0.4	63	5.3	0	0.0	0	0.0	1	0.2	228	19.3
Ericaceae (Tetrads)	1	0.2	31	2.7	2	0.4	143	12.1	2	0.3	456	38.7
Myrica -type	3	0.6	94	8.0	4	0.7	285	24.2	1	0.2	228	19.3
Sambucus	0	0.0	0	0.0	1	0.2	71	6.1	0	0.0	0	0.0
Total Shrubs	10	1.9	315	26.7	10	1.9	713	60.5	11	1.7	2507	212.8
Vitis	1	0.2	31	2.7	0	0.0	0	0.0	0	0.0	0	0.0
Epiphytes	1	0.2	31	2.7	0	0.0	0	0.0	0	0.0	0	0.0

Appendix J. US 2 Bog palynomorph tabulation (continued)

Depth (cm below surface)	2.5				47.3				89.1			
Age (yr B.P.)	-14				514				1010			
	Count	Percent	Conc.	Influx	Count	Percent	Conc.	Influx	Count	Percent	Conc.	Influx
Ambrosia -type	25	4.7	787	66.8	5	0.9	356	30.3	4	0.6	912	77.4
Artemisia	1	0.2	31	2.7	3	0.6	214	18.2	4	0.6	912	77.4
Chenopodium -type	3	0.6	94	8.0	0	0.0	0	0.0	2	0.3	456	38.7
Cyperaceae	106	19.7	3337	283.3	60	11.2	4277	363.1	37	5.8	8432	715.9
Menyanthes trifoliata	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Poaceae	5	0.9	157	13.4	8	1.5	570	48.4	4	0.6	912	77.4
Rosaceae	0	0.0	0	0.0	2	0.4	143	12.1	0	0.0	0	0.0
Tubuliflorae	3	0.6	94	8.0	2	0.4	143	12.1	3	0.5	684	58.0
Total NonArboreal Herbs	143	26.6	4501	382.2	80	14.9	5702	484.1	54	8.5	12306	1044.8
Total Terrestrial Pollen	537	100.0	16904	1435.2	538	100.0	38347	3255.7	634	100.0	144481	12266.4
Equisetum	3	0.6	94	8.0	0	0.0	0	0.0	1	0.2	228	19.3
Lycopodium clavatum	1	0.2	31	2.7	0	0.0	0	0.0	1	0.2	228	19.3
Lycopodium lucidulum	0	0.0	0	0.0	0	0.0	0	0.0	1	0.2	228	19.3
Lycopodium obscurum	0	0.0	0	0.0	0	0.0	0	0.0	1	0.2	228	19.3
Lycopodium (total)	1	0.2	31	2.7	0	0.0	0	0.0	3	0.5	684	58.0
Osmunda cinnamomea	0	0.0	0	0.0	1	0.2	71	6.1	0	0.0	0	0.0
Osmunda regalis -type	1	0.2	31	2.7	3	0.6	214	18.2	1	0.2	228	19.3
Pteridium aquilinum	0	0.0	0	0.0	2	0.4	143	12.1	5	0.8	1139	96.7
Selaginella	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Total Ferns and Allies	5	0.9	157	13.4	6	1.1	428	36.3	10	1.5	2279	193.5
Unknowns	3	0.6	94	8.0	1	0.2	71	6.1	2	0.3	456	38.7
Total Upland Pollen and Spores	545	100.0	17156	1456.5	545	100.0	38846	3298.0	646	100.0	147215	12498.6
Nymphea	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Potamogeton	0	0.0	0	0.0	1	0.2	71	6.1	0	0.0	0	0.0
Sphagnum	0	0.0	0	0.0	3	0.5	214	18.2	3	0.5	684	58.0
Typha latifolia	22	3.9	693	58.8	1	0.2	71	6.1	1	0.2	228	19.3
Total Aquatics	22	3.9	693	58.8	5	0.9	356	30.3	4	0.6	912	77.4
Total Determinable Pollen and Spores	567	100.0	17848	1515.3	550	100.0	39203	3328.3	650	100.0	148127	12576.0
Indeterminate Grains	12	2.1	378	32.1	11	2.0	784	66.6	12	1.8	2735	232.2
Total Pollen and Spores	579	100.0	18226	1547.4	561	100.0	39987	3394.9	662	100.0	150861	12808.1
Eucalyptus grains counted	514				227				71			
No. of *Eucalyptus* tablets	1				1				1			
Sample volume (cm^{3})	1.00				1.00				1.00			
Accumulation rate (cm yr^{-1})	0.0849				0.0849				0.0849			
Eucalyptus grains added	16180				16180				16180			
Eucalyptus concentration	16180				16180				16180			
Total Pollen Influx (gr cm^{-2} yr^{-1})	1547				3395				12808			

Appendix J. US 2 Bog palynomorph tabulation (continued)

US2 Bog, Mackinac County, Michigan				
Depth (cm below surface)	120.0			
Age (yr B.P.)	1370			
Taxa	Count (No.)	Percent (%)	Conc. (gr cm^{-3})	Influx (gr cm^{-2} yr^{-1})
Abies	11	2.2	2738	232.5
Acer (undiff.)	1	0.2	249	21.1
A. pensylvanicum	0	0.0	0	0.0
A. rubrum	1	0.2	249	21.1
A. saccharum	3	0.6	747	63.4
Acer (total)	5	1.0	1245	105.7
Betula	89	17.6	22154	1880.9
Carpinus/Ostrya -type	3	0.6	747	63.4
Carya	1	0.2	249	21.1
Celtis occidentalis	1	0.2	249	21.1
Fagus	27	5.3	6721	570.6
Fraxinus (undiff.)	3	0.6	747	63.4
Fraxinus (total)	3	0.6	747	63.4
Juglans (total)	0	0.0	0	0.0
Larix laricina	16	3.2	3983	338.1
Picea (undiff.)	32	6.3	7966	676.3
Picea (total)	32	6.3	7966	676.3
Pinus (undiff.)	46	9.1	11450	972.1
Pinus banksiana/resinosa (Diploxylon)	41	8.1	10206	866.5
Pinus strobus (Haploxylon)	95	18.8	23648	2007.7
Pinus (total)	182	36.0	45304	3846.3
Platanus occidentalis	1	0.2	249	21.1
Populus	0	0.0	0	0.0
Quercus	32	6.3	7966	676.3
Salix	1	0.2	249	21.1
Thuja occidentalis/Juniperus -type	31	6.1	7717	655.1
Tilia americana	2	0.4	498	42.3
Tsuga canadensis	34	6.7	8463	718.5
Ulmus	8	1.6	1991	169.1
ARBOREAL POLLEN (TOTAL)	479	94.7	119234	10123.0
Alnus crispa	1	0.2	249	21.1
Alnus rugosa -type	6	1.2	1494	126.8
Corylus	1	0.2	249	21.1
Ericaceae (Tetrads)	0	0.0	0	0.0
Myrica -type	0	0.0	0	0.0
Sambucus	0	0.0	0	0.0
Total Shrubs	8	1.6	1991	169.1
Vitis	0	0.0	0	0.0
Epiphytes	0	0.0	0	0.0

Appendix J. US 2 Bog palynomorph tabulation (continued)

Depth (cm below surface)	120.0			
Age (yr B.P.)	1370			
	Count	Percent	Conc.	Influx
Ambrosia -type	1	0.2	249	21.1
Artemisia	3	0.6	747	63.4
Chenopodium -type	1	0.2	249	21.1
Cyperaceae	11	2.2	2738	232.5
Menyanthes trifoliata	1	0.2	249	21.1
Poaceae	1	0.2	249	21.1
Rosaceae	0	0.0	0	0.0
Tubuliflorae	1	0.2	249	21.1
Total NonArboreal Herbs	19	3.8	4730	401.5
Total Terrestrial Pollen	506	100.0	125955	10693.6
Equisetum	0	0.0	0	0.0
Lycopodium clavatum	0	0.0	0	0.0
Lycopodium lucidulum	0	0.0	0	0.0
Lycopodium obscurum	0	0.0	0	0.0
Lycopodium (total)	0	0.0	0	0.0
Osmunda cinnamomea	0	0.0	0	0.0
Osmunda regalis -type	1	0.2	249	21.1
Pteridium aquilinum	1	0.2	249	21.1
Selaginella	1	0.2	249	21.1
Total Ferns and Allies	3	0.6	747	63.4
Unknowns	0	0.0	0	0.0
Total Upland Pollen and Spores	509	100.0	126702	10757.0
Nymphea	1	0.2	249	21.1
Potamogeton	1	0.2	249	21.1
Sphagnum	1	0.2	249	21.1
Typha latifolia	0	0.0	0	0.0
Total Aquatics	3	0.6	747	63.4
Total Determinable Pollen and Spores	512	100.0	127449	10820.4
Indeterminate Grains	6	1.2	1494	126.8
Total Pollen and Spores	518	100.0	128942	10947.2
Eucalyptus grains counted	65			
No. of *Eucalyptus* tablets	1			
Sample volume (cm^3)	1.00			
Accumulation rate ($cm\ yr^{-1}$)	0.0849			
Eucalyptus grains added	16180			
Eucalyptus concentration	16180			
Total Pollen Influx ($gr\ cm^{-2}\ yr^{-1}$)	10947			

Appendix K. Carnegie Trail Pond Palynomorph Tabulation

Carnegie Trail Pond, Mackinac County, Michigan

Depth (cm below water surface)	44.5				85.0			
Depth (cm)	2.5				43.0			
Age (yr B.P.)	-30				200			
Taxa	Count (No.)	Percent (%)	Conc. (gr cm^{-2})	Influx (gr cm^{-2}yr^{-1})	Count (No.)	Percent (%)	Conc. (gr cm^{-2})	Influx (gr cm^{-2}yr^{-1})
Abies	25	4.2	2809	500	6	1.0	674	120
Acer (undiff.)	3	0.5	337	60	0	0.0	0	0
A. pensylvanicum	7	1.2	787	140	2	0.3	225	40
A. rubrum	3	0.5	337	60	1	0.2	112	20
A. saccharum	3	0.5	337	60	6	1.0	674	120
Acer (total)	16	2.7	1798	320	9	1.5	1011	180
Betula	65	10.8	7303	1300	62	10.3	6966	1240
Carpinus/Ostrya -type	3	0.5	337	60	1	0.2	112	20
Fagus	5	0.8	562	100	5	0.8	562	100
Fraxinus undiff.	2	0.3	225	40	1	0.2	112	20
Fraxinus (total)	2	0.3	225	40	1	0.2	112	20
Juglans (undiff.)	1	0.2	112	20	0	0.0	0	0
Juglans (total)	1	0.2	112	20	0	0.0	0	0
Larix laricina	11	1.8	1236	220	22	3.7	2472	440
Picea (undiff.)	56	9.3	6292	1120	56	9.3	6292	1120
Picea (total)	56	9.3	6292	1120	56	9.3	6292	1120
Pinus (undiff.)	29	4.8	3258	580	71	11.8	7978	1420
Pinus banksiana/resinosa (Diploxylon)	52	8.6	5843	1040	39	6.5	4382	780
Pinus strobus (Haploxylon)	85	14.1	9551	1700	87	14.5	9775	1740
Pinus (total)	166	27.6	18652	3320	197	32.7	22135	3940
Populus	4	0.7	449	80	0	0.0	0	0
Quercus	29	4.8	3258	580	20	3.3	2247	400
Salix	1	0.2	112	20	2	0.3	225	40
Thuja occidentalis/Juniperus -type	75	12.5	8427	1500	18	3.0	2023	360
Tsuga canadensis	5	0.8	562	100	28	4.7	3146	560
Ulmus	3	0.5	337	60	1	0.2	112	20
ARBOREAL POLLEN (TOTAL)	467	77.6	52473	9340	428	71.1	48091	8560
Alnus rugosa -type	20	3.3	2247	400	6	1.0	674	120
Corylus	1	0.2	112	20	3	0.5	337	60
Myrica -type	0	0.0	0	0	1	0.2	112	20
Sambucus	4	0.7	449	80	4	0.7	449	80
Total Shrubs	25	4.2	2809	500	14	2.3	1573	280
Ambrosia -type	28	4.7	3146	560	4	0.7	449	80
Artemesia	2	0.3	225	40	7	1.2	787	140
Chenopodium -type	6	1.0	674	120	1	0.2	112	20
Cyperaceae	58	9.6	6517	1160	134	22.3	15056	2680
Menyanthes trifoliata	1	0.2	112	20	0	0.0	0	0
Poaceae	11	1.8	1236	220	11	1.8	1236	220
Rosaceae	1	0.2	112	20	0	0.0	0	0
Rumex	1	0.2	112	20	0	0.0	0	0
Tubuliflorae	2	0.3	225	40	1	0.2	112	20
Potentilla -type	0	0.0	0	0	1	0.2	112	20
Umbelliferae	0	0.0	0	0	1	0.2	112	20
TOTAL NonArboreal Herbs	110	18.3	12360	2200	160	26.6	17978	3200
TOTAL Terrestrial Pollen	602	100.0	67641	12040	602	100.0	67641	12040
Lycopodium annotinum	0	0.0	0	0	1	0.2	112	20
Lycopodium lucidulum	1	0.2	112	20	1	0.2	112	20
Lycopodium (total)	1	0.2	112	20	2	0.3	225	40
Osmunda cinnamomea	0	0.0	0	0	2	0.3	225	40
Osmunda regalis -type	4	0.7	449	80	14	2.3	1573	280
Pteridium aquilinum	2	0.3	225	40	1	0.2	112	20
Total Ferns and Allies	7	1.1	787	140	19	3.1	2135	380
Unknowns	1	0.2	112	20	1	0.2	112	20
Total Upland Pollen and Spores	610	100.0	68540	12200	622	100.0	69889	12440
Brasenia schreberi	2	0.3	225	40	2	0.3	225	40
Nuphar	0	0.0	0	0	2	0.3	225	40
Potamogeton	0	0.0	0	0	2	0.3	225	40
TOTAL Aquatics	2	0.3	225	40	6	1.0	674	120
Total Determinable Pollen & Spores	612	100.0	68765	12240	628	100.0	70563	12560
Indeterminate Grains	3	0.5	337	60	9	1.4	1011	180
Total Pollen & Spores	615	100.0	69102	12300	637	100.0	71574	12740
Pediastrum colonies	1	0.2	112	20	1	0.2	112	20
Nymphaeceae basal cells	12	2.0	1348	240	7	1.1	787	140
Nymphaeceae sclerids	1	0.2	112	20	1	0.2	112	20
Thuja stomata	1	0.2	112	20	1	0.2	112	20
Eucalyptus grains counted	144				72			
No. of *Eucalyptus* tablets	1				1			
Sample volume (cm^3)	1.00				2.00			
Accumulation rate (cm yr^{-1})	0.1780				0.1780	(extrapolated)		
Eucalyptus grains added	16180				16180			
Eucalyptus concentration	16180				8090			
Total Pollen Influx	12300				12740			

Appendix L. American beech tallies

Elbow Lake, Mackinac County, Michigan

Depth (cm)	Age (yr BP)	*Fagus* Count	Percent of TTP	Running Ave. (3x)	Percent Increase	*Fagus* Influx (gr cm^{-2} yr^{-1})	Total Influx (gr cm^{-2} yr^{-1})	TTP Count
0.0	0	27	5.2			145	3473	623
9.0	113	26	4.9	5.9	-4.3	334	7983	604
11.0	210	40	7.6	6.2	-18.5	484	6250	581
13.0	310	33	6.0	7.6	-11.7	358	5782	602
15.0	410	47	9.1	8.6	-7.9	599	7197	553
17.0	505	61	10.6	9.3	9.4	568	5931	621
19.0	605	47	8.2	8.5	13.3	434	5745	611
21.0	705	35	6.7	7.5	8.7	689	11477	562
23.0	800	44	7.6	6.9	-5.0	291	4417	632
25.0	900	35	6.4	7.3	4.3	360	6165	584
27.0	1000	42	7.8	7.0	-13.6	397	5702	586
29.0	1095	38	6.7	8.1	-8.0	306	5037	608
31.0	1195	51	9.7	8.8	-9.3	494	5614	564
33.0	1295	50	9.9	9.7	-3.3	615	7114	549
35.0	1390	49	9.4	10.0	-1.0	176	2024	545
37.0	1490	62	10.7	10.1	-0.7	385	4083	625
39.0	1590	63	10.2	10.2	11.7	717	7725	652
41.5	1710	51	9.6	9.1	6.2	617	7259	569
44.0	1835	42	7.5	8.6	11.3	316	4694	609
46.5	1950	51	8.6	7.7	-10.5	663	8298	624
49.0	2045	36	7.0	8.6	-2.6	1915	29044	535
54.0	2120	54	10.2	8.8	6.0	1948	21644	575
59.1	2200	50	9.3	8.3	42.0	1549	18341	573
65.6	2300	29	5.5	5.9	58.6	764	16512	594
72.1	2400	16	2.8	3.7	48.0	319	13486	637
78.5	2500	15	2.8	2.5	25.0	278	11420	583
81.5	2545	12	1.9	2.0	53.8	249	15230	706
86.5	2620	7	1.3	1.3	-2.5	197	17023	567
89.0	2700	4	0.7	1.3	2.6	66	10998	653
92.3	2800	11	2.0	1.3	5.4	220	12434	587
95.5	2900	6	1.2	1.2	-5.1	232	22072	549
98.5	3000	3	0.5	1.3	2.6	47	10209	606
114.5	3500	12	2.2	1.3	-11.6	97	5407	633
117.9	3600	6	1.1	1.4	34.4	173	17825	605
121.1	3700	5	1.0	1.1	18.5	98	11794	576
124.0	3790	6	1.1	0.9	-20.6	164	17143	603
126.5	3870	3	0.6	1.1	-29.2	58	10347	593
129.0	3960	9	1.7	1.6	-20.0	163	11635	616
131.5	4055	15	2.5	2.0	11.1	254	11860	671
132.8	4100	9	1.8	1.8	35.0	129	8367	561
135.5	4200	6	1.1	1.3	21.2	111	11508	592
138.2	4300	6	1.1	1.1	0.0	152	15294	584
141.0	4400	6	1.1	1.1	3.1	122	12308	572
143.7	4500	6	1.1	1.1	28.0	120	12946	612
146.4	4600	6	1.0	0.8	0.0	148	16155	638
149.2	4700	2	0.4	0.8	0.0	37	11788	603
151.9	4800	6	1.1	0.8	-26.5	167	18648	644
154.6	4900	5	1.0	1.1	17.2	125	14328	549
157.5	5000	7	1.3	1.0	-3.3	114	9990	578
160.1	5100	3	0.6	1.0	42.9	72	14519	579
162.8	5200	6	1.1	0.7	-8.7	117	12226	587
165.6	5300	2	0.4	0.8	-8.0	47	14753	584
168.3	5400	5	0.8	0.8	8.7	72	10252	681
171.0	5500	7	1.3	0.8	4.5	123	10461	575
173.8	5600	1	0.2	0.7	100.0	14	8040	579
176.5	5700	4	0.7	0.4	-26.7	55	8705	613

Appendix L. (continued)

Elbow Lake, Mackinac County, Michigan

Depth (cm)	Age (yr BP)	*Fagus* Count	Percent of TTP	Running Ave. (3x)	Percent Increase	*Fagus* Influx (gr cm^{-2} yr^{-1})	Total Influx (gr cm^{-2} yr^{-1})	TTP Count
179.0	5790	1	0.2	0.5	25.0	12	11175	621
181.5	5860	3	0.6	0.4	0.0	54	11096	584
186.8	6000	2	0.4	0.4	50.0	36	10723	566
190.7	6100	1	0.2	0.3	100.0	21	13005	602
194.5	6200	1	0.2	0.1		25	14873	577
198.4	6300	0	0.0	0.1		0	17444	619
202.3	6400	0	0.0	0.0		0	15080	562
206.1	6500	0	0.0	0.1		0	17297	574
210.0	6600	1	0.2	0.1		31	18756	570
213.8	6700	0	0.0	0.1		0	20389	575
216.5	6770	0	0.0	0.0		0	16042	632
219.0	6835	0	0.0	0.0		0	17999	631
221.5	6900	0	0.0	0.0		0	11368	567
225.0	6990	0	0.0	0.0		0	17959	557
241.5	7935	0	0.0	0.0		0	28365	689
244.0	8000	0	0.0	0.0		0	23076	753

Appendix L. (continued)

Nelson Lake, Mackinac County, Michigan (data courtesy of Dr. Hazel Delcourt)

Depth (cm)	Age (yr BP)	*Fagus* Count	Percent of TTP	Running Ave. (3x)	Percent Increase	*Fagus* Influx (gr cm^{-2} yr^{-1})	Total Influx (gr cm^{-2} yr^{-1})	TTP Count
0.5	0	25	5.0			244	4923	504
14.5	109	18	3.5	4.7	-17.2	137	3985	517
23.5	255	28	5.5	5.6	-10.6	179	3360	505
38.0	512	40	7.9	6.3	-4.1	348	4530	509
50.0	726	28	5.5	6.6	22.4	186	3457	505
66.0	1010	34	6.3	5.4	-6.9	255	4122	541
74.0	1250	23	4.3	5.8	13.8	114	2733	533
82.0	1484	35	6.7	5.1	2.7	269	4046	521
90.0	1758	22	4.2	4.9	24.4	224	5383	530
98.0	2032	22	3.9	4.0	21.4	197	5105	562
106.0	2307	20	3.8	3.3	25.6	167	4412	533
110.0	2444	11	2.1	2.6	34.5	74	3536	533
118.0	2718	10	1.9	1.9	28.9	80	4267	533
130.0	3034	9	1.8	1.5	2.3	94	5215	509
138.0	3231	4	0.8	1.5	10.0	44	5501	506
150.0	3525	9	1.8	1.3	5.3	65	3619	509
158.0	3721	7	1.4	1.3	18.8	61	4373	517
170.0	4075	3	0.6	1.1	77.8	16	2647	538
174.0	4241	6	1.2	0.6	-40.0	46	3811	513
182.0	4575	0	0.0	1.0	25.0	0	3075	531
186.0	4739	9	1.8	0.8	-14.3	55	3053	510
194.0	5071	3	0.6	0.9	100.0	25	4193	506
198.0	5237	2	0.4	0.5	75.0	20	5123	548
202.0	5403	2	0.4	0.3	100.0	17	4314	509
206.0	5569	0	0.0	0.1		0	5990	562
210.0	5917	0	0.0	0.0		0	3637	542
214.0	6290	0	0.0	0.0		0	4327	509
218.0	6663	0	0.0	0.0		0	2630	551
222.0	7037	0	0.0			0	527	505

Appendix L. (continued)

Ryerse Lake, Mackinac County, Michigan (data courtesy of Dr. Richard Futyma)

Depth (cm)	Age (yr BP)	*Fagus* Count	Percent of TTP	Running Ave. (3x)	Percent Increase	*Fagus* Influx (gr cm^{-2} yr^{-1})	Total Influx (gr cm^{-2} yr^{-1})	TTP Count
121.0	597	48	7.5	7.6	-6.7	288	3866	640.0
125.0	753	55	7.6	8.1	-0.5	198	2680	723.0
130.0	948	53	9.2	8.1	25.5	312	3454	577.5
135.0	1143	42	7.6	6.5	43.1	280	3711	551.0
140.0	1337	15	2.6	4.5	37.7	126	4742	567.5
145.0	1532	19	3.3	3.3	-2.7	106	3144	572.0
150.0	1727	23	3.9	3.4	0.8	115	2990	589.5
155.0	1921	18	2.9	3.4	-11.7	114	3866	616.0
160.0	2116	18	3.2	3.8	6.1	95	2938	555.5
165.0	2311	31	5.2	3.6	22.0	175	3247	591.5
170.0	2505	14	2.3	2.9	101.6	92	3969	619.0
176.0	2757	8	1.3	1.5	-7.2	68	5155	615.0
181.0	2983	5	0.8	1.6	9.2	24	2938	622.5
186.0	3323	18	2.6	1.4	6.6	85	3247	692.0
191.0	3550	5	0.9	1.3	126.2	36	3969	552.0
196.0	3833	4	0.5	0.6	16.1	19	3557	743.5
201.0	4122	2	0.3	0.5	3.3	12	3454	581.0
206.0	4432	5	0.7	0.5	30.0	16	2474	760.5
211.0	4742	3	0.5	0.4	134.3	17	3454	613.0
216.0	5052	0	0.0	0.2		0	2990	735.5
221.0	5363	0	0.0	0.0		0	4639	689.0
226.0	5673	0	0.0	0.0		0	4021	993.0
231.0	5983	0	0.0	0.0		0	3814	806.0
236.0	6390	1	0.1	0.0		2	2010	805.0
241.0	6944	0	0.0	0.0		0	2835	625.0
246.0	7500	0	0.0	0.1		0	3608	727.5
251.0	8054	1	0.2	0.1		4	2577	602.0
256.0	8609	0	0.0	0.1		0	1804	957.5
261.0	9164	0	0.0	0.0		0	3196	838.5

Appendix L. (continued)

Beaverhouse Lake, Mackinac County, Michigan

Depth (cm)	Age (yr BP)	*Fagus* Count	Percent of TTP	Running Ave. (3x)	Percent Increase	*Fagus* Influx (gr cm^{-2} yr^{-1})	Total Influx (gr cm^{-2} yr^{-1})	TTP Count
1.0	-40	15	3.0	2.4	7.0	22	804	501.0
17.0	60	12	1.9	2.3	-8.5	145	8541	645.0
19.0	70	10	2.0	2.5	1.8	25	1430	512.0
20.6	160	18	3.1	2.4	-4.8	56	2001	579.0
22.4	260	16	2.8	2.6	4.8	58	2269	567.0
24.2	370	13	2.4	2.4	9.0	44	2045	553.0
26.0	470	8	1.5	2.2	14.3	31	2349	538.0
27.8	570	12	2.3	2.0	-6.4	25	1198	521.0
29.6	670	9	1.7	2.1	-8.3	22	1403	529.0
31.4	780	15	2.9	2.3	7.6	54	2085	520.0
33.2	880	13	2.2	2.1	-13.1	39	1862	579.0
35.0	980	10	1.7	2.4	4.6	22	1436	604.0
36.9	1090	16	3.0	2.3	-3.4	58	2152	536.0
38.7	1190	13	2.5	2.4	-15.6	23	1080	530.0
40.5	1290	14	2.6	2.9	3.4	50	2124	543.0
42.3	1400	21	3.4	2.8	-4.1	53	1732	610.0
44.1	1500	14	2.6	2.9	3.7	32	1410	536.0
46.7	1600	17	2.9	2.8	7.6	107	3946	580.0
50.1	1700	12	2.2	2.6	1.1	85	4253	554.0
53.5	1800	14	2.7	2.6	10.8	154	6106	528.0
56.9	1900	13	2.5	2.3	5.2	123	5160	520.0
60.3	2000	11	1.9	2.2	10.7	139	7506	568.5
63.8	2100	9	1.7	2.0	12.9	127	7857	526.0
67.2	2200	9	1.8	1.8	-9.1	121	7178	500.0
70.6	2300	9	1.6	1.9	-5.5	71	4707	566.0
74.0	2400	14	2.6	2.0	14.0	128	5208	531.0
77.4	2500	12	2.2	1.8	17.0	67	3462	555.0
80.8	2600	4	0.8	1.5	26.6	61	8496	502.0
84.2	2700	3	0.5	1.2	58.5	23	4719	548.0
87.6	2800	7	1.3	0.8	0.5	71	6062	520.0
93.3	2900	2	0.4	0.8	-13.4	101	29478	539.0
100.0	3000	4	0.8	0.9	38.8	116	16220	511.0
115.0	3100	6	1.0	0.6	-26.2	122	13095	588.0
125.9	3200	2	0.4	0.9	7.8	63	19085	551.0
136.7	3300	8	1.3	0.8	15.9	217	18586	630.0
144.6	3400	3	0.5	0.7	15.2	38	7926	563.0
154.3	3550	3	0.6	0.6	13.5	37	7399	514.0
157.6	3600	0	0.0	0.5	-2.7	0	4351	544.0
164.1	3700	5	1.0	0.5	1.2	43	5344	507.0
170.7	3800	3	0.6	0.5	-19.9	32	6503	508.0
177.2	3900	3	0.6	0.7	22.7	30	6148	538.0
183.7	4000	3	0.5	0.5	37.4	32	6384	567.0
187.5	4100	3	0.5	0.4	-1.9	11	2550	608.0
190.5	4200	0	0.0	0.4	48.9	0	2442	620.0
193.6	4300	3	0.6	0.3	83.9	10	1816	510.0
196.6	4400	0	0.0	0.1	-35.2	0	2182	558.0
199.7	4500	0	0.0	0.2	15.6	0	2434	552.0
202.8	4600	2	0.3	0.2	0.0	22	6989	625.0
205.8	4700	3	0.5	0.2	-17.0	6	1245	644.0
208.9	4800	0	0.0	0.2	-2.5	0	3298	639.0
212.0	4900	1	0.2	0.2	39.7	4	2352	620.0
215.0	5000	2	0.3	0.2	0.0	7	2336	581.0
218.1	5100	1	0.2	0.2	30.2	6	3431	527.0
221.2	5200	0	0.0	0.1	181.4	0	5584	516.0
225.0	5325	0	0.0	0.0	-4.9	0	10588	605.0
227.5	5406	0	0.0	0.0		0	10395	556.0
229.0	5455	1	0.2			15	8344	501.0

VITA

William Petty Rivers was born in Crawfordsville, Indiana on June 28, 1965, to Anne Marie (van Wagtendonk) Petty and Robert Owen Petty. From under the shade of a magnificent American beech tree he grew up watching a small portion of the Beech-Maple Forest succeed back from an old pasture to a young forest. After graduating from South Montgomery High School in May 1983, he attended Grinnell College in Grinnell, Iowa. He received a Bachelor of Arts degree from Grinnell in May of 1987 with a major in Biology and a concentration in Environmental Studies. After teaching at Grinnell for one year, he entered the Graduate Program in Ecology at the University of Tennessee. While in the Ecology program he conducted research under the direction of Dr. Frank McCormick on the effects of Hurricane Hugo on seedlings in the tropical rain forest of Puerto Rico. He completed this research for a Master's degree in Ecology which he received in May of

1993. In August of 1991, he entered the Department of Geological Sciences at the University of Tennessee to begin a Master's degree in geology with Drs. Paul and Hazel Delcourt as his co-advisors. His research on the geomorphic history of the landscape along the southern coast of Upper Michigan provides much of the background information on beach-ridge development and lake-level fluctuation which has made this dissertation possible. Upon completion of his doctorate from the Department of Ecology and Evolutionary Biology, Wil, his wife Rebecca Young Rivers, and their daughter Sarah Elizabeth, will be moving to Canton, New York where Wil will be a Fellow at the Center for Independent Scholars affiliated with The Associated Colleges of the St. Lawrence Valley.