Paleoecology of a Wild Rice (*Zizania spp.)* Lake in Northwestern Ontario

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ABSTRACT

The high density of archaeological sites around Whitefish Lake, coupled with abundant wild rice currently growing there circumstantially indicates that this resource was economically important to precontact people. This study analyzes lake sediment cores to reconstruct the paleoecology of Whitefish Lake and document the antiquity of wild rice (*Zizania spp.*).

A vibracorer was used to obtain a 4.5 m core from Whitefish Lake that was sampled for pollen and phytoliths at 2 cm intervals. Three additional short cores were obtained to study the modern pollen and phytolith sequence that were likely missed using the vibracorer. These cores revealed several events: 1) a deep-water phase, likely related to proglacial Lake O'Connor, followed by a Mid-Holocene arid period; and 2) the identification of wild rice microfossils dating back to roughly 6,000 cal yr BP. This research also establishes the utility of multiproxy analysis involving both pollen and phytoliths to track paleovegetation changes.

The analysis also revealed the early forest that inhabited the area prior to the drying event that persisted throughout the mid-Holocene. The ped-like structures within the Whitefish Lake core, coupled with other evidence of a buried forest at the Old Fort William site (Boyd et al., 2010; Kingsmill, 2011) demonstrate the consequences of the warming and drying trends of the early to mid Holocene. Sediment and pollen profile analysis of the mid-section of the core indicate that by 4,905 cal yr BP the Whitefish Lake basin had started to fill up again with water. The subsequent bioproductivity of the lake is indicated by the sapropel in the sediment.

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DEDICATION

I would like to dedicate this work to my family. My husband, Clarence Surette, has stood by my side through many challenges and unexpected surprises. He has helped me grow professionally as a student and personally as wife, partner, and mother to two beautiful children (Edmond and Olivia). My children have taught me patience and perseverance as my husband and I have learned what having a family truly means. I have been very blessed in my life and have learned many valuable lessons.

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CHAPTER 1: INTRODUCTION

1.1 Problems and Significance of the Study

The focus of this study is on reconstructing the paleovegetation of Whitefish Lake (Fig 1.1) using pollen recovered from four sediment cores and to identify the entry of wild rice *(Zizania spp*.) into the area. Historically, wild rice was an important staple among many indigenous groups providing a readily storable and reliable food source (Cross, 1938; Mather and Thompson, 2000). Wild rice harvesting at Whitefish Lake is also a very important economic activity to the Seine River First Nation today (pers. Comm. Dr. Peter Lee Department of Biology, Jan 7, 2018). This study will provide evidence of their long history of reliance on the grass economically and politically regarding land claims and treaty rights.

In 2008, a long core and a short core were extracted, with two additional supplementary short cores recovered in 2016. This paleovegetation study adds to the previous work done in Northwestern Ontario by McAndrews, 1984, Saarnisto (1974), Bjork (1985), Liu (1990), Boyd et al., 2010; 2013, Moos and Cumming (2011) and others.

This study also addresses the antiquity of the wild rice (*Zizania palustris*) found in the lake. Wild rice has been an important food source for native peoples for centuries but determining its initial arrival into northwestern Ontario has remained a challenge. Formerly pollen and macro-remains have been used, but seeds are sparse, and pollen is neither efficient nor conclusive beyond the Family level. To improve clarity of interpretation, phytoliths were also considered, and proved to be a valuable analytical tool in addition to other multiproxy data.

1.2 An Overview of the Study Area

Whitefish Lake (Fig 1.1), located 45 min west of Thunder Bay, near the village of Nolalu, was chosen for this study. Whitefish Lake has water depths averaging between 7 to 8 feet (2-2.5

m) deep in most areas and a 22 feet deep (6 m) fissure that runs through the lake near Macgillivray Island (Fig 1.2).

Figure 1.1. Study area and location of Whitefish Lake.

The climate consists of winters averaging -14.8 ºC in January and summers averaging 17.6 ºC in July. Precipitation averages around 31.3 mm in the winter and about 89 mm in the summer (Environment Canada). The ecozone of the area is boreal shield (Wiken et al., 1996).

The water catchment area around Whitefish Lake does not extend much beyond 5 km to the west of the lake, minimizing the amount of pollen transported into the lake by flowing water. A small river drains from east side of the lake that contains no stands of wild rice. This may be due to the increased wind and wave exposure on that end of the lake. Stands of wild rice can be found on the west and south side of the lake.

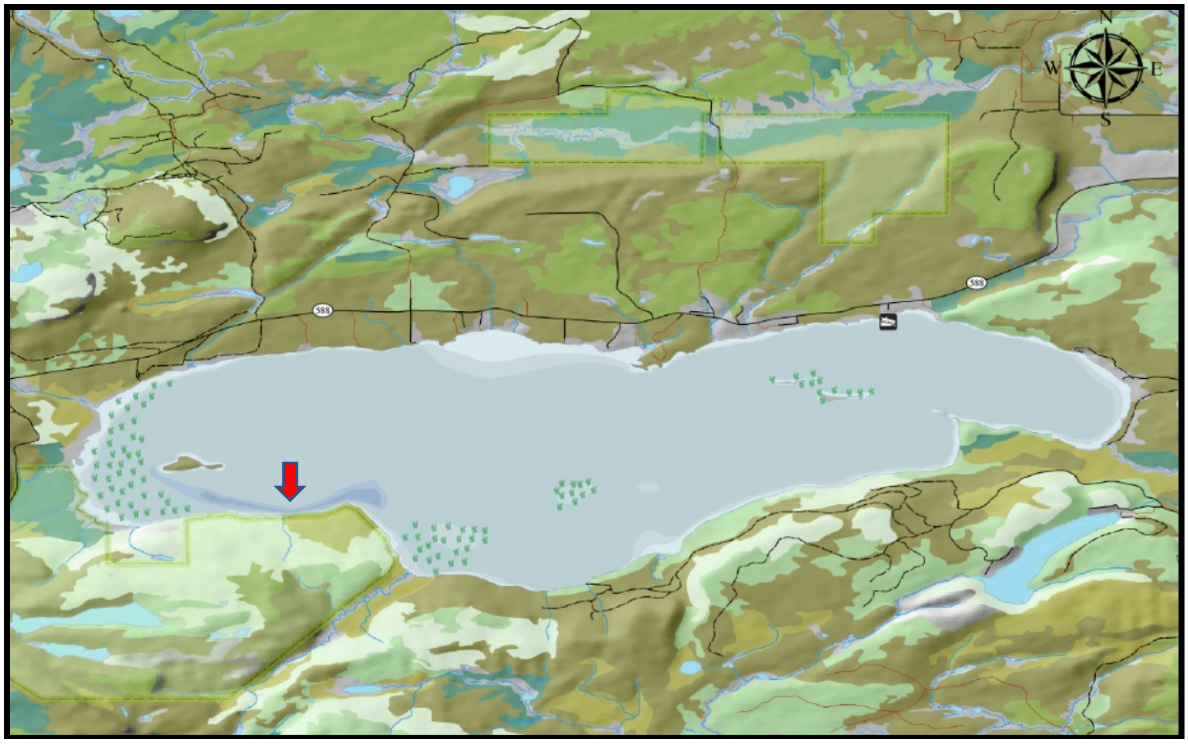

Figure 1.2 Bathymetry map of Whitefish Lake showing a deep fissure south of Macgillivray Island (pointed out by red arrow) and extensive wild rice stands (*Zizania palustris)* (green dots). Taken from Northwest Ontario Outdoors (Taken from https://www.nwoutdoors.ca/product/whitefish-lake-bathymetry-map/, 2017)

1.3 Brief Summary of Archaeology around Whitefish Lake

There are several archaeological sites in and around Whitefish Lake, suggesting an extensive prehistoric occupation of the area. The earliest occupations of the area are of Paleoindian origin (Tower Road (DbJm-6) and Billings Bridge (DbJm-32)) (Schweitzer, 2014). However, the majority of the sites on the modern shorelines of the lake exhibit Late Period Middle Woodland and Late Woodland affinities (Dawson, 1974; 1978; 1980; 1987). Notable Woodland sites in the area include the Macgillivray (DbJm-3), Martin Bird (DbJm-5), McCluskey (DbJm-2), and Mound Island (DbJl-2) sites (Boyd, 2010; Dawson, 1974, 1976, 1978, 1980, 1983, 1987). Dawson reports that the Macgillivray Site, located on Macgillivray Island, shows two separate occupations. The mound feature indicates an early Middle Woodland occupation (circa 200 B.C. to A.D. 300) likely of the Laurel Tradition. The second occupation is

assigned to the Late Woodland period (roughly A.D. 700 to A.D. 900) (Dawson, 1980). The Martin-Bird Site, also located on MacGillivray Island (Dawson, 1987) also yielded a sparse Laurel ceramic assemblage and a mound feature likely associated with a more extensive Late Woodland occupation represented by Blackduck ceramics.

Of these locations, the Martin-Bird site has one the largest variety of Woodland vessels present with Laurel, Brainerd, Blackduck, Sandy Lake, and Selkirk wares (Dawson 1987; Boyd, 2010). Radiocarbon dates from both sites on the island reveals a contemporaneous occupations. The MacGillivray Site is dated to about 290 $\pm$ 80 ^{14}C yr B.C. and the Laurel component at the Martin Bird Site dates to about 330 $\pm$ 145 B.C. (Dawson, 1974)

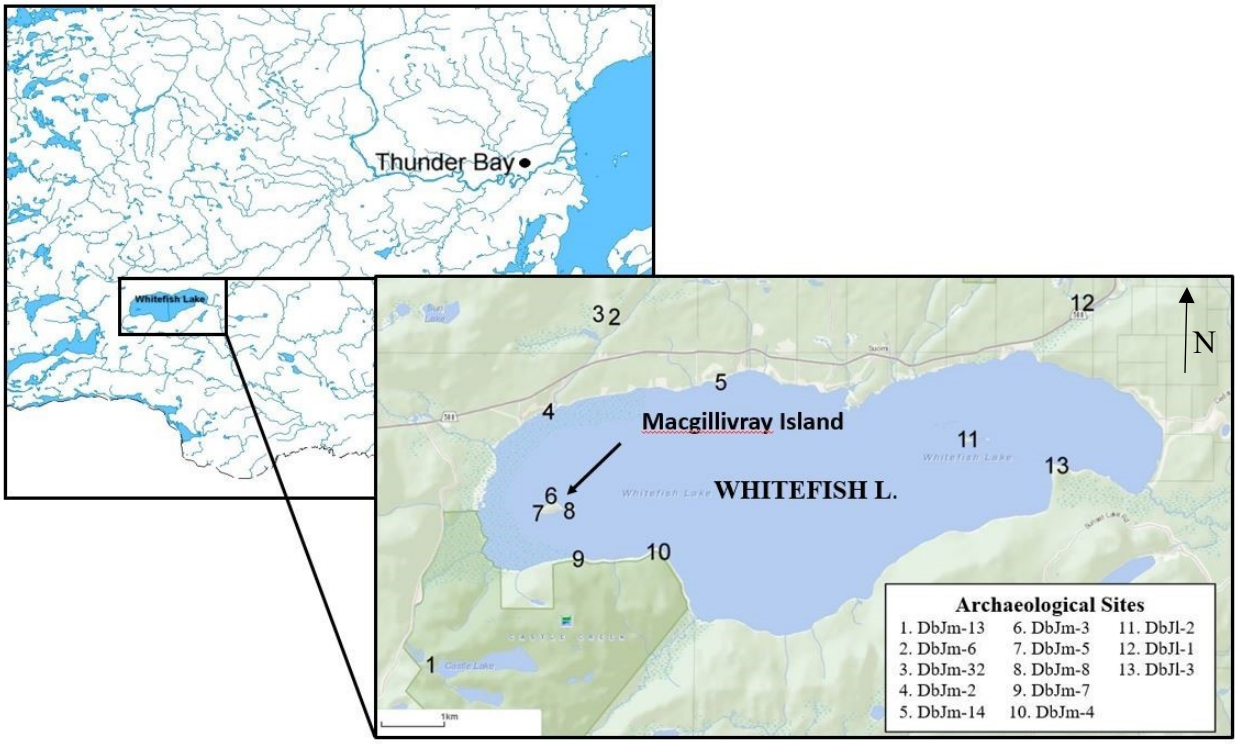

Figure 1.3 Archaeological sites located in the study area.

The McCluskey Site is located on the north shore of Whitefish Lake shows successive occupation over approximately 2000 years. The oldest occupation at this site belongs to the

Middle Woodland Laurel Culture, and the younger part belongs to Late Woodland period based on the Blackduck ceramics (Dawson, 1974). As with the other sites, a burial mound was also present at this site. The bone recoveries suggest it was a spring to fall occupation. Although there is no evidence of wild rice in the site, the location suggests that wild rice was likely part of their subsistence base (Dawson, 1974). Mound Island, located at the east end of Whitefish Lake also shows multiple occupations. Ceramic recoveries place the earliest habitation during the late Middle Woodland period. The ceramics also suggest a re-occupation during the Late Woodland period. As the name of the site suggests, burial mounds were noted at this site. The number of burial mounds in the area speaks to the importance of the area to precontact people before Europeans arrived.

Diagnostic *Zizania* spp. phytoliths were found in the carbonized food residues on five of the seven of the archaeological sites found within the study area (Boyd et al., 2014). These samples were identified on wares affiliated with the Laurel (Middle Woodland) Composite and Blackduck (Late Woodland) Complex. Wild rice phytoliths were also found on grinding stones, soil from features, and fire-cracked rock (FCR) from some of the same sites. Although the focus of this study was primarily on *Zizania* spp., *Zea mays* phytoliths and starch granules were also found in six of the seven sites analyzed (including Laurel, Blackduck, and Sandy Lake ceramics, grinding stones, FCR, and soil from features) (Boyd et al., 2013; Surette et al., 2011).

This demonstrates the economic importance of wild rice at several locally important sites. Due to its importance as a food source, addressing the antiquity of wild rice availability at Whitefish Lake is crucial. To that end, sediment cores were extracted from the lake bottom to try to identify how early the wild rice established itself in the lake.

CHAPTER 2: PALEOVEGETATION OF NORTHERN MINNESOTA AND NORTHWESTER ONTARIO

2.1 Introduction

This chapter provides an overview of the paleo-vegetative sequence since the Laurentide Ice Sheet (LIS) retreated. Previous pollen analyses are summarized to review major vegetation changes that occurred in NW Ontario during the Holocene period. Lakes from both northern Minnesota and northwestern Ontario will be reviewed (figure 2.1) to illustrate the general trends and changes in vegetation that occurred in the area throughout the Holocene.

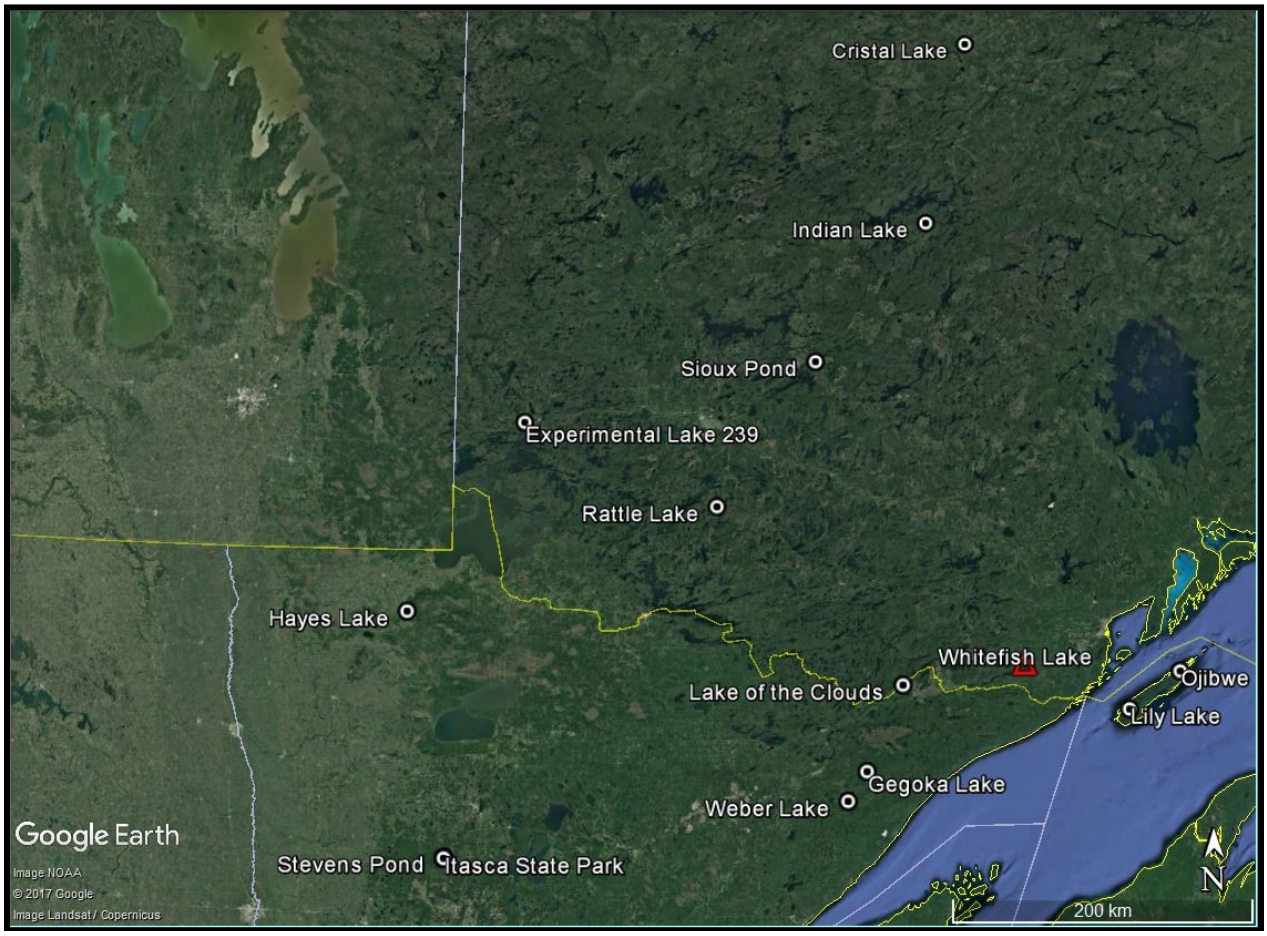

Figure 2.1 Map showing lakes from northern Minnesota and Northwestern Ontario. These lakes are chosen because they represent a well-established vegetational history based on pollen studies and have well dated cores dating back to the early Holocene. The study area is marked with a red triangle.

2.2 Northern Minnesota

2.2.1 Gegoka Lake

A study of Gegoka Lake (figure 2.1), by James Huber (1995), represents local and regional trends in vegetation and lake productivity during the last 10,000 years. The importance of this study is discussed here due to the possible emergence of wild rice with an associated date in the area. His analysis indicates that vegetation began with a shrub parkland/open conifer forest, progressing to a spruce-pine forest, and finally a mixed conifer-hardwood forest (Huber, 1995: 23).

Zone GL-1 is considered a transitional zone. This zone is dominated by *Betula* and *Picea* and dates to between 10,500 -10,200 ^{14}C yr BP. *Picea* (spruce) values range between 32% to 38%, while *Pinus* (pine) values range between 20% and 21%. *Betula* (birch) pollen reaches its maximum of 8% to 16% at this level (Huber, 1995: 26). The NAP (non-arboreal pollen) consists of *Cyperaceae* (sedges), *Artemisia* (artemisia), *Ambrosia*-type (ragweed), and *Gramineae* (grasses). It is in this zone that *Cyperaceae* and *Artemisia* also attain their maximum pollen percentages at 10.6% and 4% respectively (Huber, 1995: 26).

Zone GL-2 begins between 10,200 to 9000 ^{14}C yr BP and is *Picea – Pinus* dominant. AP (arboreal pollen) percentages are considerably higher in this zone compared to the previous zone (81% to 97%). *Picea* starts to decline in the upper part of this zone and *Pinus banksiana/resinosa* (jack pine/red pine), becomes the dominant taxon. *Pinus* increases from 25% to 71%. *Picea* decreases to 30% to 4%. *Betula* sees a decline from 8% to 4% then up to 17%. The NAP prominent types *(Cyperaceae, Artemisia, Ambrosia*-type and *Gramineae)* gradually decline (Huber, 1995: 26). The aquatic taxa, *Potamogeton* (Pondweed), *Sparganium*-type (Bur-reed), *Typha Latifolia* (Cattail), *Nymphaea* (Water Lily), and *Myriophyllum exalbescens*-type (Spiked Water Milfoil), occur here as well (Huber, 1995: 27

In **Zone GL-3**, *Pinus banksiana/resinosa, Betula, Alnus* (alder), and *Picea* dominate between 9000 BP to 7000 ^{14}C yr BP. AP values make 80% to 92% of the pollen spectra. *Pinus banksiana/resinosa* decrease in this zone (33% to 58%). *Betula* ranges between 11% to 22%. *Picea* peaks at 7% and then declines to less than 2%. *Pinus strobus* (white pine) increases from 2% to 7% and *Alnus* increases from 4% to 16% and decreases to 7%. The prominent herbs in this zone (*Cyperaceae, Gramineae, Artemisia, Ambrosia*-type, *Chenopodiaceae/Amaranthaceae* (goosefoot/amaranth), *Tubuliflorae* (aster), *Pteridium*-type (fern), *Equisetum* (horsetail), and *Dryopteris*-type (wood fern) have values up to 5% (Huber, 1995: 27). Aquatic plants (*Potamogeton, Sparganium-type, Typha Latifolia, Nymphaea, and Myriophyllum alterniflorum*-type) are sparsely present (Huber, 1995: 28).

In **Zone GL-4,** a change in composition occurs between 7000 and 6000 ^{14}C yr BP. The dominant AP are; *Pinus, Betula*, and *Alnus*. Deciduous plants increase at the expense of *Picea* (less than 3%). *Pinus banksiana/resinosa* declines from 47% to 21% to be replaced by *Pinus strobus*, which increases from 15% to 40% (Huber, 1995: 28). *Betula* increases from 8% to 19% and then falls to 14%. *Quercus* (oak) is the second most dominant deciduous plant with values up to 4% followed by *Ulmus* (elm), *Ostrya /Carpinus* (ironwood/hophornbeam), and *Fraxinus nigra* (ash) with values of 2%. *Alnus* (alder) remains important with values of 4% to 10%. Together the AP values range between 86% and 92%. NAP values for *Cyperaceae, Gramineae, Ambrosia*-type, *Artemisia, Chenopodiniaceae/Aramanthaceae,* and *Pteridium*-type remain low around 4%. Aquatics at this time include; *Potamogeton, Typha latifolia, Sparganium*-type, *Nymphaea, Myriophyllum exalbescens*-type, and *Isoetes macrospora* (quillwort) (Huber, 1995: 29).

Zone GL-5 contains high values AP ranging between 87% and 93%, and is dominated by *Pinus, Picea,* and *Betula*. Huber (1995: 29) notes an increase in *Picea* from 3% to 8% and *Betula* from 11% to 19%. *Quercus* is present with values up to 2%. Shrub values remain low except for *Alnus,* which increase from 5% to 8%. *Gramineae* in general is more abundant (2.2% - 5.2%), which Huber (1995: 32) attributes to the possible establishment of wild rice (*Zizania aquatica*) in the lake.

In **Zone GL-6,** *Pinus, Picea, Betula* and *Alnus* dominate. AP values remain high, ranging between 89% and 93%. *Picea* increases to 8% and *Betula* falls to 15%. *Pinus* in general increases with *P. strobus* increasing from 32% to 38% and *P. banksiana/resinosa* increasing from 16% to 20%. Gramineae becomes more abundant increasing to 5.2% at the bottom of **zone GL-6** but falls to 3.6 % near top of the core. Alnus remains stable ranging between 5% and 7%. There is a small increase in *Ambrosia*-type pollen, which Huber (1995: 33) interprets as possibly signally the arrival of Euro-American settlers. Aquatics present in this zone include *Potamogeton, Typha latifolia, Sparganium*-type, *Nuphar* (yellow pond lily)*, Myriophyllum exalbescens*-type, *Isoetes macrospora,* and *Lycopus*-type (bugleweed) (Huber, 1995: 30).

2.2.2 Weber Lake

Webber Lake (figure 2.1) was chosen for its late-glacial and early post-glacial environmental record. **Zone 1** with its NAP dominance and rather high Picea values represents a stage of open vegetation with spruce scattered or in groups as shrubs, grasses and herbs covered the open ground. A xeric element is prominent (e.g., *Ambrosia*) creating a "woodland-prairie-tundra", presumed to have existed at the time (Fries, 1962: 300). The transition from silt and clay to clay-gyttja is believed to reflect the change from late-glacial to post-glacial climatic conditions (Fries, 1962: 300).

Zone 2 is characterized by decreasing NAP and high *Betula*, forming the beginning of the post-glacial forest period. Size measurements of the birch pollen point to *B. glandulosa* (American dwarf birch). Two radiocarbon dates were obtained from the *Betula* maximum: 10,550 +/-300 and 10,180 +/-160 ^{14}C yr BP (Fries, 1962: 302). **Zone 3** was carbon dated to 9,150 +/- 130 ^{14}C yr BP and is characterized by decreasing *Picea* and increasing Pinus values and by a maximum of *Quercus*, *Ulmus*, and other thermophilous (warm temperature) trees. This may correspond to a conifer-hardwood forest probably indicating a climate warmer than that of today (Fries, 1962:303). **Zone 4**, with dominating *Pinus* and increasing *Alnus* and *Betula*, corresponds to a gyttja layer rich in plant fragments belonging to *Potamogeton robbinsii* (robin's pondweed), at the top of which a radiocarbon date was obtained: 7,300 +/- 140 ^{14}C yr BP. The zone ends with a slight increase in NAP probably indicating a drier period and perhaps increased fire (Fries, 1962: 304).

Zone 5 is characterized by a dominance of *Pinus* and an under-representation of *Picea*, *Alnus*, *Betula*, and other deciduous trees. **Zone 6** shows a reduction of *Pinus* pollen and grades indistinctly into the following zone (Fries, 1962: 305). **Zone 7** is characterized by an increasing amount of *Picea*, *Abies* (balsam fir), and *Larix* (larch) pollen. This is interpreted as a local expansion of the surrounding bog with its cover of black spruce and intermixture of *Larix* and *Thuja* near the lake. The occurrence of *Tsuga* pollen is new to the area. There is an increase of weed pollen, mainly *Ambrosia*, and of *Betula* pollen, reflecting the weed flora at an adjacent logging camp and the pioneer vegetation invading the cleared areas in connection with the timber cutting and consequent heavy birch growth (Fries, 1962: 305).

2.2.3 Lake of the Clouds

Lake of the Clouds is located in Lake County (figure 2.1), in the Boundary Waters Canoe area in northern Minnesota. The lake core was divided into six distinct zones. **Zone LC1** has tundra-like vegetation. Based on sedimentation rates it is suggested that this zone dates to 11,000 - 10,300 yr cal BP. This zone is characterized by non-arboreal pollen (NAP) of at least 40%. This includes *Cyperaceae, Ambrosia, Artemisia, Gramineae, Tubuliflorae, Chenopodium* and *Humulus* (hop). Arboreal pollen contributors include *Salix* (willow), *Picea*, and *Fraxinus* as the most common. *Potamogeton* is the only important aquatic taxon. Although, the only taxa diagnostic of tundra is *Saxifraga oppositifolia* (saxifrage), Craig (1972: 51) believes that the combination of *Salix, Cyperaceae,* and *Potamogeton* represents a tundra and associated aquatic vegetation to that of Weber Lake. *Picea* dominated forest extended from Kansas to Saskatchewan in the late-glacial time (Wright, 1970) and is therefore inferred to have been present close to southern and western Minnesota during the time **zone LC-1** was being deposited (Craig, 1972: 52). The upper subzone contains pollen from *Cyperaceae, Salix* believed to be in the area locally (Craig, 1972: 52). **Zone LC-2** was determined to be a *Picea* forest with *Pinus* and thermophilous deciduous trees and dates to 9,200 yr BP. Betula is present in this zone but does not dominate like at Weber Lake but *Betula* does peak at the same time. This suggests that local soil conditions differed at both lakes resulting in better growing condition at Weber Lake. This zone represents boreal spruce forest (Craig, 1972: 52). Wright (1968b) established that pine reached northern Minnesota from the east about 10,000 ^{14}C BP and had already disappeared from southern Minnesota by this time.

Zone LC-3 dates to about 9,200 yr cal BP. Forests at this time were dominated by *Pinus banksiana/resinosa* (over 50%) and *Betula* (10%). Craig (1972: 53) explains that *Betula* arrived

in the area (and in most of the northeast) around 9,500 BP. He also notes that *Alnus* reached the area in 8,300 BP, after *Betula* arrives, which seems to be the norm in other areas as well. NAP percentages are low. *Picea* and thermophilous trees are low (Craig, 1972: 53). **Zone LC-4** has similarities to **Zone LC-3** and begins around 8,300 yr BP. It is dominated by *Pinus, Betula,* and *Alnus.* Craig (1972: 54). *Pinus* values are high, between 60% and 70%, and *Pinus strobus* rapidly increases through time. Craig (1972: 54) notes that *Picea* declines during this period and is nearly absent. There is an increase in NAP mainly *Gamineae*, *Ambrosia* and *Chenopodium*-type with a peak in *pteridium* spores around 7000 BP. Craig (1972: 54) notes an increase in prairie vegetation from region blowing into the site.

Zone LC-5 dates to about 6,500 BP. *Pinus* was very important peaking at around 70% while *Picea* (nearly absent) had declined likely a dry climate. *Pinus* had reached its maximum in this zone and *Picea* had reached a minimum (Craig, 1972: 54). **Zone LC-6** shows an increase *Picea* and *Thuja* around 3,000 BP and a decline in pine. The change in vegetation suggests more precipitation as *Picea marinna* prefers more moist conditions and *Thuja* prefers swampy areas. *Alnus crispa* is higher here than previous levels and tends to grow along slopes above lakes. All three pollen types indicate cooler, moister conditions.

2.2.4 Itasca Transect

A comprehensive analysis of postglacial vegetation of the Itasca State Park in northern Minnesota (figure 2.1) was undertaken by John McAndrews (1966) involving eleven ponds in a transect referred to as the Itasca transect. He chose this area in the Itasca State park because it contained the greatest diversity of landforms and plant communities. It contains Pine-Hardwood Forest, Mesic Deciduous forest, Oak Savanna habitats, and Prairie vegetation (McAndrews, 1966). The ponds chosen in this transect are as follows; Martin Pond, Cindy Pond, Bog D Pond,

Bog A Pond, Bad Medicine Pond, McCraney Pond, Reichow Pond, Terhell Pond, Horse Pond, Faith Pond, and Thompson Pond.

In the Itasca transect, there is an early vegetation assemblage that has no modern analogues. Occurring around 12,000 yr BP, a Boreal Forest type vegetation was present. McAndrews (1966) notes that *Picea* was the dominant tree at that time especially in the lower part of the spectrum. Other arboreal pollen (AP) types include *Populus, Larix, Juniperus/Thuja, Fraxinus, Ulmus,* and *Betula.* This is similar to present day boreal forest vegetation except that pine is missing. The high *Populus* values, McAndrews notes (1966: 56) are not matched in modern vegetation zones even in areas dominated by *Populus* today. McAndrews (1966: 56) discusses two plausible explanations: 1) That *Populus* was overwhelmingly abundant in the areas; or 2) that special conditions existed that allowed high concentrations of the pollen to preserve. The non-arboreal pollen (NAP) is less than 15% in most samples and therefore does not play a large role at this time (McAndrews, 1966: 56). McAndrews (1966: 56) also notes the presence of *Artemsia* and other shrub pollen present suggests open patches in the forest likely on well-drained soils.

The *Pinus banksiana/ resinosa – Pteridium* assemblage zone occurs around 11,000 yr BP. As the warming trend continued, McAndrews (1966: 56) describes a prairie succession in the west and a pine-dominated (mostly *banksiana/*resinosa) forest in the east (McAndrews,1966: 56). He attributes the limited presence of *Pinus strobus* to long distance travel as opposed to it being present locally (McAndrews, 1966: 56). *Picea, Larix, Betula, Ulmus,* and *Abies* are also present in significant quantities. Although this zone has no true modern analogues in the area, McAndrews (1966: 57) compares it to *Pinus strobus* assemblages. He interprets the *Pinus* pollen

as that belonging to *Pinus banksiana* for the most part as it ranges northward in of the Pine-Hardwood forest and throughout the Boreal Forest.

The warmer and drier climate continued until 8,500 yr BP when Oak Savanna replaced the pine forest. The Oak Savanna also replaced some of the prairie on the crest of the Big Stone Moraine about this time (McAndrews, 1966: 60). The *Ambrosia* peak zone occurs shortly after 8,000 and 7,000 yr BP (60% at Thompson Pond and 35% at Terhell Pond) marking a maximum temperature and aridity resulting in erosion of pond margins at Thompson Pond during droughts (McAndrews, 1966: 60). Increased herb pollen is evident in northeastern Minnesota (Fries, 1962) and low lake levels occurred in east-central Minnesota (Cushing, 1963).

Around 4,000 yr BP, mesic deciduous forest succeeded the Oak Savanna on the crest both the Itasca and Big Stone Moraines (McAndrews, 1966: 62). McAndrews (1966: 62) describes the zone as an invasion of deciduous trees onto the prairie and oak-savannah diminishing shade intolerant prairie species. It was about this time that *Tilia* first entered the area, although it may have been present in the surrounding region (Cushing, 1963; Wright et al., 1964).

Beginning about 2,700 yr BP, pine trees begin appearing on the Itasca Moraine forming the Pine-Hardwood forest by 2,000 yr BP (McAndrews, 1966: 63). Previous pollen studies (McAndrews, 1959; Cushing 1963) show that pine was present within 80 miles southeast of the transect for several thousand years. It is believed that the invasion and subsequent dominance of pine on the Itasca Moraine is attributed to lower summer temperatures and shorter summer growing season with an increase in winter snowfall.

2.2.5 Hayes Lake

Hayes Lake is located in Ontario near the Minnesota border just southeast of Kenora (figure 2.1) McAndrews (1982: 43) divided the core into three main zones and four subzones. **Zone 1** is a varved clay section and dominated by herbed pollen indicating a tundra environment (McAndrews, 1982: 43). **Zone 2** begins around 11,900 ^{14}C yr BP. As Lake Agassiz retreated northwards, enabling terrestrial plant colonization, first with herbs, and later replaced by spruce dominated assemblage indicating a warming trend (McAndrews,1982: 43). McAndrews (1982: 43) also noted that the spruce forest was relatively diverse with the presence of larch, birch, poplar and elm. **Zone 3** is dominated by jack/red pine and birch around 10,000 ^{14}C yr BP at the contact between zones 2 and 3. This signals the beginning of the Holocene (McAndrews, 1982: 43). This zone is further subdivided into four subzones. **Subzone 3a** has low alder and herbs (3a/3b 9,200 ^{14}C yr BP). Between **Subzones** 3b and 3c, at roughly 6,400 ^{14}C yr BP, McAndrews notes an increase in herb pollen and a decrease in spruce pollen. **Subzone 3d** (3,600 ^{14}C yr BP) has high spruce, fir and larch pollen and low poplar and herbs.

2.3 Ontario Sites

2.3.1 Clay Belt

Three lakes were studied by Liu (1990) in Ontario's Clay Belt that stretch between the Boreal Forest and the Great Lakes-St. Lawrence forest (Ritchie, 1987); Lake Nina, Jack Lake, and Lake Six. This study was chosen because multiple lakes are discussed. They all include a detailed vegetation chronology using multi-proxy analysis (e.g. pollen and macrofossils), have multiple radiocarbon dates, and are situated along the boreal forest and Great Lakes – St. Lawrence forest boundary. A summary of the overall vegetation changes along the Clay Belt (figure 2.2) is discussed below:

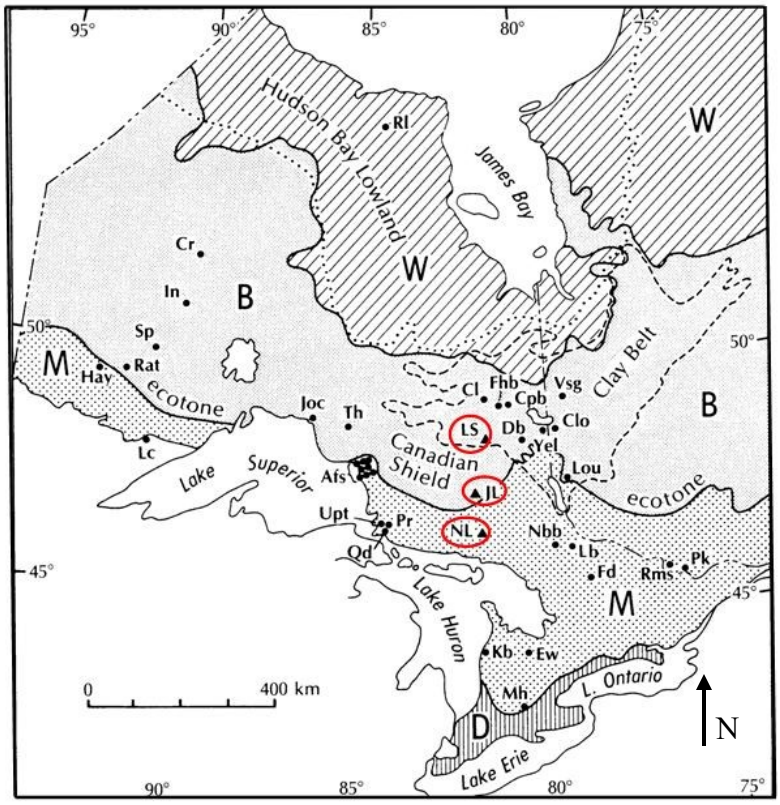

Figure 2.2 Map of the Clay belt (from Liu, 1990). Circles indicate the lakes used in his study.

In the early Holocene, around 10,000 yr BP, *Picea glauca* was dominant while very little *Picea mariana* was present (Liu, 1990: 184). *Quercus*, *Ulmus*, and *Populus* along with heliophytic (plants attracted to sunlight) herbs and shrubs were likely more abundant then their modern counterparts (Liu, 1990: 205, 206). Liu (1990: 205) hypothesized that the newly deglaciated soil may have been more nutrient rich or more basic and perhaps loamy in texture providing an ideal substrate for *Picea glauca* to thrive initially (Ritchie 1959; Terasmae and Matthews, 1980). By roughly 8,500 yr BP, the climate began to warm, and *Pinus* begins to outcompete *Picea* in the boreal forest, which later transformed into the Great Lakes – St. Lawrence forest around 7,400 yr BP (Liu, 1990; 206).

Pinus strobus continued to spread north constrained only by the Clay Belt (Liu, 1990: 207). Between 6,000 to 4,500 yr BP, *Thuja* also spread northward, favoring the Clay Belt and its

calcareous soils and wetland habitats (Liu, 1990: 208). As the climate began to cool again, *Thuja* decreased along with most of the *Pinus strobus*. The environment stabilized to modern conditions by 2,600 yr BP (Liu, 1990: 205).

2.3.2 Rattle Lake

The Rattle Lake pollen sequence was divided into five zones with three subzones. **Zone R1** is the earliest ice-free period beginning between 11,400 BP -11,100 ^{14}C yr BP. This zone is characterized by pioneer vegetation composed of *Compositae*, *Fraxinus*, *Chenopodium*, and *Ulmus*. Bjork (1985: 855) notes high influx values of *Fraxinus* indicating it grew locally or nearby. He suggests that local vegetation was not entirely tundra. *Fraxinus* may have migrated into the area from southeastern Minnesota at 13,000 ^{14}C yr BP and around 12,000 ^{14}C yr BP southwest of Lake Superior (Cushing, 1967) at a rate of about 300 m per year. One explanation is that islands may have provided suitable niches or refugia for *Fraxinus* to colonize (Bjork, 1985:55; Crawford, 2013). It is also likely that a portion of the pollen may have come from long distance transport from meltwater surface runoff (Bjork, 1985:55; Yu and Wright Jr., 2001). It is noted that when the glaciogenic influences decreased, so did the pollen influx values from extra-regional sources (Bjork, 1985: 855). The vegetation may have been composed of a tundra-park ecology with scattered tree stands. **Zone R2** begins around 11,100 to 10,200 ^{14}C yr BP and is dominated by *Salix, Cyperaceae, Gramineae, Compositae,* and *Picea* in the pollen assemblage (Bjork, 1985: 856). Low pollen and influx levels combined with a change in the lithostratigraphy from clay gyttja to clay indicates a climatic deterioration severe enough to cause *Fraxinus and Ulmus* to disappear but was not enough to wipe out the *Picea* population (Bjork, 1985:856). The deterioration was likely due to the Younger Dryas cooling event, which occurred around the same time (Yu and Wright Jr., 2001). **Zone R3** begins around 10,200 to

9,900 ^{14}C yr BP. The dominant vegetation during this period is *Betula, Ulmus,* and *Picea*. A transition occurs in the vegetation from park-tundra to the formation of the boreal forest where *Betula* dominates. *Ulmus* was present or nearby and *Picea* was beginning to dominate. **Zone R4** lasted from 9900 to 8600 ^{14}C yr BP. The pollen assemblage is composed of *Picea, Cupressaceae, Larix, Populus,* and *Ulmus. Picea* now dominates the forest with *Larix,* and *Populus*. *Pinus* pollen is not significant at this point and more likely present in the surrounding area (Bjork, 1985: 857).

Zone R5 lasts from 8600 to 5900 ^{14}C yr BP and is dominated by *Pinus* and *Betula* pollen (Bjork, 1985: 857). This zone is divided into 3 subzones. **Subzone 5a** dates to between 8600 and 7900 ^{14}C yr BP. This subzone is dominated by *Pinus*, which may be a reflection of over-representation. Spruce (particularly *Picea glauca*) would have been restricted to low-lying, moist areas (Bjork, 1985: 858). **Subzone 5b** occurs between 7900 and 6400 ^{14}C yr BP. *Pinus, Betula, Alnus, Compositae, Quercus, Juniperus* characterize this subzone. Three new species appear here, *Pinus strobus, Alnus crispa,* and *A. rugosa* (Bjork, 1985: 858). At the same time the drier and warmer climate allowed the prairie to expand east into Minnesota peaking around 7200 ^{14}C yr BP. The warmer, drier climate (8000 – 7500 ^{14}C yr BP) also seemed to favor other species like *Fraxinus, Quercus,* and *Ulmus* and may have caused a rapid expansion of *Pinus strobus* around Rattle Lake (Bjork, 1985: 858). As in Northern Minnesota, Bjork (1985: 858) also notes an increase in *Compositae* and *Chenopodiaceae* as prairie conditions approached Rattle Lake. As the climate cooled, about 1000 yrs later, the *Pinus strobus* pollen values begins to drop along with *Ambosia* and *Chenopodiaceae* pollen (Bjork, 1985: 858). **Subzone 5c** is a *Pinus, Betula,* and *Alnus* subzone occurring from 6400 to 5900 ^{14}C yr BP. Bjork (1985: 858) considers this a post-prairie period. *Ambrosia and Chenopodium* become less frequent along

with *Pinus*, *Juniperus* and *Quercus*. *Ostrya - Carpinus* pollen increase and is typical for post-prairie vegetation found in similar cases in eastern and northeastern Minnesota (Bjork, 1985: 858).

2.3.3 Sioux Pond

Bjork (1985: 860) analyzed 32 levels identifying three zones and four subzones. **Zone SP1** dates to 10,100 - 9,900 ^{14}C yr BP. This zone is characterized by *Compositae, Ulmus, Juniperus, Cyperaceae, Picea,* and *Salix*. The pollen composition indicates a tundra-like vegetation that is similar to Rattle Lake, with stands of *Picea* and *Ulmus* (Bjork, 1985: 860). Any migration rate differences Bjork (1985: 861) attributes to differences in landscape formations and less to do with climate. **Zone SP2** dates between 9,900 - 9,500 ^{14}C yr BP and is composed of *Picea, Larix, Compositae,* and *Betula.* Boreal forest elements start to appear in the area prior to 9,500 ^{14}C yr BP. Bjork (1985: 861) describes how the pollen sequence shows that *Betula* and *Larix* were present just before *Picea.* Herbs are also present indicating that they likely occupied exposed and inhospitable islands in glacial Lake Agassiz. **Zone SP3** encompasses the period between 9500 - 3500 BP dominated by high values of *Pinus* and *Betula.* This zone is also subdivided into four sub-zones (Bjork, 1985: 861).

Subzone SP3a occurs between 9500 - 9200 ^{14}C yr BP, dominated by *Pinus, Betula, Corylus,* and *Picea.* Bjork notes this subzone represents a transition from a late glacial-type environment to pine dominated boreal forest. **Subzone SP3b** dates to 9200 - 8300 ^{14}C BP, dominated by *Pinus, Betula, Alnus,* and *Picea,* boreal forest vegetation. Subzone SP3a and SP3b indicate that aquatic vegetation was present. **Subzone SP3c** occurs between 8300 - 7000 ^{14}C yr BP, characterized by *Pinus, Betula, Fraxinus, Juniperus,* and *Compositae.* The dominant pollen is *Pinus* and *Betula* (Bjork, 1985: 862). Due to the increase in juniper and ash pollen it

was likely warmer and drier at this time. An increase in herbaceous pollen also indicates that this was also the time of prairie expansion (Bjork, 1985: 862). **Subzone SP3d** is *Pinus* and *Abies* dominated dating from 7000 – 3500 ^{14}C yr BP. The pollen values show that the vegetation was dominated by balsam fir (Bjork, 1985: 862). High concentration of Pine pollen indicate that white pine was common in the area. White spruce becomes more dominate over time as pine decreases becoming as common as *Picea glauca* (Bjork, 1985: 862).

2.3.4 Indian Lake

Indian Lake is located within the southwestern part of Central Plateau area of the Boreal Forest region. Black spruce dominates the area around the lake and jack pine can be found on well-drained soil with some larch interspersed (Bjork, 1985: 862). Bjork divided the core into three pollen assemblages and the uppermost zone subdivided into three.

Zone I1 begins around 9300 - 9200 ^{14}C yr BP and is dominated by *Compositae*, *Pinus, Cyperaceae, Salix,* and *Larix*. Open vegetation was replaced early by boreal forest. Strandline diagrams from Teller and Thorleifson (1983) show Indian Lake was quickly raised above Lake Agassiz after deglaciation, creating a continuous landmass allowing for rapid migration of boreal forest (Bjork, 1985: 862). **Zone I2** begins about 9200 - 8800 ^{14}C yr BP. *Picea, Larix, Compositae, Chenopodiaceae* are important in this zone. A spruce and larch dominated forest was first to arrive in newly deglaciated areas similar to Rattle Lake and Sioux Pond, lasting about 400 years. Herbs were also common indicating areas of open land (Bjork, 1985: 862).

Zone I3 begins around 8800 - 6100 ^{14}C yr BP and is divided into three subzones: a, b, and c. **Subzone I3a** lasts until about 7400 ^{14}C yr BP and is dominated by *Pinus, Betula, Alnus,* and *Abies.* Spruce and larch were partially replaced by fir and birch as the forest became more diversified. Pine and aspen and alder were present (Bjork, 1985: 863). **Subzone I3b lasts**

between 7400 - 6500 ^{14}C yr BP, dominated by *Pinus, Betula,* and *Compositae.* White pine reached 10% of the total pollen assemblage around 7000 ^{14}C yr BP. The evidence suggests that white pine arrived at Sioux Pond and Indian Lake at the same time indicating two migration routes. This subzone also coincides with the maximum of prairie expansion farther southwest (Bjork, 1985: 863). **Subzone I3c** is short lasting from 6500 to 6100 ^{14}C yr BP. *Pinus* begins as the dominant pollen but gradually decreases along with *Betula. Picea* may have been favored by climate change, marked by decrease prairie pollen influx. *Picea mariana* became the dominate spruce species as less than one third of the spruce pollen is *Picea glauca (Bjork, 1985: 863)*.

2.3.5 Cristal Lake

Cristal Lake is about 2 km^2 and lies in the southeastern part of the northern coniferous area of the boreal forest region (Rowe, 1972). Black spruce dominates the forest around Cristal Lake. The core has been divided into two zones (C1 and C2) with three subzones (C2a, C2b, and C2c) (Bjork, 1985: 863). **Zone C1** is dated between 7000 – 6900 ^{14}C yr BP. This zone is dominated by *Picea, Compositae, Salix, Cyperaceae,* and *Cupressaceae.* The presence of *Ambrosia* is relatively high and could represent a distant source possibly from Rattle Lake, Sioux Pond, or Indian Lake. With the melting ice, the local soil was likely too unstable to support tree growth. The forest would have remained open creating a late glacial environment despite warmer conditions (Bjork, 1985: 863). Macrofossil finds of *Larix, Picea, Salix, Ranunculaceae* (buttercup), and *Cyperaceae* support an interpretation of very open forest with elements of shrubs and herbs present.

Zone C2 dates between 6900 to 6000 ^{14}C yr. BP. This zone was divided into three subzones. **Subzone C2a** lasted from 6900 to 6600 ^{14}C yr BP. *Pinus, Betula,* and *Alnus* pollen dominated this section. Bjork (1985: 863) describes a short phase dominated by spruce then

replaced pine and birch. White spruce, tamarack, and balsam fir were also common. **Subzone C2b** dates from 6600 - 6200 ^{14}C yr BP and is primarily dominated by *Pinus, Picea, Betula, Alnus,* and *Abies*. *Pinus strobus* pollen peaks during this period. Bjork (1985: 863) describes dry, sandy areas like those on the Agutua Moraine as good places for white pine to grow. The maximum influx for *Pinus strobus* is reached slightly after the corresponding maximum at Indian Lake. The brief presence of *Pinus strobus* at Cristal Lake suggests that it could not have migrated much farther north (Bjork, 1985: 863). **Subzone C2c** spans from 6200 - 6000 yr BP. *Pinus, Betula, Picea,* and *Alnus* dominate this period. During this period jack/red pine and white birch increase as white pine decrease and black spruce gradually replaces white pine. White spruce increases during this time up to 30% as black spruce remains the same at 13% to present. This demonstrates considerable change in the boreal forest since the end of the climate optimum (Bjork, 1985: 863).

2.3.6 Experimental Lake Area (ELA) Lake 239

Lake 239 from the ELA is a well dated lake located in northwestern Ontario near the current parkland-forest. **Zone C** 11,600 - 8600 cal yr BP documents an initial post glacial assemblage. Spruce dominated forest with ambrosia and other deciduous trees are in low abundance. The forest transitions to pine dominated and remains that way to present (Moos and Cumming, 2011: 1236). **Zone B** dates from 8600 - 4500 cal yr BP. *Picea* decreases, *Cupressaceae* and *Ambrosia* increase indicating a more open forest. *Pinus* decreases from over 80% to around 50% and then increases again. The temperature increases 1-2 ºC higher than the modern average. Precipitation increases as well more during the summer season than the winter (Moos and Cumming, 2011: 1236). Temp. are the highest during the mid-Holocene. **Zone A** 4500 cal yr BP - present *Pinus* remains the dominant taxa. *Picea* increases indicating a return to

closed canopy forest supported by decrease in herbaceous pollen. The temperature decreases as well as the precipitation but not as low as during the post-deglaciation period.

2.4 Summary of the Holocene Vegetative Sequence

2.4.1 Early Holocene

The early Holocene begins sometime after 12,000 cal yr BP when the LIS started to retreat from northern Minnesota and northwestern Ontario (Cushing, 1963; McAndrews, 1966; 1982; Bjork, 1985). In many areas, tundra-like vegetation was the first to colonize (Fries, 1962; Craig, 1972; Bjork, 1985). This is suggested by the presence of *Artemisia*, an indicator of a dry environment, and *Gramineae*, which can be an indicator of open vegetation (Webb III and McAndrews, 1976). The presence of *Ambrosia* is significant because it is a pioneering species, one of the first to move into a new or recently disturbed area (Fries, 1962; Craig, 1972).

Bjork's (1985) assessment of the re-vegetation of Northwestern Ontario indicates tundra vegetation in the earliest ice-free period at Rattle Lake around 11,400 yr BP. In the Itasca State Park, McAndrews (1966) notes vegetation assemblages that do not share modern analogues. For example, a boreal forest-type of environment existed first, dominated by pioneering taxa such as *Picea* and *Populus* (McAndrews, 1966). McAndrews (1966) suggests that, with a period of rapid warming, ice blocks became isolated, buried and slowly melted, allowing for a boreal-type forest to migrate into the area as opposed to the typical tundra-like environment normally associated with the retreat of glaciers.

In Northwestern Ontario, the pioneering vegetation is mostly herb-dominated tundra consisting of grasses and sedges (McAndrews, 1982; Bjork, 1985; Moos and Cumming; 2011). As the LIS continued to retreat north, the tundra-like vegetation migrates north as well as seen at Rattle Lake, between 11,400 – 11,100 ^{14}C yr BP, and Sioux Pond between 10,100 to 9,900 ^{14}C yr

BP. Spruce dominated forest replaces the tundra vegetation for the rest of the early Holocene (McAndrews, 1982; Bjork, 1985; Moos and Cumming, 2011).

In northern Minnesota, a succession of prairie vegetation occurred in the northwestern part of Minnesota and a pine forest dominated forest occupied areas to the east (McAndrews, 1966). At about 8,500 ^{14}C yr BP, oak savannah replaced the pine forest. Spruce and pine continue to populate more northern areas, another indication of warmer conditions (Craig, 1972). At Hayes Lake, the tundra environment is replaced by spruce dominated forest around 11,900 cal yr BP (McAndrews, 1982) and continues northward (Bjork, 1985).

On the Canadian Shield, the postglacial boreal forest on the upland is dominated by white spruce and almost no black spruce (Liu, 1990). Liu (1990) hypothesizes that the abundance of white spruce was due to the abundance of fresh water and un-leached postglacial soil. Further north, a tundra environment existed until 11,400 ^{14}C yr BP at Rattle Lake with spruce moving in at 11,100 ^{14}C BP. As the ice sheet continued to retreat north there is evidence of a tundra landscape mixed with stands of sprue and elm (Bjork, 1985).

At Gegoka Lake between 10,200 and 9000 ^{14}C yr BP, arboreal pollen increases as pine moves in and spruce starts to decline (Huber, 1995). Herbaceous pollen, like *Artemisia, Cyperaceae, Ambrosia-type,* and *Gramineae* start declining as well and continue to decline until the beginning of the mid-Holocene (Fries, 1962; Craig, 1972; Huber, 1995). In northwestern Ontario, a similar decline in tundra vegetation also occurs. At Rattle Lake, the tundra begins to decline, and the boreal forest begins to form (Bjork, 1985). At around 9500 ^{14}C yr BP the boreal forest replaced the tundra.

2.4.2 Middle Holocene

In northwestern Minnesota, the presence of oak increases and becomes more important in the area during the middle Holocene, (Fries, 1962; McAndrews, 1966). Temperatures reach a maximum during the Middle Holocene as indicated by the *Ambrosia* peak zone (McAndrews, 1966). The climate became warmer and drier resulting in increased herb pollen in general with a decrease in lake levels within the Itasca Park and also observed at Stevens Pond, Webber Lake (Fries, 1962; McAndrews, 1966; Janssen, 1967). The *Ambrosia* peak is also noted at Gegoka Lake with a general increase in herb pollen (Huber, 1995). At Lake of the Clouds (Craig, 1972) and Hayes Lake around ~6,400 ^{14}C (McAndrews, 1982) an increase of herb pollen and decreased white spruce indicates drier conditions. At Lake St. Croix, the *Ambrosia* peak is smaller and occurs slightly later likely due to cooler conditions in the valley (Eyster-Smith et al., 1991). Pine becomes the most dominant arboreal pollen (Craig, 1972; Watts, 1972) and the warm trend is marked by an increase in herbaceous pollen.

In northwestern Ontario, the warm trend is marked by the proliferation of white cedar in Ontario's Clay Belt. In Lui's study (1990), he discusses how the lowered water levels allowed cedar to spread in the area when it was otherwise limited to swamp and peatland. The Clay Belt provided a unique calcareous substrate favorable for cedar with the warmer climate (Liu, 1990). White pine expands into Rattle Lake as the presence of *Compositae* and *Chenopodiaceae* pollen increased. The shift in vegetation suggests prairie conditions were moving east and north as well (Bjork, 1985).

2.4.3 Late Holocene

During the Late Holocene conditions become moister as mesic deciduous forest succeed oak savanna in northern Minnesota (McAndrews, 1966). *Tilia* first enters the local area around

this time (McAndrews, 1995), although it may have been present in the surrounding region earlier (Cushing, 1963; Wright et al., 1964). Other mesic forest elements such as ash, alder, and elm reach a maximum around 4000 ^{14}C yr BP before they start to decline (McAndrews, 1966; Janssen, 1967; Huber, 1995; Flakne, 2003).

Pine trees appear in northwestern Minnesota sometime after 3000 ^{14}C yr BP creating a pine-hardwood forest by 2000 ^{14}C yr BP (McAndrews, 1966). A similar event occurs at Lake St. Croix slightly earlier, at about 3500 ^{14}C yr BP (Eyster et al., 1991). This vegetation change is attributed to a climate shift to cooler and shorter summers and increased winter snowfall (McAndrews, 1966).

In Ontario, the cooling effect increases the amount of spruce pollen along with fir, larch (Bjork, 1985; Liu, 1990; McAndrews, 1982) and pine (Liu, 1990; Moss and Cumming, 2011) and prairie vegetation decreases (Bjork, 1985; McAndrews, 1982), such as *Cupressaceae* and *Ambrosia* (Moos and Cumming, 2011). The ecotone changes to the modern boreal forest (Ritchie, 1987) and stabilizes at Lake 239 around ~4500 cal yr BP (Moos and Cumming, 2011). At around 3,500 BP, the ecotone changes to the modern boreal forest (Ritchie, 1987) and stabilizes at Lake Six after 3,000 ^{14}C yr. BP and at Jack Lake around 2,600 BP.

CHAPTER 3. HISTORY OF WILD RICE IN NORTH AMERICA

3.1 Modern Ecology of Wild Rice

Three types of wild rice grow in North America: northern wild rice (*Zizania palustris*), southern wild rice (*Zizania aquatica*), and Texas wild rice (*Zizania texana*) (Horne and Kahn, 2000). Figure 3.1 shows an approximate distribution of modern wild rice. As can be seen, southern wild rice is restricted to eastern Ontario, Quebec and the East Coast. Northern wild rice occurs in the temperate and boreal forest climates around the Great Lakes area and as far west as northern Alberta. *Zizania texana* is less widespread growing only in Texas. Although, researchers know where wild rice currently grows, there very little known about its distribution before European contact.

Northern wild rice prefers to grow in flooded soils, shallow lakes, along quiet river margins, and in inlets and outlets with soft organic bottoms (Macins, 1969; Oelke, 1993; Quayyum, 1995). It grows to about 60 cm to 70 cm (roughly 2.0 ft) tall (Oelke, 1993) and prefers water depths between 30 cm and 60 cm (1.0-2.0 ft) (Aiken et al., 1988) and can be as deep as 1.0 m (3.0 ft). Water depths should not fluctuate more than 15 to 30 cm (0.5 – 1.0 ft) below 30 cm (1.0 ft) or above 1.0 m (3.0 ft). Water depths too shallow will cause the plant to become too weak and easily uprooted and depths too deep will decrease the amount of required sunlight to reach the plant to allow photosynthesis to occur (Aiken et al., 1988) and cause them to drown (Thomas and Stewart, 1969; Quayyum, 1995). High precipitation in the winter leading to high spring runoff that tapers off with a gradual decrease in precipitation throughout the summer offers the best growing conditions (Macins, 1969).

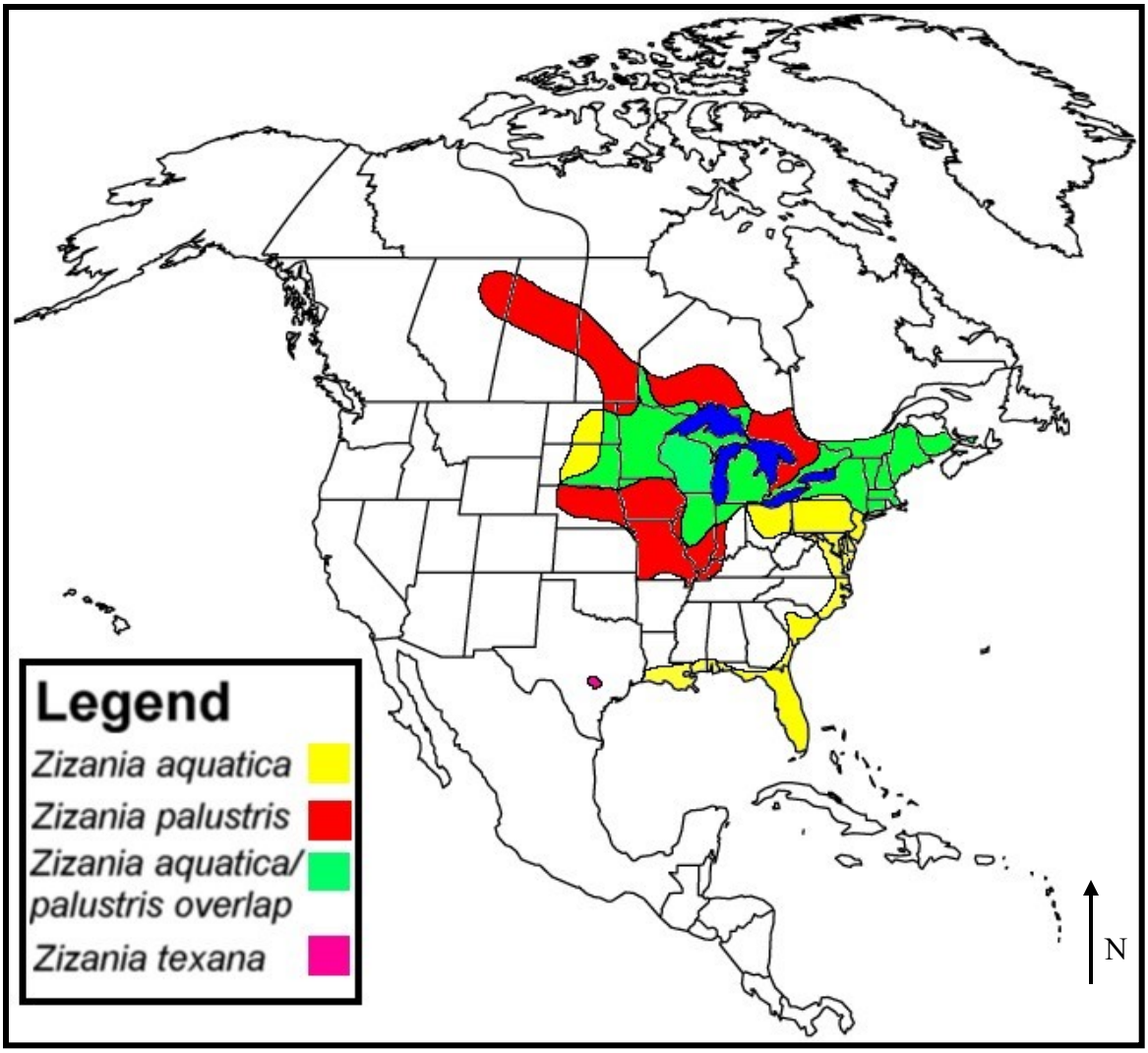

Figure 3.1 Modern distribution of wild rice (*Zizania* spp.) in North America (after Archibold et al., 1985; Barkworth, 2007; modified by Surette, 2008).

Wild rice also requires an adequate supply of oxygen, which explains the importance of water flowing through wild rice stands (Aiken et al., 1988). The dissolved gases in the water are important during the submerged stages of wild rice growth. For example, Lee and Stewart (1981) noted that lakes with high eutrophication showed a reduction in available carbon dioxide available thereby limiting the production of wild rice.

The mature seeds of northern wild rice have an after ripening period in water at freezing or near freezing temperatures of about 3ºC. Once temperatures reach about 7ºC in the spring, the

seeds will then germinate. These attributes make wild rice well adapted to northern latitudes (Aiken et al., 1988; Oelke, 1993).

Northern wild rice is intolerant of shade and is a poor competitor with several aquatic shoreline plants (Quayyum, 1995). Emergent species such as cattail (*Typha latifolia*), big bulrush (*Scirpus acutus*) and horsetail (*Equisetum fluviatile*) tend to start their spring growth before wild rice reaches the water's surface first and having a well-established network of roots and stems with shoots at regular intervals (Aiken et al., 1988).

Floating-leaf plants, like the water lilies (*Nymphaea spp.* and *Nuphar spp.*), the watershield (*Brasenia spp.*), and the bur reed (*Sparganium spp.*), also pose a problem for wild rice as they start to grow in the spring before wild rice crowding and reducing their leaf density (Aiken et al., 1988). Water lilies are not always a threat because they can thrive in deeper water than wild rice. However, in some cases where water levels rise to 60 cm (2 ft.), it allows these plants to become better-established preventing wild rice from growing when water levels become ideal for them (Aiken et al., 1988).

Nevertheless, one underwater perennial species, the Robbin's pondweed (*Potamogeton robinsii*), has shown to improve growing conditions for wild rice (Aitken et al., 1988; Lee, P.F. 1988; Quayyum et al., 1999). Research has shown that lakes in Northwestern Ontario containing many minerals in the soil only become habitable for wild rice after Robbin's pondweed has colonized the lake (Aiken et al., 1988; Quayyum et al., 1999). In a study by Lee (1987), it was demonstrated that wild rice stands grew better inside clumps of Robbin's pondweed with a 10-fold increase in the dry weight as opposed to those growing outside the clumps. He notes that in sections of clay rich lakes where Robbin's pondweed has colonized there is also higher levels of organic matter, phosphorus, iron, and zinc with lower values for pH, calcium, magnesium, and

potassium (Lee, 1987). Lee (1987) concluded that the lack of available phosphorus in most aquatic environments is a limiting factor for the growth of wild rice. In areas where Robbin's pondweed is established colonies the lack of available phosphorus is no longer a problem.

Several aquatic plants, like cattail, white water lily and yellow water lily, were identified in the Bull's Point core sample that prefer similar habitats to that of wild rice. The data from the core indicates that as these plants increase in frequency so does the grass pollen (Lee et al., 2004). This could mean that there is an increase in grass diversity. The varieties of plant species are also indicators of environmental changes. A decrease of the presence of cattail pollen in the core suggests an increase in water levels (Lee et al., 2004).

The identification of wild rice pollen was based on several criteria. First, Lee et al. (2004) used size and frequency to determine the presence of wild rice in the core. However, a problem occurred when the researchers compared contemporary pollen to fossil pollen. Fossil wild rice pollen from the core was smaller than modern pollen, which could cause under representation in the record due to false identification. To compensate, the micromorphology of the pollen was identified using the SEM allowing them to distinguish wild rice from other grass pollen (Lee et al., 2004).

Another study compared data from two lake cores taken from Lake Ogechie (Yost and Blinnikov, 2007). In this study, the pollen data taken from an earlier core was compared to the phytolith data analyzed in a second core taken from the same lake. What Yost and Blinnikov (2007) noticed was that as the grass pollen (known as *Poaceae* or *Graminae*) increased in McAndrews' pollen data so did the frequency in wild rice phytoliths (figure 3.2). However, the two graphs are not a perfect match. Although the amount of wild rice phytoliths increases in the same layer as the pollen the overall content of phytoliths decreases. This discrepancy has no

definitive answer. The differences could be due to a change in plant densities in the lake. At present, it is assumed that phytoliths are deposited where the plants die, which could mean that the variety of grasses may have increased in the area around the lake and densities may have decreased in the lake. The study demonstrates that both proxies can give similar data and work well in conjunction with each other.

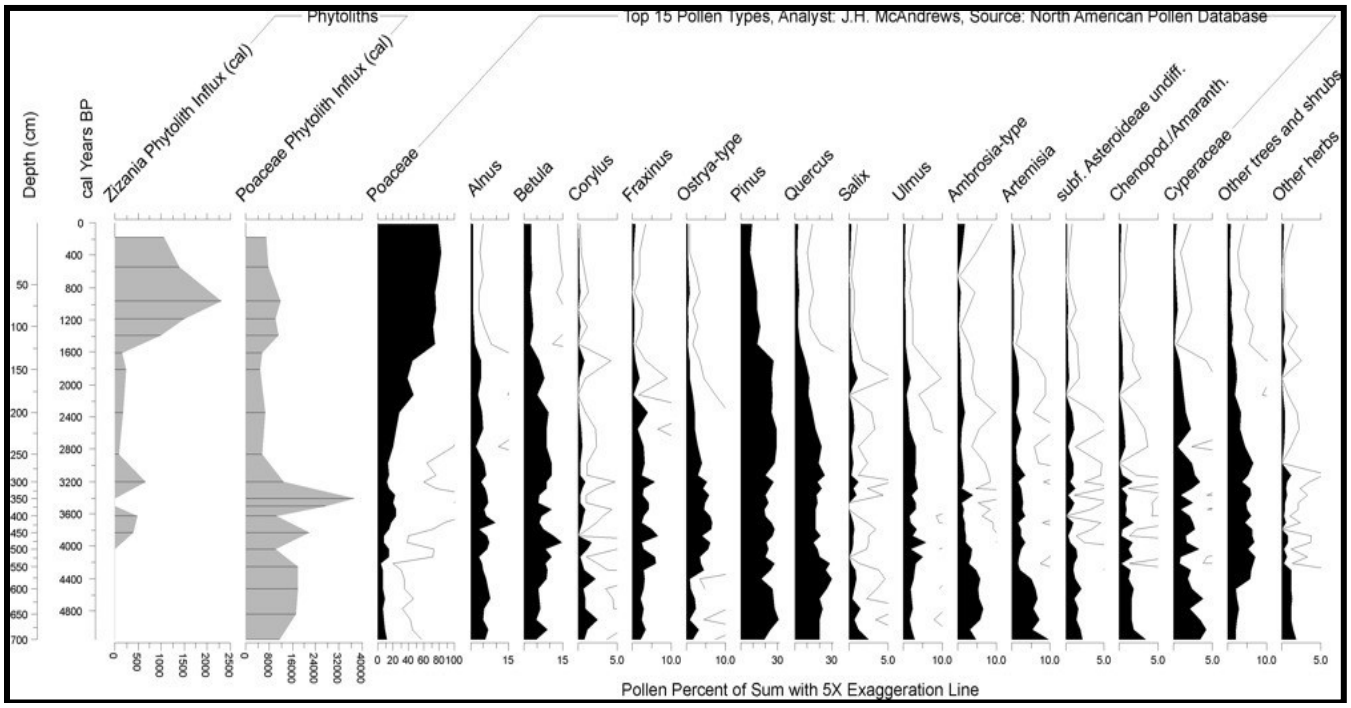

Figure 3.2 Wild Rice Phytolith Data graphed with Pollen Data from McAndrews for Lake Ogechie, Mille Lacs Kathio State Park, MN. (from Yost, 2007, figure 54 pp. 135).

An older study conducted by McAndrews (1969) was concerned with trying to differentiate wild rice pollen from other grass pollen in Rice Lake and Fox Pond. Figure 3.3 shows a sharp increase in the abundance of grass pollen in the *Ambrosia* and *Pinus* dominated zone. To identify wild rice pollen, he compared modern wild rice pollen to fossil pollen and determined that most of wild rice pollen fell into a size range between 25 – 32 µ. Another proxy McAndrews (1969) used was the seed content in the core. What he found was that wild rice seeds were only found in the *Ambrosia* and *Pinus* layer, the same layer the wild rice pollen was

found. By analyzing the seeds, McAndrews (1969) noticed that the younger seeds were larger in size compared to the older seeds. A radiocarbon date was taken at this level and an uncalibrated year of 2450 ± 100 ^{14}C yr BP marks the first colonization or at least the proliferation of wild rice (McAndrews, 1969).

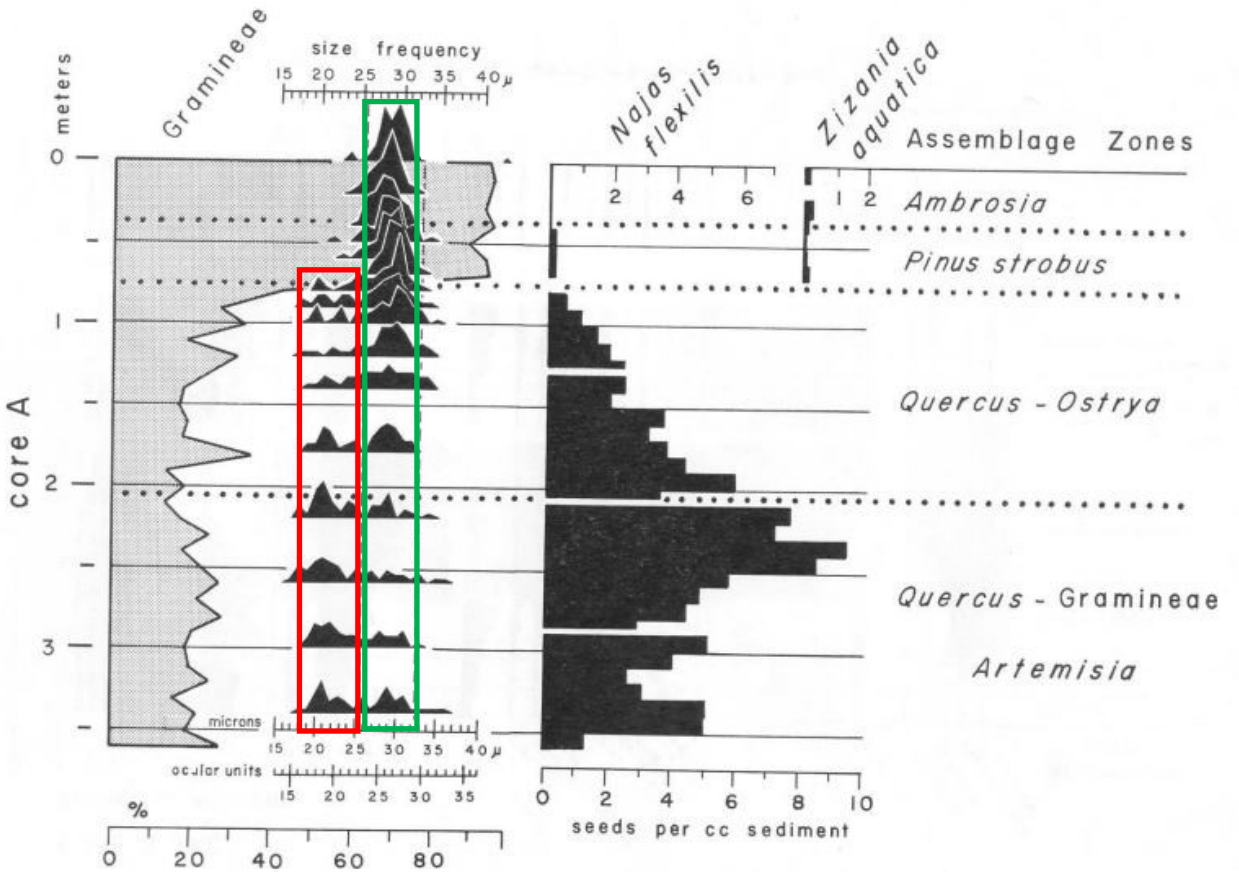

Figure 3.3 Size, distribution, and frequency of fossil wild rice pollen compared to fossil seeds (taken from McAndrews, 1969: pp 1674). Red rectangle represents smaller fossil wild rice pollen. Green rectangle represents modern size range of wild rice pollen.

3.2 Previous Evidence of Wild Rice in the Archaeological Record

There are several lines evidence available to determine the presence of wild rice at archaeological although many of them have limited information. Macrofossil remains are among the most useful and indisputable pieces of evidence archaeologists and ecologists can use. Macrofossils are identifiable plant remains usually consisting of seeds, cones, needles, leave, etc.

Microfossils such as pollen and phytoliths are also useful for reconstructing paleo-diets and paleoenvironments. Pollen grains are produced during specific stages of a plants life cycle (during the flowering stage) and therefore may not always be produced if the plant does not reach maturity. However, phytoliths form during all stages of the plants life (Hart et al., 2003). The direct archaeological evidence that suggest wild rice consumption mainly consists of threshing pits and charred grains. Although evidence of wild rice consumption exists, it is difficult to pinpoint the time it arrived in an area based on archaeological information alone.

The bulk of archaeological sites known to contain macrobotanicle evidence of wild rice are found in the United States (Johnson, 1969a; Moffat and Arzigian, 2000; Arzigian, 2000; Ford and Brose, 2003). These sites are important because they help archaeologists place a timeline on wild rice consumption. Many archaeological sites date to the Middle Woodland period and the Late Woodland with a few as early as late Archaic (figure 3.2, table 1). These periods are based on pottery styles and tool types that have been described and dated and assigned cultural affiliations. Sites that do not have dates assigned to them can be dated based on their cultural affiliations (Johnson, 1969a; Arzigian, 2000). However, cultural affiliation can only give a time frame in which a site was occupied based on the type of artifacts found and many types have tinges spanning 500 – 1000 years. In some cases, it is possible to narrow the time span using stylistic characteristics allowing these cultural affiliations to be suitable for estimating dates when no other absolute dating methods are available.

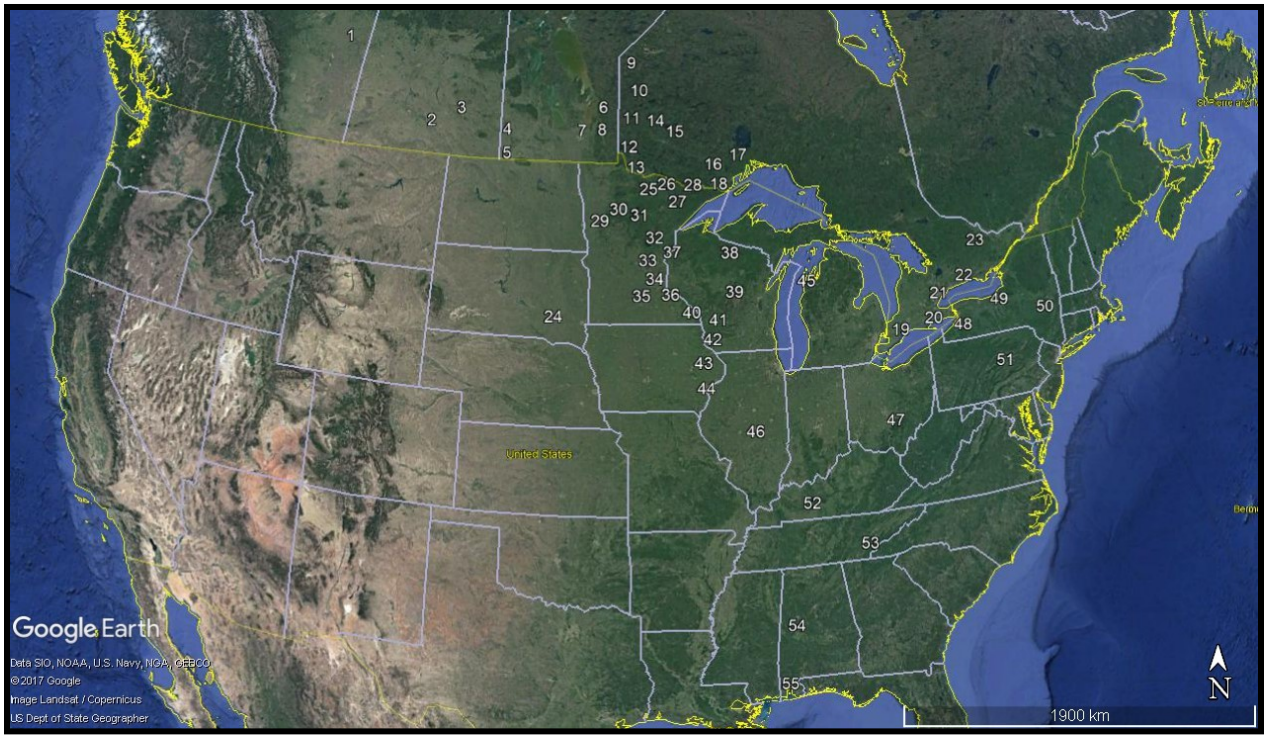

Figure 3.4 Map showing archaeological sites containing evidence of Wild Rice. Key can be found in Table 1.

Table 1. Key to figure 3.2 listing sites in map

	Site	Location	Affiliated Period/Tradition/Culture	Wild Rice Evidence	Citation
1	FfOt-9	Alberta	Grinding Stone	Phytoliths	Surette, 2017
2	Garratt (EcNj-7)	Saskatchewan	Avonlea	Phytoliths	Lints, 2012
2	Avonlea (EaNg-1)	Saskatchewan	Avonlea	Phytoliths	Lints, 2012
3	Lebret (EeMw-25)	Saskatchewan	Avonlea	Phytoliths	Lints, 2012
4	Miniota (EaMg-12)	Manitoba	Avonlea	Phytoliths	Lints, 2012
5	Duthie (DiMe-16)	Manitoba	Northeastern Plains Village	Phytoliths	Boyd and Surette, 2010
5	Snyder II (DgMg-15)	Manitoba	Late Plains Woodland	Phytoliths	Boyd and Surette, 2010
5	Elliot Village (DgMg-52)	Manitoba	Late Plains Woodland	Phytoliths	Boyd and Surette, 2010
5	Brockington Occupation II (DhMg-7)	Manitoba	Bird Lake	Phytoliths	Boyd and Surette, 2010
5	Brockington Occupation III (DhMg-7)	Manitoba	Plains Woodland/Williams Complex	Phytoliths	Boyd and Surette, 2010
6	Wanipigow (EhLb)	Manitoba	Late Woodland	Ricing Pit, Seed	Boyd and Surette, 2010
6	C-5B (EfKv-6)	Manitoba	Winnipeg River Phase	Phytoliths	Boyd and Surette, 2010
6	LM-6 (EfKv-37)	Manitoba	Winnipeg River Phase	Phytoliths	Boyd and Surette, 2010
7	Wright EaLg-9)	Manitoba	Blackduck	Phytoliths	Boyd and Surette, 2010
7	Healing (EbLf-29)	Manitoba	Late Precontact	Phytoliths	Boyd and Surette, 2010
8	Portage du Bonnet (EcKx-13)	Manitoba	Blackduck	Phytoliths	Boyd and Surette, 2010
8	Whitemouth Falls (EaLa-1)	Manitoba	Late Woodland	Phytoliths	Boyd and Surette, 2010
8	Porth (EaLa-2)	Manitoba	Sandy Lake	Phytoliths	Boyd and Surette, 2010
8	1915 (EaKx-16)	Manitoba	Late Woodland	Phytoliths	Boyd and Surette, 2010
8	Anderson II (EbKw-30)	Manitoba	Rainy River Phase	Phytoliths	Boyd and Surette, 2010
9	FdKo-2	Ontario	Feature Soil	Phytoliths	Boyd and Surette, 2010
10	Kirkness KA6 (EjKl-4)	Ontario	Late Woodland	Phytoliths	Boyd and Surette, 2010

11	Rowdy Lake (EdKo-6)	Ontario	Blackduck	Phytoliths	Boyd and Surette, 2010
12	Fisk (DlKp-1)	Ontario	Laurel, Bird River, Selkirk	Phytoliths, Seed	Boyd and Surette, 2010
12	Ballinacree (DkKp-8)	Ontario	Selkirk, Laurel	Phytoliths	Boyd and Surette, 2010
12	Ballinamore (DkKp-9)	Ontario	Selkirk	Phytoliths	Boyd and Surette, 2010
12	Ballysadare (DkKp-10)	Ontario	Late Woodland	Phytoliths	Boyd and Surette, 2010
12	Bundoran (DjKn-5)	Ontario	Laurel, Blackduck	Phytoliths	Boyd and Surette, 2010
12	Meek (DjKp-3)	Ontario	Blackduck	Phytoliths	Boyd and Surette, 2010
12	Spruce Point (DjKq-1)	Ontario	Sandy Lake, Selkirk	Phytoliths	Boyd and Surette, 2010
12	Ash Rapids East (DjKq-4)	Ontario	Blackduck, Selkirk, Sandy Lake	Phytoliths	Boyd and Surette, 2010
13	Long Sault (DdKm-1)	Ontario	Blackduck	Phytoliths	Boyd and Surette, 2010
13	River Road (DeKq-1)	Ontario	Late Woodland	Phytoliths	Boyd and Surette, 2010
13	Nestor Falls (DgKl-3)	Ontario	Blackduck	Phytoliths	Boyd and Surette, 2010
14	EcKf-6	Ontario	Late Woodland	Phytoliths	Boyd and Surette, 2010
14	EcKf-8	Ontario	Selkirk	Phytoliths	Boyd and Surette, 2010
14	EcKg-1	Ontario	Selkirk	Phytoliths	Boyd and Surette, 2010
14	Wenasaga Rapids (EdKh-1)	Ontario	Bird River	Phytoliths	Boyd and Surette, 2010
15	DlKb-5	Ontario	Blackduck	Phytoliths	Boyd and Surette, 2010
15	EaKb-13	Ontario	Blackduck	Phytoliths	Boyd and Surette, 2010
15	Sand Spit (EbKb)	Ontario	Laurel, Blackduck	Phytoliths	Boyd and Surette, 2010
15	Vermillion River (EcJw-1)	Ontario	Laurel	Phytoliths	Boyd and Surette, 2010
15	Two Point Sand Bar (EcKc-4)	Ontario	Sandy Lake	Phytoliths	Boyd and Surette, 2010
16	Cressman (DfJn-1)	Ontario	Laurel	Phytoliths	Boyd and Surette, 2010
17	Duffield Bay (DhJf-6)	Ontario	Laurel	Phytoliths	Boyd and Surette, 2010

18	Mound Island (DbJl-2)	Ontario	Woodland	Phytoliths	Boyd and Surette, 2010
18	MacCluskey (DbJm-2)	Ontario	Blackduck	Phytoliths	Boyd and Surette, 2010
18	Macgillivray (DbJm-3)	Ontario	Laurel	Ricing Jig, Phytoliths	Dawson, 1980, Boyd and Surette, 2010
18	Martin Bird (DbJm-5)	Ontario	Blackduck, Laurel	Storage Pits, Phytoliths	Wright, 1995
19	Kelly	Ontario	Early Ontario Iroquois	Seed	Ounjian, 1998
20	Grand Banks (AfGx-3)	Ontario	Princess Point	Seed	Saunders, 2002
21	Parsons (AkGv-8)	Ontario	Late Ontario Iroquois	Seed	Monckton, 1998
21	Seed-Barker (AkGv-1)	Ontario	Late Ontario Iroquois	Seed	Crawford, 1985
22	McIntyre	Ontario	Late Archaic	Ricing Jig	Johnston, 1984
23	Highland Lake	Ontario	Late Woodland	Seed	von Gernet, 1992
24	Mitchell	South Dakota	Middle Missouri	Seed	Benn, 1974
25	Nett Lake	Minnesota	Blackduck	Seed	Johnson, 1969b
26	Big Rice	Minnesota	Laurel	Seed, Phytoliths	Burchill, 2014; Valppu, 1989; Valppu and Rapp, 2000
27	Windy Bead	Minnesota	Soil, Stone Tool	Phytoliths	Burchill, 2014
27	No Beard	Minnesota	Grinding Stone	Phytoliths	Burchill, 2014
28	Saga Island	Minnesota	Laurel	Phytoliths	Burchill, 2014
29	Lower Rice Lake	Minnesota	Late Woodland	Ricing Jig	Bakken, 2006; Johnson, 1969a
29	Mitchel Dam	Minnesota	Late Woodland (Blackduck, Sandy Lake)	Ricing Jig	Johnson, 1969a
29	Upper Rice Lake	Minnesota	Late Woodland	Ricing Jig, Processing Camp	Johnson, 1969a
30	Lost Lake	Minnesota	Middle Woodland	Phytoliths	Burchill, 2014
30	Cass Lake I	Minnesota	Middle Woodland	Seed, Phytoliths	Kluth and Thomspon, 1995
30	Scott	Minnesota	Late Woodland (Blackduck)	Parching Container, Ricing Jig	Cooper and Johnson, 1964; Johnson, 1969a
31	Ogema-Geshik	Minnesota	Brainerd	Phytoliths	Thompson et al., 1994
32	Aquipaguetin Island	Minnesota	Late Woodland	Ricing Jig	Johnson, 1969a
32	Petaga Point	Minnesota	Late Woodland-Early Historic	Ricing Jig, Parching Ring, Seed	Bleed, 1969; Johnson, 1969a, 1969b
32	Cooper Village	Minnesota	Late Prehistoric (Oneota)	Seed	Johnson, 1985; Lucking, 1973; Schaaf, 1979

32	Vineland Bay	Minnesota	Late Prehistoric-Early Historic	Ricing Jig	Johnson, 1985
32	Wilford	Minnesota	Late Prehistoric	Seed, Ricing Jig	Schaaf, 1979, 1981
32	Ricing Site	Minnesota	Woodland	Storage and Ricing Pits	Rothaus, 2001
33	21AN106	Minnesota	Middle Woodland	Phytoliths	Forsberg and Dobbs, 1997
34	Sawmill Sites	Minnesota	Historic	Ricing jig	Johnson, 1969a
35	Old Shakopee Bridge	Minnesota	Middle-Late Woodland	Seed, Ricing Jig	Gibbon, 1976
36	Bartron	Minnesota	Oneota	Seed	Gibbon, 1979
36	Bryan	Minnesota	Oneota	Seed	Zalucha, 1987
37	XY Company	Wisconsin	Historic	Seed	Oerichbauer, 1982
38	Fishers Island	Wisconsin	Late Woodland	Seed	Moffat and Arzigian, 2000
38	Ghost Shirt Island V	Wisconsin	Late Woodland	Seed	Moffat and Arzigian, 2000
38	Robinson	Wisconsin	Late Woodland	Seed	Moffat and Arzigian, 2000
39	Sanders	Wisconsin	Effigy Mound	Seed	Crawford and Hurley, 1982
40	Filler	Wisconsin	Protohistoric	Seed	Hunter, 1990
40	Olson	Wisconsin	Oneota	Seed	Hunter, 1990
40	Overhead	Wisconsin	Oneota	Seed	Arzigian et al., 1990
40	Pammel Creek	Wisconsin	Oneota	Seed	Arzigian, 1989, Arzigian et al., 1989
40	Sand Lake	Wisconsin	Oneota?	Seed	Hunter, 1990
40	Tremaine	Wisconsin	Oneota	Seed	Hunter, 1990
40	Valley View	Wisconsin	Late Prehistoric	Seed	Stevenson, 1985
41	Hunter Channel (47Cr312a)	Wisconsin	Millville phase - Middle Woodland	Seed	Arzigian, 1987
41	Hunter Channel (Cr312c)	Wisconsin	Millville phase - Middle Woodland	Seed	Arzigian, 1987
41	Hunter Channel (Cr313a)	Wisconsin	Millville phase - Middle Woodland	Seed	Arzigian, 1987
41	Hunter Channel (Cr313b)	Wisconsin	Millville phase - Middle Woodland	Seed	Arzigian, 1987
41	Mill Coulee Shell Heap	Wisconsin	Millville phase - Middle Woodland	Seed	Arzigian, 2000
41	Mill Pond	Wisconsin	Middle - Late Woodland	Ricing Jig	Arzigian, 2000
42	Brogley Rockshelter	Wisconsin	Woodland	Seed	Tiffany, 1974
43	Hadfields Cave	Iowa	Middle Woodland	Seed	Benn, 1980
44	Sand Run Slough	Iowa	Late Archaic-Middle Woodland	Seed	Lopinot, 1987
45	Dunn's Farm	Michigan	Late Archaic-Early Woodland	Seed	Ford and Brose, 1975

45	Schultz	Michigan	Middle-Late Woodland	Seed	Lovis et al., 2001
46	Scovill	Illinois	Middle Woodland	Seed	Munson et al., 1971
47	Kettle Hill Cave	Ohio	N/A	Seed	Goslin, 1952
48	Simmons	New York	Archaic-Early Woodland	Phytoliths	Hart et al., 2007
49	Hunter's Home	New York	Archaic-Early Woodland	Phytoliths	Hart et al., 2003, 2007
49	Kipp Island	New York	Archaic-Early Woodland	Phytoliths	Hart et al., 2003, 2007
49	Wickham	New York	Archaic-Early Woodland	Phytoliths	Hart et al., 2003, 2007
50	Parslow Field	New York	Archaic-Early Woodland	Seed	Asch Sidell, 2000
51	Catawissa	Pennsylvania	Late Woodland	Seed	King, 1999
51	Memorial Park	Pennsylvania	Late Woodland	Seed	Hart and Asch Sidell, 1996
52	Carlston Annis	Kentucky	Late Archaic	Seed	Crawford, 1982
53	Bacon Bend	Tennessee	Late Archaic	Seed	Chapman and Shea, 1981
53	Chota	Tennessee	Historic	Seed	Chapman and Shea, 1981
53	Iddins	Tennessee	Late Archaic	Seed	Chapman and Shea, 1981
54	Moundville	Alabama	Mississippian	Seed	Scarry, 2003
55	Bottle Creek	Alabama	Mississippian	Seed	Scarry, 1995

3.2.1 Archaeological Evidence of Wild Rice in the upper U.S.

In the upper United States, evidence of wild rice consumption appears early in the archaeological record. At the Dunn Farm Site in Michigan (figure 3.2, table 1), Ford and Brose (2003) found remains of charred wild rice grains associated with a cremation burial. Based on the feature and other artifacts recovered from the site date as far back the late Middle Period (Archaic) or Early Woodland (about 400 B.C. to about 600 B.C.) (Hart et al., 2003). Several other Middle Period sites in Tennessee, Kentucky, New York, Michigan, and Iowa are Middle Period sites with evidence of wild rice (Chapman and Shea, 1981; Crawford, 1982; Asch Sidell, 2000; Hart et al., 2003; Hart et al., 2007; Ford and Brose 1975; Lopinot, 1987). In Ontario, there is at least one late Middle Period site, the McIntyre site, with a ricing jig feature (Johnston, 1984) and likely others that have not been discovered yet.

Other slightly younger sites that contain wild rice can be found in, Wisconsin, Minnesota and South Dakota (figure 3.2, table 1). A fragment of a wild rice seed found at the Parslow Field

site in the Schoharie River valley (New York) was sent away for AMS dating and returned with a date of 2386 $\pm$ 48 ^{14}C B.P. (Hart et al., 2003). The date establishes a minimum date for when wild rice was consumed in the region but it cannot tell us specifically how early it first entered the area. The phytolith data extracted from carbonized residues confirm that wild rice was consumed in the area with maize (Hart et al., 2003). This study dates the presence of wild rice in the area and confirms its importance to aboriginal diets. It also draws a connection between wild rice consumption and maize horticulture (Hart et al., 2003).

In Wisconsin (figure 3.2, table 1) at Prairie du Chien, wild rice seeds were recovered using intensive flotation. Radiocarbon dates were applied to the seeds dating them to A.D. 784 – 1227 (Moffat and Arzigian, 2000). Although wild rice appears earlier in some sites (i.e. Dunn Farm site in Michigan), archaeologists believe it may be the cause of population expansions during the Late Woodland period (Johnson, 1969a; Lofstrom, 1987). At Prairie du Chien several features were found (i.e. hearth and storage/roasting pits) strongly indicating spring and summer use. Artifacts and shell middens associated with Middle Woodland cultures were discovered dating the wild rice beds to at least A.D. 100-200 (Arzigian, 2000). Several sites in the Mississippi River headwaters region also show evidence of wild rice consumption (Johnson, 1969a). At Gull Lake Dam, phytolith analysis was useful for a variety of purposes. Phytoliths found in the pottery indicate that wild rice was consumed at the time the pottery was discarded (Thompson et al., 1994). The pottery sherds recovered have a net impressed style that is classified as Brainerd Ware placing the site occupation at approximately A.D. 300 (Johnson, 1969a). The site has indications of older occupations but the one of importance in this study is the Brainerd Ware occupation where the wild rice phytoliths were found.

The evidence found at the majority of these sites, such as Scott Site, Shakopee Bridge Site, Lower Rice Site, and Big Rice Site) consists of mainly features, like ricing jigs and storage/cooking pits (Johnson, 1969a; Gibbon, 1976; Rajnovich, 1984; Moffat and Arzigian, 2000; Arzigian, 2000). At some sites, Shakopee Bridge Site and Big Rice Site, multiple lines of evidence suggested wild rice consumption. At these sites archaeologists recovered rice grains along with ricing jigs (Johnson 1969; Gibbon, 1976). At the Big Rice site phytolith evidence has also been recovered (Burchill 2014). At other sites (Shea Site and Ogema-Geshik), phytoliths have indicated wild rice consumption (Toom, 2004; Thompson et al., 1994). The Shea Site has evidence of Sandy Lake Ware, which gives the wild rice in the area an approximate age of A.D. 1000 possibly older (Toom, 2004). Brainerd Ware was recovered from the Ogema-Geshik putting a date of about 700-800 B.C. (Thompson et al., 1994; Moffat and Arzigian, 2000).

Studies by Benn (1974) at the Mitchell Site in South Dakota, seeds were analyzed to try to determine the kinds of diets aboriginals occupying the site had. The author determined that wild rice was gathered occasionally. Through association of other archaeological remains, which were not mentioned in this particular study, archaeologists are able to infer that by at least A.D. 850 – 1250 wild rice had established itself in the area (Benn, 1974).

3.2.2 Archaeological Evidence of Wild Rice in Northern Ontario

In Ontario, there is a growing number of sites containing evidence of wild rice. In Northern Ontario, several sites including Wenasaga Rapids, Nestor Falls, Rowdy Lake, Balincree, the Meek site, the Ballinamore site and most of the sites around Whitefish Lake, are some examples of site containing phytolith evidence of wild rice and a few seeds (figure 3.2, table 1) (Boyd and Surette, 2010; Surette, 2008).

In southern Ontario at Cootes Paradise is a Princess Point Site with a long occupation from about 5000 to 350 yrs BP. No direct evidence was found at the site, but it rests in close proximity to wild rice stands growing in the area (Lee et al., 2004). The material evidence recovered from the site is relevant to the transition to crop cultivation, between 1000 and 2000 yrs BP (Lee et al., 2004). The only evidence to support the argument that the inhabitants at Cootes Paradise could have consumed wild rice comes from a core sample taken from Bull's Point (Lee et al., 2004). During the analysis of the core, evidence of wild rice pollen was discovered using an SEM (Scanning Electron Microscope) microscope.

CHAPTER 4: LATE HOLOCENE ARCHAEOLOGY IN NORTHWESTERN ONTARIO

4.1 Introduction

The current archaeological culture-historical framework for Northwestern Ontario is typically discussed using three broad precontact divisions, known as the Early (ca. 9,000-7,000 BP), Middle (ca. 7,000-2,000 BP), and Late (ca. 2,200-750 BP) periods (Korejbo, 2011; Mantey and Pettipas, 1996; Playford, 2015; Taylor-Hollings, 2017). These names update the terminology used previously by archaeologists such as Paleoindian (ca. 7,000-2,000 BP), Shield Archaic (ca. 7,000-2,000 BP), Initial Woodland (now Middle Woodland) and Terminal Woodland (now Late Woodland), which have negative connotations for many descendent populations of indigenous Canadians who find these terms inappropriate. Following the Late Period, Europeans began to arrive in Northwestern Ontario at various locations during the fur trade or Protocontact Period. In order to provide context for this project in the broader scheme of Canadian archaeological research, this chapter presents a brief discussion of the culture history of Northwestern Ontario and archaeology of Whitefish Lake, focusing on the Late Period (Middle and Late Woodland) that is most relevant to this study.

This chapter will give a brief discussion of the archaeology of northwestern Ontario, focusing on the Late Period (Middle and Late Woodland) and the importance of wild rice as a food source. Many archaeological sites in northwestern Ontario are found beside or near modern wild rice (*Zizania palustris*) stands (Johnson, 1969a; Arzigian, 2000). It was believed that wild rice was an important prehistoric staple because many sites occur near wild rice stands despite the fact that little direct evidence of its consumption exists (Arzigian, 2000; Johnson, 1969a; Rajnovich, 1984; Valppu and Rapp, 2000) but the importance of its use before European arrival is relatively unknown (Johnson, 1969a; Rajnovich, 1984). However, microfossil research on carbonized residues found on pottery has provided new information on the paleodiets of

prehistoric populations and new evidence supporting wild rice consumption at many Lake of the Woods sites in northwestern Ontario (Boyd and Surette, 2010; Boyd et al., 2013; Surette 2008). It remains difficult to determine if wild rice was traded into areas, or if it was already established when prehistoric people arrived.

4.2 The Early Period (ca. 9,000-7,000 BP)

In Northwestern Ontario, the Early Period is characterized by archaeological sites that were occupied after the retreat of glacial ice and subsequent. These locations usually represent small groups of hunter-gatherers who subsisted mainly on caribou and large game with the most characteristic artifact type being Plano Type lanceolate spear points and other lithics manufactured from local materials (Ross 1995). Although there is currently no evidence known for this period at Whitefish Lake, there are nearby archaeological sites from this time frame in the region. The Thunder Bay area is a well-known locality for Early Period research and sites. Old Tower Road Site (DbJm-6), Billings Bridge (DbJm-32), the Cummins site (DcJi-1) and the Mackenzie Site (DdJf-9) are some examples of Early Period paleo found within the Thunder Bay area (Dawson, 1983; McCulloch, 2015; Schweitzer, 2014), so it is likely that the Whitefish Lake area was also occupied during that time.

4.3 The Middle Period (ca. 7,000-2,000 BP)

Although encompassing the longest amount of time, the Middle Period is probably the least understood time frame in Northwestern Ontario archaeology. There is a lack of information, which may have led researchers to believe there are very few sites or misinterpreting some of them. Based on tool technology it is believed that Middle Period cultures likely relied on big game hunting. They likely exploited seasonally available plants as well. Currently, this period is not well represented in the immediate Whitefish Lake area.

However, it is likely that this location was occupied during the Middle Period since nearby locations in the Thunder Bay region have been identified (e.g., Hinshelwood, 2004).

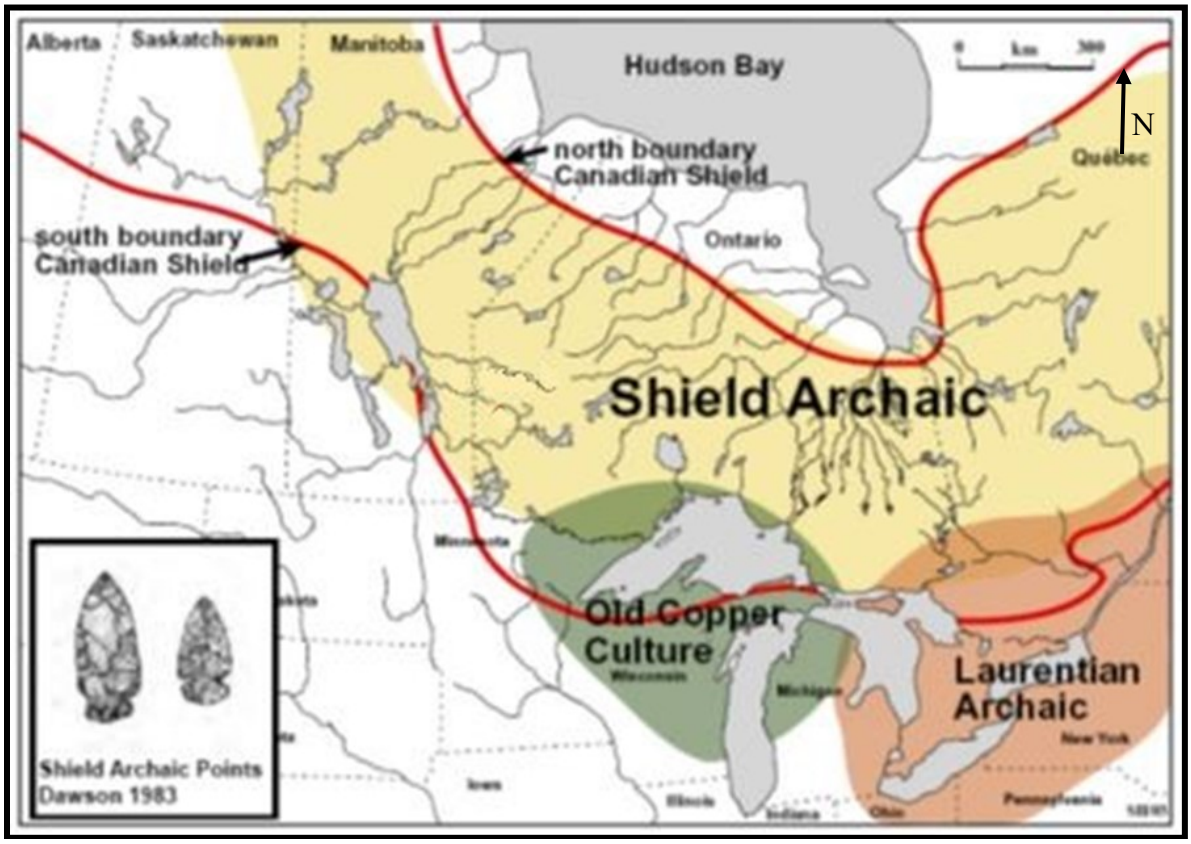

Figure 4.1 A general distribution of Middle Period culture in northwestern Ontario and surrounding areas (from Hamilton, 2007).

4.4 Late Period: Middle Woodland (ca. 2,200-750 BP)

In Northwestern Ontario, the Laurel Configuration (Reid and Rajnovich 1991) is the most common and earliest dated Middle Woodland culture (Figure 1), which is well established in the archaeological record across the area (Taylor-Hollings, 2017; Wright, 1967). Early Woodland wares have not been positively identified in northwestern Ontario but have been noted in southern Ontario and nearby northern Minnesota (Taylor-Hollings, 2017). Woodland occupations are distinguished from the Middle Period by the invention of pottery. Middle Woodland vessels are much finer in construction than the Early Woodland wares (Rapp Jr. et al.,

1995), which tend to have very thick walls and simple bowl shapes. Stylistic characteristics of Middle Woodland vessels (Figure 1) include conoidal to subconoidal shapes, smooth surface finishes, straight or slightly flared rims, flat or pointed lips, and relatively thick walls (Meyer and Hamilton, 1994). Pots are decorated with various stamped and dragged impressions along with punctates and bosses, while others are completely plain (Anfinson, 1979; Mason, 1981; Meyer and Hamilton, 1994; Rapp Jr. et al., 1995; Taylor-Hollings, 2017).

In Northwestern Ontario, Laurel is the earliest Woodland culture to establish itself in the area (Wright, 1967; Taylor-Hollings, 2017). However, evidence of Brainerd ware has recently been discovered at Whitefish Lake (Dr. Jill Taylor-Hollings personal communication) (Boyd, 2010). As for the Late Woodland period, Sandy Lake and Blackduck are found in the study area and overlap with then Plains Woodland cultures to the west (Johnson and Johnson, 1998). Selkirk sites are mostly located in the Boreal Forest ecotone and the Great Lakes-St. Lawrence forest in northern Minnesota (Wright, 1967). In northwestern Ontario, southern types of pottery such as Huron/Iroquois been found suggesting trade or perhaps a larger movement of Woodland people from the south and the east congregating in areas like Whitefish Lake, where food is abundant, for large social or ceremonial events (Dawson, 1978). In Northwestern Ontario during the Middle Woodland Period, site frequency and size tend to increase from the previous period, which may be due to biases in recovery methods (wet screening versus dry screening and screen size) and ease of access to these sites as compared to earlier ones. There is also the question of site preservation. Older sites tend to not be preserved as well and therefore evidence of diet is more likely to be lost. If there truly is an increase in site density and size, the trend might be due to climate amelioration leading to increased plant based food that could lead to increased population size especially during the Late Woodland Period (Syms, 1977). Dawson (1983)

suggests an increase in the number of seasonal villages during the Late Period and that they are typically found where natural floral communities are currently abundant. There seems to be a shift during the Late Period Woodland from previously diverse foraging strategies to more focused subsistence patterns. These changes are suggested from evidence of larger gatherings and longer seasonal settlements during the warm seasons, taking advantage of local food sources like several fish species and wild rice (Fritz et al., 1993; Scarry and Yarnell, 2011). Settling areas for longer periods would have led to larger settlements and in some areas, may have lead to horticulture and further development of wild rice stands.

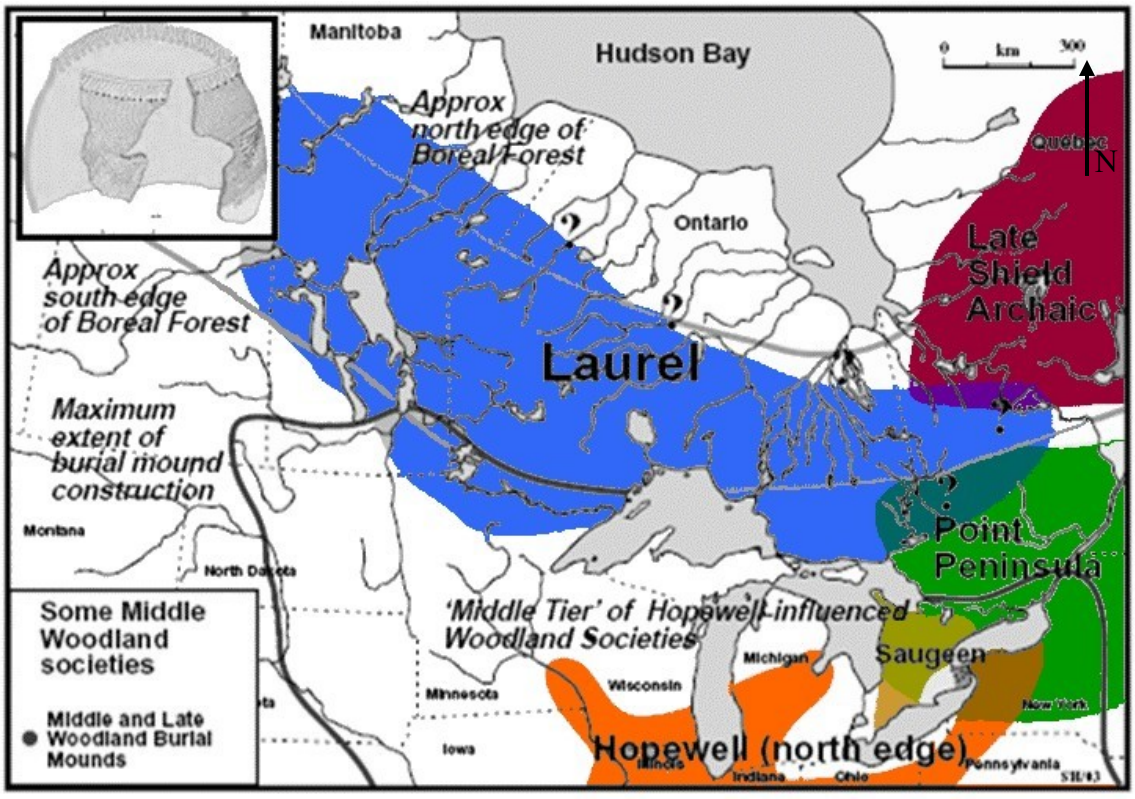

Figure 4.2 General distribution of Laurel and other Middle Woodland cultures (from Hamilton, 2007). In the upper left-hand corner is an example of a partially completed Laurel pot.

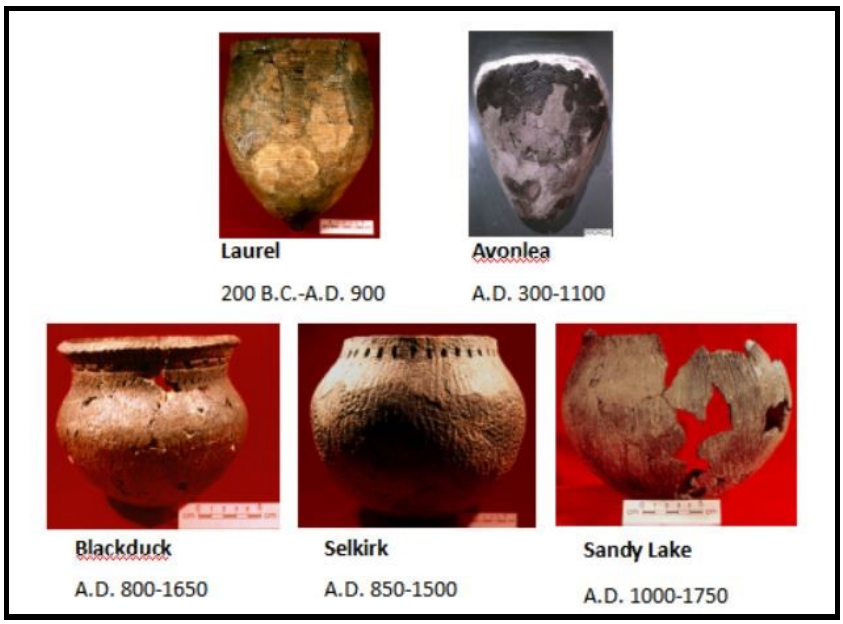

Figure 4.3 Examples of various Woodland pottery wares (Picture from: Canadian Museum of History "GATHER AROUND THIS POT"
http://www.historymuseum.ca/cmc/exhibitions/archeo/ceramiq/cerart2e.shtml

Many archaeological sites in Northwestern Ontario, including the ones at Whitefish Lake, are found beside or near modern wild rice (*Zizania palustris*) stands (Arzigian, 2000; Johnson, 1969a). It is believed that wild rice was an important precontact staple, despite the fact that little direct evidence of its consumption exists (Arzigian, 2000; Johnson, 1969a; Rajnovich, 1984; Valppu and Rapp, 2000). However, research on microfossils found in carbonized residues from pottery has provided new information about the paleodiets of precontact populations and evidence supporting wild rice consumption at many sites in Northwestern Ontario (Boyd and Surette, 2010; Surette, 2008). Ethnographic research also indicates that many aboriginal peoples' diets had a significant reliance on wild rice (Johnson, 1969a; Rajnovich, 1984).

In Minnesota, the appearance of storage pits and large earthworks (Arzigian, 2008; Mason, 1981) are associated with the Middle Woodland Period, which the former could potentially indicate the beginnings of small-scale gardening or horticulture there (Anfinson,

1997). Rare burial mounds on the islands at Whitefish Lake (Dawson, 1978, 1987) indicate that community earthworks were taking place in this location during that period as well.

Laurel ware has been identified at the Martin-Bird (Dawson 1987), MacGillivray (Dawson 1980), and Mound Island sites (Dawson 1978) on Whitefish Lake. However, there are sherds that comprise a wide variety of types suggesting that different groups of people were present during the Middle Woodland resulting in several different occupations. Recently, a few sherds of Middle Woodland Brainerd ware of the Elk Lake Culture (Hohman-Caine and Goltz 1995) were identified at the Martin-Bird site on Whitefish Lake (Boyd et al., 2014). Some radiocarbon dates from northern Minnesota, where Brainerd is more commonly found, indicate much earlier date making it several hundred years earlier than Laurel (Hohman-Caine and Goltz 1995; Hohman-Caine et al. 2012). However, the early results (effectively putting this into the Early Woodland period) remain controversial amongst many archaeologists (Burchill, 2014).

4.5 The Late Period - Late Woodland Cultures (ca. 1250-250 BP)

The Late Woodland Period is distinguished from other time frames mostly by innovations in pottery styles and manufacturing methods, although there are also differences in projectile point and other lithics from previous periods. People made small side-notched and triangular projectile points during this time frame (Taylor-Hollings, 2017). Late Woodland pottery is usually globular in shape with constricted necks and usually fabric-impressed (a.k.a. textile impressed) surface finishes (Hamilton et al., 2007). Decoration consists of cord wrapped object impressions, punctates, bosses, and stamps in many modes and occurs mainly on the lip and neck (Meyer and Hamilton, 1994). Late Woodland occupations are found at hundreds of sites in Northwestern Ontario making it possible to outline territories that various populations occupied during this time (see Figure 4.5) (Hamilton et al., 2007).

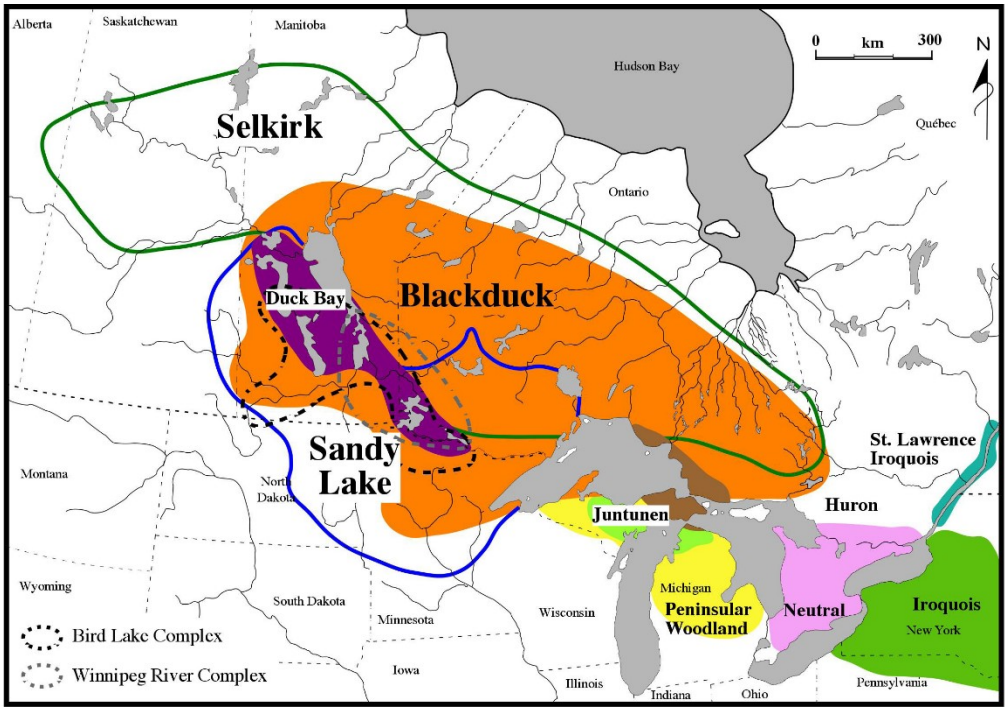

Figure 4.4 Map showing approximate distribution of Late Period: Late Woodland affiliations (from Hamilton et al., 2003:49; from Taylor-Hollings, 2017:108)

In Northwestern Ontario, there is evidence of several Late Woodland cultures that occupied the region including Blackduck Complex, Psinomani Culture (who made Sandy Lake ware), Selkirk Composite groups who created Winnipeg Fabric-impressed ware, and the Rainy River Composite (Taylor-Hollings, 2017). Late Woodland Cultures are distinguished from one another by they way their wares are produced. For example: Blackduck vessels have a rim with a pronounced flare and complex decorations (Dawson, 1983; Hamilton et al., 2007; Mason, 1981; Meyer and Hamilton, 1994), whereas Sandy Lake vessels tend to have straighter rims and limited decoration often only on the interior (Taylor-Hollings, 1999). Winnipeg Fabric-impressed vessels have a different form of surface finish, usually less flaring along the rims, and fewer decorations (Meyer and Hamilton, 1994). Rainy River Composite vessels have distinctive rim/neck flares, stamps combined with cord wrapped object impressions, and similar fabric impressed exterior to Winnipeg Fabric-impressed vessels.

There appears to be a transitional period as well where both middle Woodland and Late Woodland cultures co-existed demonstrated by transitional vessels possessing attributes belonging to the Laurel composite and Blackduck traditions. One theory is that Late Woodland Cultures, like Blackduck, are believed to have developed from the Middle Woodland Laurel composite. Another theory is that the two periods overlapped and co-existed where the Laurel composite faded away leaving Blackduck to take its place (Hyslop, 2009; Meyer et al., 2008; Taylor-Hollings, 2017; Wright, 1967).

Subsistence practices of Middle and Late Period Woodland cultures are difficult to interpret in Boreal Forest sites, usually because very little faunal and/or plant material are preserved in the acidic soils (Wright, 1995). Based on the bones that have been recovered, beaver and moose are some of the more important animals they hunted, among other large, medium and small game (Dawson, 1983; Stoltman, 1973). Very few fish bones and scales preserve long enough to be recovered. Those that have been recovered suggest that the Late Period Laurel culture consumed fish, such as whitefish, sturgeon, northern pike and others (Dawson, 1983; Wright, 1967). The belief is that fish remains tend to be associated with large spring and summer camps, and land based animal remains indicate cold season camps.

Subsistence patterns among Late Woodland sites are typically more varied because many groups tend to live in more than one ecozone (figure 4.4) (Hamilton et al., 2003; Taylor-Hollings, 2017). For instance, Blackduck and Sandy Lake sites have been found on the plains as well as in the boreal forest (Hamilton, 1982; Hamilton et al., 2007; Nicholson, 1996). At sites on the plains, the primary food resource appears to have been centered on hunting bison (Taylor-Hollings, 1999). In the boreal forest, there is a much more varied subsistence base. However, in light of the absence of tangible zooarchaeological and archaeobotanical remains archaeologists

have relied mainly on ethnographic and historical documentation to infer the breadth of their subsistence economy. Faunal remains typically include moose and caribou, along with beaver, waterfowl and fish. Many researchers (Johnson, 1969a; O'Brien and Holland, 1992; Rajnovich, 1984; Thompson et al., 1994) assume that wild rice played a role in Late Woodland diets inferred by the close proximity of several sites to modern wild rice stands. However, until recently, many Late Period sites lacked any evidence to prove wild rice was being consumed.

Chapter 5: Methodology

5.1 Introduction

This chapter will be reviewing the utility of pollen and phytolith analysis as proxies for reconstructing the paleovegetation of Whitefish Lake and the surrounding area. The advantages and limits of both forms of analysis will be discussed to demonstrate the best way each will be used in this project. Techniques and equipment used in the field to obtain the cores will be discussed along with the lab procedures for future reference especially regarding the phytolith processing as some of the procedures were developed here at Lakehead University.

5.2 Field Methods

Previous work on identifying wild rice (*Zizania palustris*) pollen grains and differentiate them from those of other grass species was based exclusively on size range (diameter) (McAndrews, 1969). However, because other grass pollen grains such as *Glyceria* spp. and *Phalaris arundinceae* can overlap in size with wild rice, this approach can potentially lead to misidentification (Huber, 2000; Lee et al., 2004). Figure 5.1 are examples of grass pollen grains and phytoliths from core WTFSH08-01. Photo A shows a lot of microrelief that is not discernible under a light microscope (photo B, figure 5.1). Furthermore, using a Scanning Electron Microscope (SEM) is very time-consuming and impractical for executing pollen counts from lake cores (Lee et al., 2004). In contrast, recent work using diagnostic phytoliths as a wild rice 'identifier' has met with considerable success (Surette, 2008; Yost, 2007). This technique is relatively quick and provides a reliable means of distinguishing this plant from other wild and domesticated grasses in sediment and food residue. Photo C (figure 5.1) is a diagnostic wild rice phytolith with features that are easily detected under the light microscope making it an ideal candidate for the identification and quantification of wild rice.

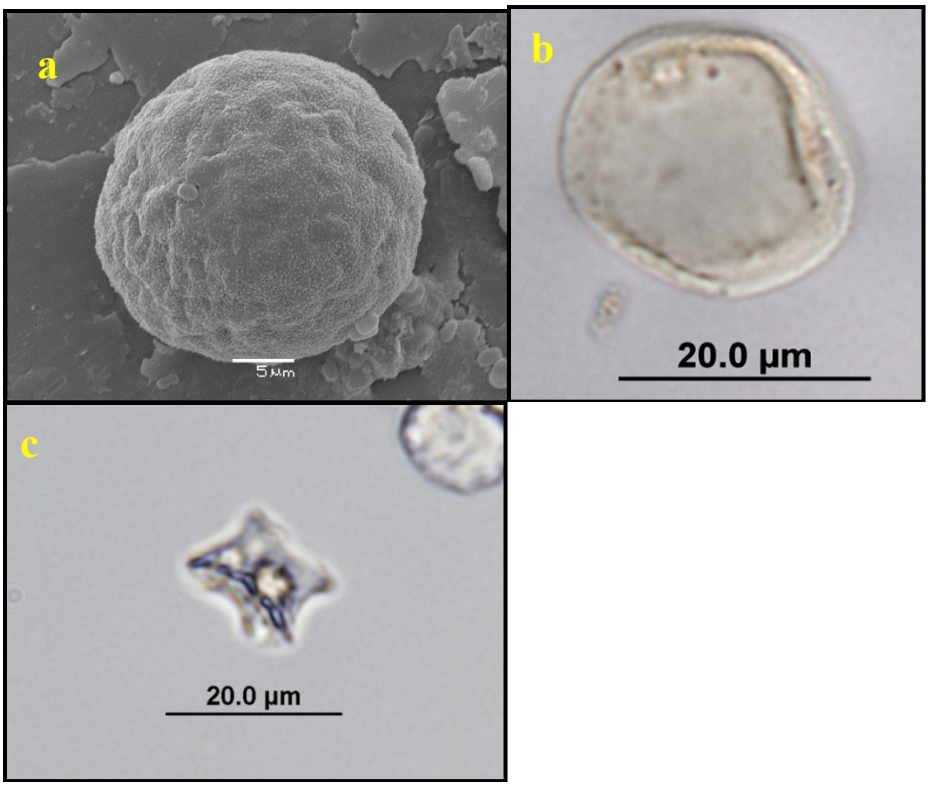

Figure 5.1 Grass pollen grains and phytolith from comparative collection and WTFSH08-01 core; a) SEM photograph of comparative Wild Rice pollen grain, b) grass pollen grain under light microscope, c) wild rice phytolith under light microscope.

In February 2008, 4.5 m of sediment was collected from Whitefish Lake using a vibracorer (Figures 5.2 & 5.3). The core was cut into three manageable sections for transportation and then stored in a freezer. To facilitate analysis the core was first thawed, and then split open (figure 5.4), photographed and described. The core was then sampled in 2 cm intervals: 3 cc taken for pollen analysis and 3 cc taken for phytolith analysis before bulk samples were taken for radiocarbon dating.

Figure 5.2 Assembling the core and adding sections of aluminum pipe.

Figure 5.3 Preparing core WTFSH08-01 for storage: photo A) cutting the long core into manageable sections; photo B) measuring and labelling core sections

Figure 5.4 Photo A) Splitting the core barrel, photo B) examining the sediments.

A short core, 1 m in length, was obtained using a Universal Corer (figure 5.5) to obtain any information potentially lost during extraction of the long core (WTFSH08-01). During the process of retrieving the long core, compaction likely occurred at the top section, thereby affecting the resolution of sedimentation. The short core was sampled at 2 cm intervals (figure 5.6) and 3 cc taken for pollen analysis and 3 cc set aside for phytolith analysis.

Figure 5.5 Universal corer used to extract the short core.

Figure 5.6 Sampling the short core, WTFSH08-02, to be sub-sampled later for pollen and phytoliths processing in the lab.

Pollen analysis was used to track regional paleovegetation changes in the Whitefish Lake watershed. However, because it is difficult to identify plants beyond the family and genus level using pollen (e.g. grasses, birch, cedar, and juniper), diagnostic rondel phytoliths (Figure 6) were used to track the presence of wild rice *(Zizania palustris)* within the lake during the Holocene.

Phytolith samples were processed following several steps: removal of clays through deflocculation; heavy liquid (sodium metatungstate) separation; acid digestion in order dissolve the organics; and, lastly, sieving through 250µm, 118µm, and 35µm mesh in order to remove as much of the diatoms as possible since they tend to dilute the samples. Pollen and phytolith samples were only collected and processed for sediments overlying the rhythmically laminated (proglacial) clay unit.

5.3 Pollen as a Proxy for Paleovegetation Analysis: Theory

Palynology is the study of palynomorphs, which are various microscopic sub-fossilized organic remains (chiefly spores and pollen grains). Palynomorphs themselves have existed since the Precambrian period but pollen grains appear later in the geological record, coinciding with the evolution of flowering plants. (Traverse, 2007). This section will review how fossilized pollen is used to reconstruct past vegetation. A brief overview of pollen analysis will be given along with the assumptions made regarding pollen grains themselves and their behaviour in different depositional deposits and how they relate to the overall vegetation of the area in question. Knowing the benefits, as well as the limits that exist in its interpretations, are important aspects in pollen analysis.

Palynology has been of interest to researchers since the 1600s (Traverse, 2007). With improved microscopes in the 19th century, the anatomy of pollen grains could be studied. In 1809, Robert Brown realized that pollen could be used as a systematic way of studying flowering

plants (Traverse, 2007). In the early 1900's, botanists saw the potential of applying pollen analysis to post-glacial studies when Lagerheim, a Swedish botanist, realized he could learn the vegetation of an area by looking at peat deposits. His protégé, Von Post, put it to good use by studying the Holocene using several peat deposits around Sweden. The new area of study was not widely popularized until after the 1920s to the 1940s when his student, Gunnar Erdtman expanded its analytical and statistical range. Erdtman is also credited with developing much of the terminology used today by palynologists (Faegri et al., 1989; Birks 2003; Traverse, 2007).

Many methodological and conceptual developments have occurred in the study of pollen. Field and laboratory methods have improved greatly over the last fifty years, along with project design and site selection (Birk, 2005). Other advances include the understanding of glacial-interglacial cycles, ecological processes that influenced early Holocene forest developments, and the impact of human land-use (especially agriculture) on past environments (Birk, 2005).

Pollen grains are good indicators of past vegetation in part because they are resilient to decay (Moore and Webb, 1978; Faegri et al., 1989; Traverse, 2007). The outer walls are composed of sporopollenin and are among the most chemically inert of the major naturally occurring organic compounds (Traverse, 2007). They are tough, hollow spheres or shells of which the contents have already disappeared due to biodegradation by bacteria or fungi.

Another advantage to studying pollen is that it is produced in large numbers. Some plant species produce pollen grains in the thousands, making them easy to retrieve in large numbers for analysis (Faegri et al., 1989; Traverse, 2007). Their small size allows them to be carried in the wind and more evenly widespread over large distances unlike other types of fossilized plant remains (Faegri et al., 1989). This is valuable in the sense that it allows for some pollen grains to be deposited in places suitable for preservation (i.e. lakes, bog, peats). However, this can

complicate interpretation since it also means that some pollen grains can be transported and deposited in areas far from their source (Moore and Webb, 1978). Some pollen grains preserve better and some plants produce more pollen than others, which could lead to over-representation or under-representation of some plants in the pollen record. Differential deposition and long-distance transportation must always be taken into consideration when studying pollen assemblages (Moore and Webb, 1978).

As important and informative as pollen analysis is, there are limitations. They are sensitive to oxidization by weathering and they do not survive well under intense heat and pressure (Traverse, 2007). Another limitation to their usefulness is the degree to which they can be identified. Using a light microscope, most pollen grains can only be identified to the family (e.g., *Poaceae* and *Chenopodium*) or genus level (Traverse, 2007). For general vegetation reconstruction purposes, this level of identification may be sufficient. However, subtle vegetation changes might be missed if plants cannot be identified more precisely (Traverse, 2007).

Another disadvantage to the study of pollen is the way in which pollen grains are produced and dispersed. Pollen grains are produced by flowering plants called angiosperms. This is the largest and most species-rich phylum of plants, with an estimated nearly half a million species (Traverse, 2007). Not all plants produce the same amount of pollen grains and they are not all dispersed the same way. This leads to the problem of over representation of plants that produce thousands of pollen grains and under representation of plants that produce very few pollen grains (Faegri et al., 1989; Traverse, 2007). Another issue that must be taken into consideration when designing a project is the size of the site (Birks, 2005). For example, a large lake will

accumulate pollen from a larger source area giving a regional picture of vegetation changes. Smaller lakes will collect pollen from a more localized source area (Birk, 2005).

There have been many developments and improvements in palynology throughout the last fifty years. These include better descriptions and methods of identification of pollen grains. Better field equipment and methods have aided in recovering and processing pollen. However, more work needs to be done to be able to identify pollen to the genus and species level, which will lead to better vegetation reconstructions.

5.4 Phytoliths and Paleoecological Research

Phytoliths are opal silica casts of cells in growing plants (Bozarth, 1987; Piperno, 2006). They occur in the stems, leaves, roots, and inflorescences of plants (Pearsall, 2008). They are carried up through the plant from groundwater in the form of monosilicic acid (Rovner, 1983; Bozarth, 1987; Piperno, 2006; Pearsall, 2008). The monosilicic acid fills in the cells and retains their shape after the cell has decayed or died (Rovner; 1983; Bozarth, 1987; Pearsall, 1982). Some plant tissues will produce more phytoliths then others (Piperno, 2006). They can be found in soils, sediments, hearths (Brown, 1984) and pottery residues (Surette, 2008). It is assumed that phytoliths represent highly localized deposition of plant communities (Piperno, 2006) although transportation by streams is likely to affect the assemblage. Therefore, as with pollen, it is important that samples should be taken away from streams and rivers to avoid additional unwanted contamination from upstream plant communities whenever possible.

The grass family is one most abundant and best-studied producers of phytoliths. Grasses produce two major classes of phytoliths: long-cell and short-cell (Pearsall, 2008). The long cells are formed in the epidermal tissue of plants and even in the edge spine, prickles, and hairs

produce phytoliths as well (Pearsall, 2008). Long cells are also formed in the stomata and vascular tissue in the epidermis.

Short-cell phytoliths are the second major class of phytoliths found across the veins of the leaf and leaf-derived tissues (Pearsall, 2008). Three grass subfamilies can be identified using short-cell phytoliths: the Festucoideae; the Panicoideae; and the Chlorodoideae. Festucoideae grasses tend to produce rondel and sinuous rectangular shaped phytoliths (Festucoid type phytoliths) (Pearsall, 2008) while Panicoideae grasses produce mostly dumbbell (bilobate) and cross-shaped phytoliths (panicoid type phytoliths) and Chloridoideae grasses produce saddles (chlorideae type phytoliths) (Brown, 1984; Mulholland, 1989).

Phytolith identification relies on knowing the shape and size of the phytoliths found in different plants. Previous researchers were able to determine that differences could be seen at finer taxonomic levels leading to better plant identification at the genus and species levels (Bozarth, 1993(a); Mulholland, 1988; Piperno, 1989, 2006). Their research identified that a large variety of phytolith shapes existed across several species. Some were repeated between many plants in the same family and some were very specific to the species and even the sub-species (Piperno, 2006; Surette, 2008). However, unlike pollen keys, there are very few standardized classification systems for phytoliths like Brown's (1984) phytolith key (Piperno, 2006). As with identifying pollen grains and macrofossils, phytoliths are identified by looking at their shape, size, and surface features (Brown, 1984; Piperno, 2006). These traits are very useful when trying to differentiate between two or more closely related species. Sometimes size or slight variations in the shape of the phytolith are the only ways to distinguish between related plants (Piperno, 2006). In other cases, it is possible to distinguish between plants based on the types of phytoliths that are found.

Phytoliths are becoming increasingly important and useful tools for reconstructing past environments and past diets of prehistoric people (Bozarth, 1987; Piperno, 2006; Rovner, 1983; Surette, 2008). While phytoliths are not routinely used in paleoecological studies, their resilience to destruction and decay, and local deposition make them an important tool when reconstructing the local environmental context of archaeological sites (Piperno, 2006). Unlike pollen, phytoliths can be used to identify specific grass species like maize (*Zea mays*) and wild rice (*Zizania* sp.) (Surette, 2008). They can also be used to distinguish between C3 and C4 grasses (Brown, 1984).

Using phytoliths to identify plants can be difficult because some plants produce multiple types of phytoliths and some phytoliths are found in several different plants. The mode of dispersal also needs to be addressed when considering plant usage and the vegetation in the area of interest (Piperno, 2006). Identification of phytoliths is usually done by using comparative material from modern plants and by using a phytolith key based on their morphology (Brown, 1984).

Sampling from an archaeological site requires well-defined contexts. Places such as hearths (Bozarth, 1993a; Mulholland, 1993; Rovner, 1983), buried soils, burial mounds, and cooking residues (Jones, 1993; Hart et al., 2003) offer good archaeological contexts. Phytoliths can be recovered from terrestrial and aquatic sediments, as well, thereby aiding with palaeoevironmental reconstruction (Blinnikov, 2005; Lentfer and Boyd, 1999, 2000).

Phytoliths are also subject to similar dispersal problems as pollen. While they are not released and float in the air like pollen does, they can be subject to wind and water distribution, which could lead to re-deposition and sorting (Stromberg, 2004). Like fine sand and silt, phytoliths can be swept into the air, especially in areas that have recently seen fire, and become

deposited and even sorted in a secondary deposit (Friedlund and Tieszen, 1994; Stromberg, 2004).

Fearn (1998) offers a good example of how phytoliths can be used to identify different types of environments. In this study, phytoliths were analyzed in sediments along with pollen in order to figure out what kind of environment the grass pollen was coming from. Different environments can be detected because different grasses produce different assemblages of phytoliths. This is a good study because it shows not only changes in wet and dry environments but also the fact that the phytoliths show more variation in grass than the pollen information does (Fearn, 1998). Fearn (1998) observed that dumbbell shaped (bilobates) phytoliths dominated in dry prairie environments, and rondel shaped phytoliths increased in waterlogged and salt marshes. Fearn's (1998) study is a good example of how looking at phytolith ratios can help researchers identify changes in moisture availability in an area. The dumbbell/rondel ratios indicate whether the grasses in the area are growing in moisture rich environments or in dryer environments. These are details that would otherwise be missed by just strictly looking at the pollen signatures of the area.

Another important study specifically considered rondel phytoliths (Surette, 2008). These rondel phytoliths were used to identify wild rice in food residues from pottery collected from the Lake of the Woods area. After looking at over forty different grass and sedge species Surette (2008) was able to determine which rondel shape was diagnostic of wild rice. Specifically, rondels with four spikes on the top and three or more indentations on the base appear to be found only in wild rice. Yost (2007) came to a similar conclusion Not only is the study helpful in identifying foods eaten by the prehistoric Woodland Cultures (Boyd et al., 2006), it is also very

useful in identifying what grass species are found in shallow lakes where grass pollen is being recovered.

Although phytolith analysis is still a relatively young field in contrast to palynology it has proven to be a useful tool where pollen has failed. Like pollen, phytoliths can be identified with ease using only a light microscope. However, not only are they more easily identifiable to the genus level (Piperno, 2006; Surette, 2008), their longevity and resistance to destruction make them ideal tools in vegetation reconstructions. Their tendency to remain in *situ* when the host plant dies and decays can help track environmental changes that would otherwise be missed by just using pollen analysis.

5.5 Paleoecological Sampling Strategy

Samples for pollen and phytolith analysis were taken every two centimetres along the entire length of the core. Three cubic centimetres (cc) were taken for analysis as close to one another as possible to obtain the best results for comparative proxy analysis. Every two centimetres was deemed fine enough sampling for paleoecological reconstruction. Ninety samples were chosen and sent to Global Geolab Limited for pollen processing. Due to time restraints, only sixty samples were chosen for analysis for this thesis. Phytolith processing was done at Lakehead University but only samples corresponding to those with grass pollen were processed for phytolith analysis in the hopes of identifying wild rice (*Zizania palustris*) rondels correlating to the grass pollen.

5.6 Laboratory Methods

5.6.1 Pollen Processing

Pollen samples were submitted to Global Geolab Limited for processing following Faergre and Iverson (1989) method. The first stage of processing is digesting the samples in acid to remove as many organic and inorganic particles as possible. Between 25 and 55 mg was place

into 10% solution of HCL and left overnight for carbonates to dissolve. The HCL was decanted, washed with distilled water and allowed to settle. This is done three times to dilute and remove any remaining calcium ions. Next, 70% hydrogen fluoride is added and oscillated for about four hours or until digestion is complete. The solution is then poured into a 50 ml test tube and centrifuged for five minutes at 2000 RPM than decant ¾ from the top of the HF. Distilled water is added while vortexing the solution and then centrifuged for two minutes and repeated until neutral. The acid is washed and centrifuged three to four times until the fine caustic material is removed. A few drops of concentrated HCL is added during this stage allowing better heavy liquid separation. Then the samples are vortexed and centrifuged for four minutes.

Stage 2 requires separation of the pollen using heavy liquid separation. About 25 ml of $ZnBr_2$ (specific gravity = 2.0) is added and vortexed thoroughly. Then each test tube is placed in an ultrasonic bath for about ten seconds. Samples should sit for about ten minutes before being centrifuged for fifteen minutes at 2000 RPM. This step is repeated three times. Next, the float is poured into another 50 ml test tube, washed and centrifuged at 2000 RPM for fifteen minutes. This step is also repeated three times. The remaining residue is transferred to a 20 ml glass test tube. At this point, a small smear should be analyzed to determine how much oxidation is required.

Stage 3 requires placing about 3 ml of Schultz solution in the residue, vortexed, and placed in the test tubes in a hot bath until oxidation is complete. The Schultz solution is removed by washing and centrifuging. Check a small smear to see if oxidation is sufficient. A 10% solution of NH4OH is added and place in a hot water bath for two minutes. Centrifuge and wash three times. Samples should be examined to see if enough oxidation has occurred. If not, add more Schultz solution and repeat.

The last stage is to mount the slides. Pipette off the sieved fractions and add one drop of polyvinyl alcohol with a glass-stirring rod. Once the residue has dried, add one drop of clear casting resin is added and the cover slip placed on the slide. The slide should be cured in about one hour. For the sieving process we requested a larger sieve size be used in order to catch larger pollen grains, such as *Zea mays* (maize). An exotic spike (*Lycopodium*) was added as well, which is necessary to calculate absolute pollen accumulation rates.

5.6.2 Phytolith Processing

The methods used for phytolith extraction follow techniques devised by Staller and Thompson (2002) and Hart et al. (2003) with some modifications. The samples were first tested for carbonates by adding a few drops of 5% HCl to each sample. No fizzing occurred in any of the samples, indicating that carbonates were not present. The next step was to remove the clays from each sample. The samples were placed in a beaker and submerged in sodium hexametaphosphate (about 25 ml or until covered) and placed on a magnetic stirrer with a magnetic stirring bar placed inside the beaker. The sediments were left to stir at a low rpm for about 15 min. This helps to mechanically break up the clays. The sample was topped off to the 8 cm line on the beaker and allowed to settle for 1 hr. After the sample has settled the supernatant was pipetted off making sure not to suck up any of the sample from the bottom. This step should be repeated until the supernatant appears clear indicating that the clays have been removed.

Once the clays were removed the samples were sieved into a 50 ml plastic centrifuge tube using a 250 μm sieve and a glass funnel. The part of the sample that made it through the sieve was labeled as *part 1*. Any part of the sample that was too large for the sieve was put into another 50 ml centrifuge tube with *part 2* marked on the label. Samples marked as *part 1* are

saved for a later step in the process and do not need to be digested in acid. Part 1 samples contain a portion of the phytoliths and will recombined with the rest later on. All samples marked as *part 2* needed to be filled with water to 50 ml and centrifuged at 3000 rpm for 5-15 min. The supernatant was then pipetted out and the samples placed into glass test tubes set in a rack for acid digestion.

Next, the water bath was filled about halfway with water and allowed to heat (about 60ºC) while the samples were placed into glass test tubes. The test tubes were only filled to about 1 inch and 50% nitric acid was added, to ensure that the samples would not spill over during digestion. Several glass test tubes were used for samples that had plenty of organics. Once the 50% nitric acid was added and the samples were placed into the water bath they were heated for a period of 24 hrs to sufficiently digest the organics.

Once the samples were sufficiently clear, (indicating the organics are digested) the test tubes were taken out of the bath they were poured into new 50 ml centrifuge tubes and filled with water to the 50 ml line. The samples were centrifuged down and the supernatant pipetted, this step was repeated five times to remove the acid from the samples. Next, the samples were filtered through a 250 μm sieve to remove large particles that remained in the samples. The samples from part 1 were recombine with the samples from part 2 and a 118 μm Nitex cloth was used to separate large diatoms from the samples and kept for future analysis. The samples that made it through the nitex cloth were stored in microcentrifuge tubes in ethanol to be mounted on slides using entellan for analysis.

Chapter 6: RESULTS
6.1 Introduction

During the winter of 2008, two cores were collected from the west side of Whitefish Lake (figure 6.1) for pollen and phytolith analysis. A long core (WTFSH08-01) (figure 6.1) was collected with a vibracorer, while a short core (WTFSH08-02) was collected with a Universal Corer. The cores were described and subsampled for pollen, phytoliths and datable organics. During the summer of 2016, two additional short cores were obtained for pollen analysis (WTFSH16-01 and WTFSH16-02) from the west side and south side of Whitefish Lake (figure 6.1). This sought to supplement the data already collected**.** The pollen grains were counted to obtain relative taxonomic quantities used to determine the paleovegetation of Whitefish Lake. Grass phytoliths, specifically diagnostic rondel types, were also counted in order to verify the presence of wild rice (*Zizania palustris*) in the lake. Radiocarbon dates were obtained from core WTFSH08-01 to help establish the sedimentation rate, a timeline for vegetation changes and the colonization of wild rice**.**

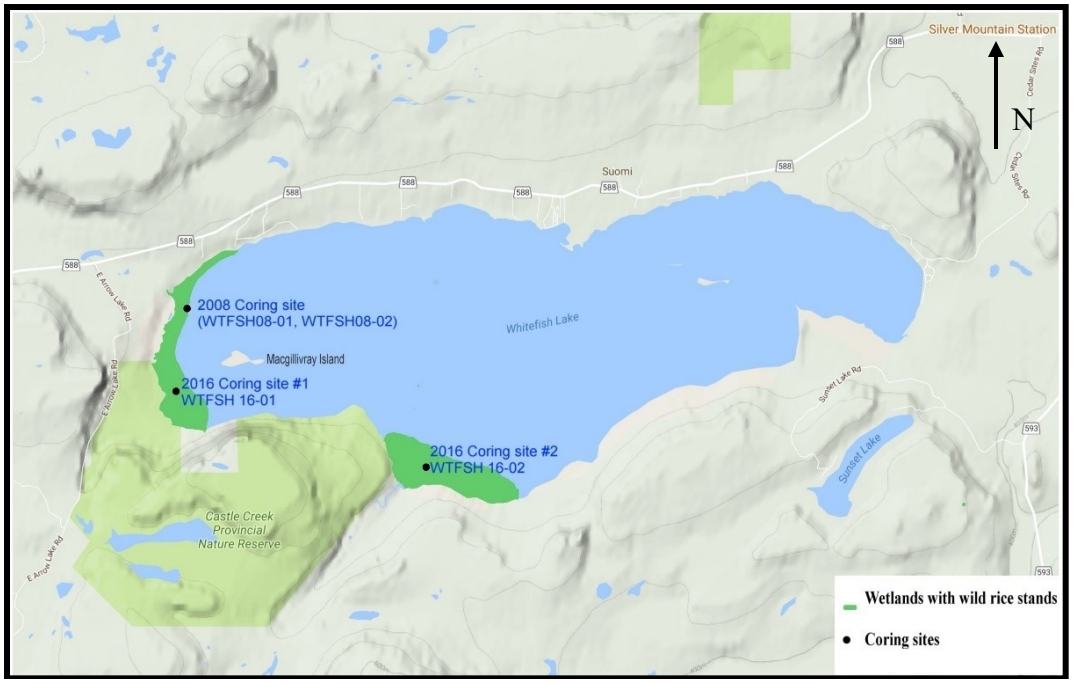

Figure 6.1 Map of coring sites taken at Whitefish Lake

6.2 Core Descriptions

6.2.1 WTFSH08-01 (Long Core)

Four stratigraphic units (A, B, C, D) were identified and described below (figure 6.2). Unit D (figure 6.1) is composed entirely of couplets. Some of them are visually distinct but most of them are faint to very faint (5YR 3/1 to 7.5YR 3/3 on the colour scale). The couplets consist of alternating light to dark laminae, parallel and horizontal in orientation appearing to alternate between silt and clay. The couplets appear to be very regular, showing very little variation in nature or appearance (figure 6.2). The couplets range from 3 mm to 1 cm in thickness with most being less than 1 mm thick, from 461.5 cm up to 289 cm for a total of ~265 couplets. Post depositional irregularities appear in two areas: between 374 cm – 388 cm; and 456 cm – 459 cm. The source of these convolutions is unknown at this time, but may derive from drop stones released from the ice, or some kind of bioturbation. Currently, there is no evidence of either of these scenarios. Another explanation could be the coring device itself created a disturbance as it penetrated the sediment.

Unit C is very dark grey (5Y 3/1) in colour, and is composed of clay to silty clay, There are no visible plant fibres or macroremains. Large ped-like structures were noted in this section (Figure 6.1). These structures or aggregates are prismatic in shape, and roughly 1-5 mm in diameter. These prismatic, ped-like structures are likely caused by shrinking and swelling (Boggs Jr., 2014) possibly due to periodic freezing and thawing, and lower water levels. The ped-like aggregates continue throughout this unit, but change from prismatic to platy structures beginning at 260 cm below the top of the core.

Units B and A are similar in appearance. In unit B, the sediment has a very dark greyish brown colour (2.5Y 3/2 Munsell Soil Colour Chart). There are visible particles (e.g. shells) and is composed of very fibrous sapropel to sapropelic gyttja. Fibres are herbaceous and contain root

hairs, stems, and leaves (possibly grass or sedge). The water content appears to be lower than then in unit A with lighter and darker areas (perhaps signalling internal differences in humification). Towards the bottom of unit B there appears to be a slight colour change from a dark greyish brown to a dark olive green (2.5Y 3/3).

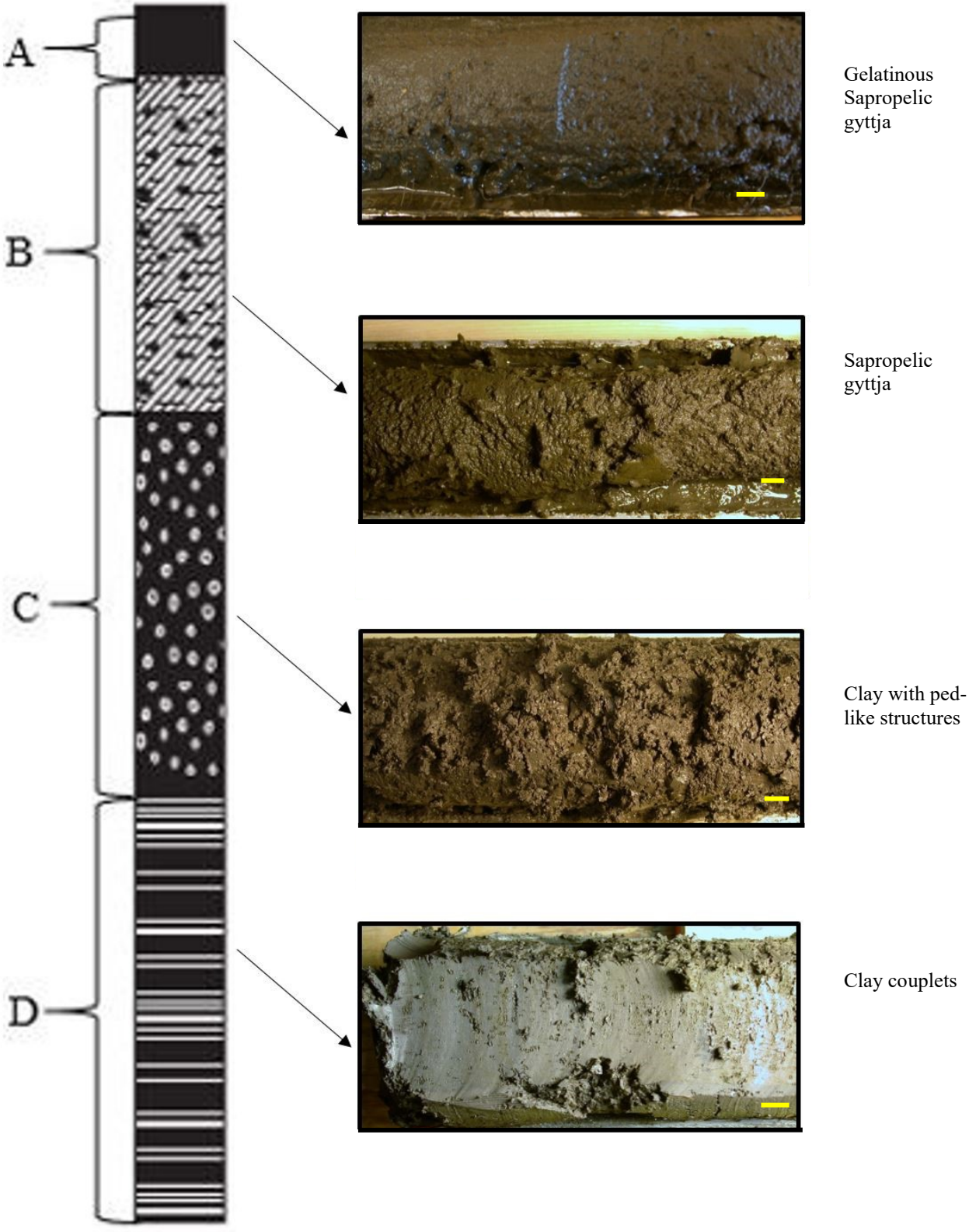

Figure 6.2 Units from the long core (WTFSH08-01). (Coordinates: N 48 13.506'/ W 90 03.882' +/- 8 m).

Unit A (figure 6.3) is a gelatinous sapropel with clay to silty sediment and occasional sand size particles, with what appears to be shells as well. The sapropel is dark, olive grey (Munsell code: 5Y 3/2). There are occasional ostracod valves visible, and herbaceous fibres are rare to occasional. The lower boundary is gradual and the water content appears slightly higher compared to unit B. Unit A is gelatinous with clay to silt particle size and contains very fibrous sapropel to sapropelic gyttja.

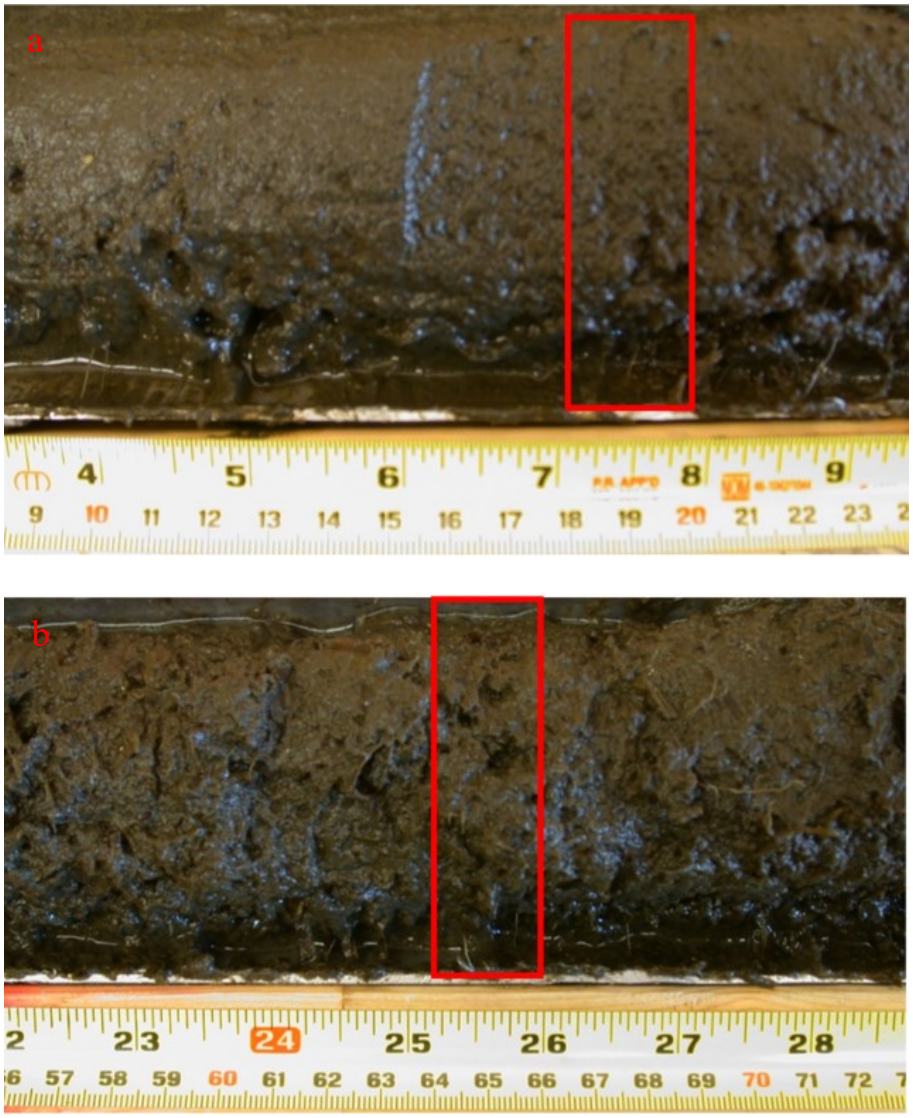

Figure 6.3 Unit A, Red rectangles in photos show where plant fibers were taken for radiocarbon dating.

The lithostratigraphy of the short cores appear to be the same and represent one stratigraphic unit. They are similar to the gelatinous sapropel found in unit A of core WTFSH08-01 (figure 6.3). The water content is high and there are plenty of plant fibers present throughout. Core WTFSH08-02 is 100 cm long and will be used to compare with the upper section of core WTFSH08-01. The two cores taken in 2016 (WTFSH16-01-RC and WTFSH16-02-RC) are only 25 cm long. They were obtained from directly within the two wild rice beds found closest to Macgillivray Island (figure 6.1), and were collected to compare the pollen spectra found at those two sites with the 2008 short core.

6.3 Radiocarbon Dates

Samples for radiocarbon dating were taken from five locations within the core. Three dates were taken from plant debris and two were taken from bulk samples because organics or plant remains were not available. The youngest date of 2640 +/- 40 cal BP (BETA-256940) (table 2) was obtained from organics retrieved from a bulk sample at level 18 – 20 cm in Unit A (Figure 6.3). A radiocarbon date of 3220 +/- 40 cal BP (BETA-256941) was obtained on organics retrieved from level 66 – 68 cm in Unit B (Figure 6.3). The oldest reliable radiocarbon date comes from level 146 – 148 cm at 4330 +/- 40 cal BP (BETA-256942). These three dates can be considered accurate due to the fact they were taken from organics within the bulk sample and are free of old carbon.

Table 2 Location of taken radiocarbon samples

Depth (cm)	Unit	Uncorrected 14C age	Calibrated age range (BP)	Lab number	Material dated	Comments
18 - 20	A	2,640 ± 40	2,790 - 2,730	Beta-256940	Graminoid debris	
64 - 66	B	3,220 ± 40	3,550 - 3,370	Beta-256941	Graminoid debris	
146 - 148	B	4,330 ± 40	4,970 - 4,840	Beta-256942	Graminoid debris	
216 - 218	C	14,820 ± 40	18,530 - 17,660	Beta-256943	Bulk sediment	Rejected
258 - 260	C	18,820 ± 40	22,560 - 22,160	Beta-256944	Bulk sediment	Rejected

Table 2 displays radiocarbon dates and the location of where they were taken.

The last two radiocarbon dates where taken from bulk samples where organics were not available. A date of 14,820 +/- 80 cal BP and 18,820 +/- 80 cal BP were obtained from Unit C at levels 216 – 218 cm and 258 – 260 cm respectively. These dates have been rejected as too old because they predate the retreat of the ice sheet and likely contained old carbon (Boyd et al., 2013; Dyke et al., 2002).

6.4. Microfossil Results

6.4.1. Long Core WTFSH08-01

The pollen data was divided into two major zones; **Zone 1** and **Zone 2** representing major changes within the biotic character of the lake. These major zones are than divided into four subdivisions: **subzone 1a** and **1b**, **subzone 2a** and **2b** (Figure 6.4). Any sediments below Zone 2 (unite D) are laminated and contain no biological remains and is therefore not represented as part of the pollen profile. **Zone 2** (figure 6.4) begins at 286 cm and ends around 150 cm. This is the oldest zone in the sequence and is divided into two subzones. **Subzone 2b** is between 286 cm and 272 cm dominated by *Abies* (balsam fir) peaking at about 12%, *Picea* (spruce) reaching ~25%, and *Pinus* (pine) reaches a peak of 40% and *Pinus strobus* in particular peaks at 24%. *Betula* (birch) and *Quercus* (oak) average about 12% each, and *Salix* (willow) appears to peak in this zone at ~10%. *Alnus* (alder) is present and peaks at 40% at a depth of 272 cm before dramatically declining to less than 5%. *Acer* (maple) also appears to peak very early

at 6% then declines to less then 3% for the remainder of the Holocene. Terrestrial herbs such as *Amaranthaceae* (amaranth), *Poaceae* (grass), and *Chenopodiinaceae* (chenopodium) are present. In **subzone 2a**, (272 cm – 150 cm) *Abies* pollen decreases to ~6% while *Picea* increases peaking at ~55% and *Pinus* pollen decreases slightly to ~30%. There is also a moderate presence of terrestrial herbs. *Ambrosia* (ambrosia) remained between ~ 4% – 6% throughout **zone 2** and *Chenopoidiineae* peaks at ~ 6%. Sedges peak in **subzone 2a** and include *Carex, Cyperaceae,* and *Cyperus*. In **subzone 2a**, *Betula* (birch) begins to increase while *Corylaceae* (hazel) decreases along with *Quercus* and *Salix.* *Chenopodiineae* increases slightly while *Ambrosia* and *Poaceae* decrease slightly and the sedges appear to tapper off.

Zone 1 starts at roughly 150 cm, and is characterized by *Picea, Pinus, Betula,* and *Alnus* (alder). *Picea* starts to decrease to between 15% and 35 % as does *Pinus* to ~ 20% and *Abies* is present but decreases to less than 6%. *Myrica gale* (sweet gale) and *Quercus* are present in moderate quantities. **Subzone 1b** begins at 150 cm and ends at 24 cm. *Betula* and *Alnus* begin to increase, *Betula* reaching 24% and Quercus peaking at ~ 6%. Terrestrial herbs remain quite low, *Ambrosia* the most abundant at ~ 2% and the sedges nearly disappear. In **subzone 1a**, *Betula* reaches its highest peak at ~ 45% while *Alnus* increases slightly to about 10%. *Salix* quantities low at less than 5% and *Quercus* is present in moderate quantities. There is a noticeable increase in terrestrial herbs, particularly in *Ambrosia* and *Poaceae*. *Ambrosia* peaks near the top at 8% and Poaceae rises significantly peaking at 6%. The presence of sedges remains very low overall and aquatic plants remain very low, less than 5% throughout the core. However, *Nuphar* increases steadily beginning at about 30 cm.

Phytolith samples recovered from the long core were also prepared and analyzed. However, the samples were crowded with diatoms and revealed very few phytoliths. It is

suspected that this may reflect inadequate lab methods. This led to the collection of additional samples that were processed using altered methods, and later published (Boyd et al., 2013). Those results will be discussed later as they relate to the pollen analysis from this core and the short cores.

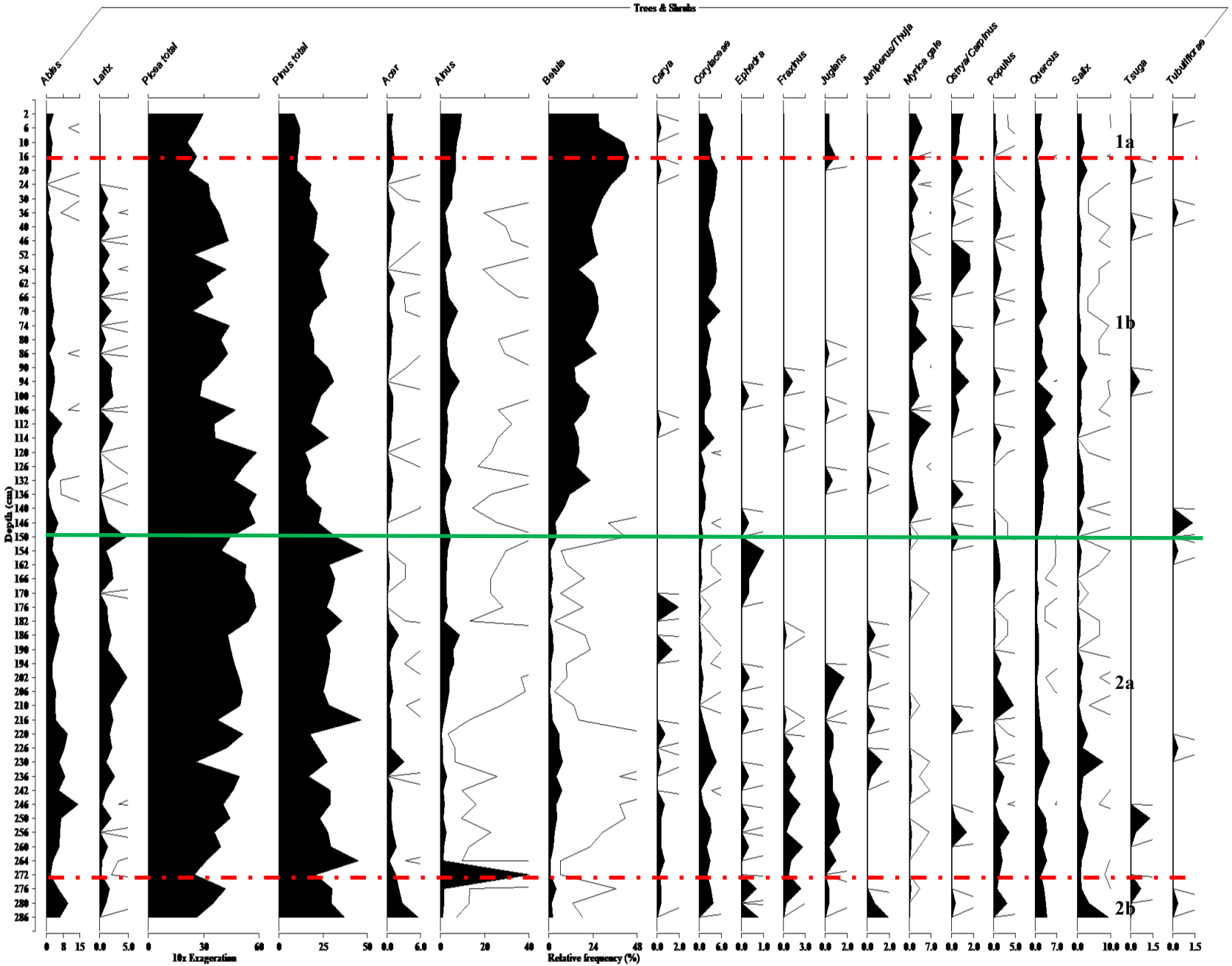

Figure 6.4 Long Core WTFSH 08-01 (Continued on next page) Green line separates Zone 1 and 2. Red hashed line represents subzones a and b.

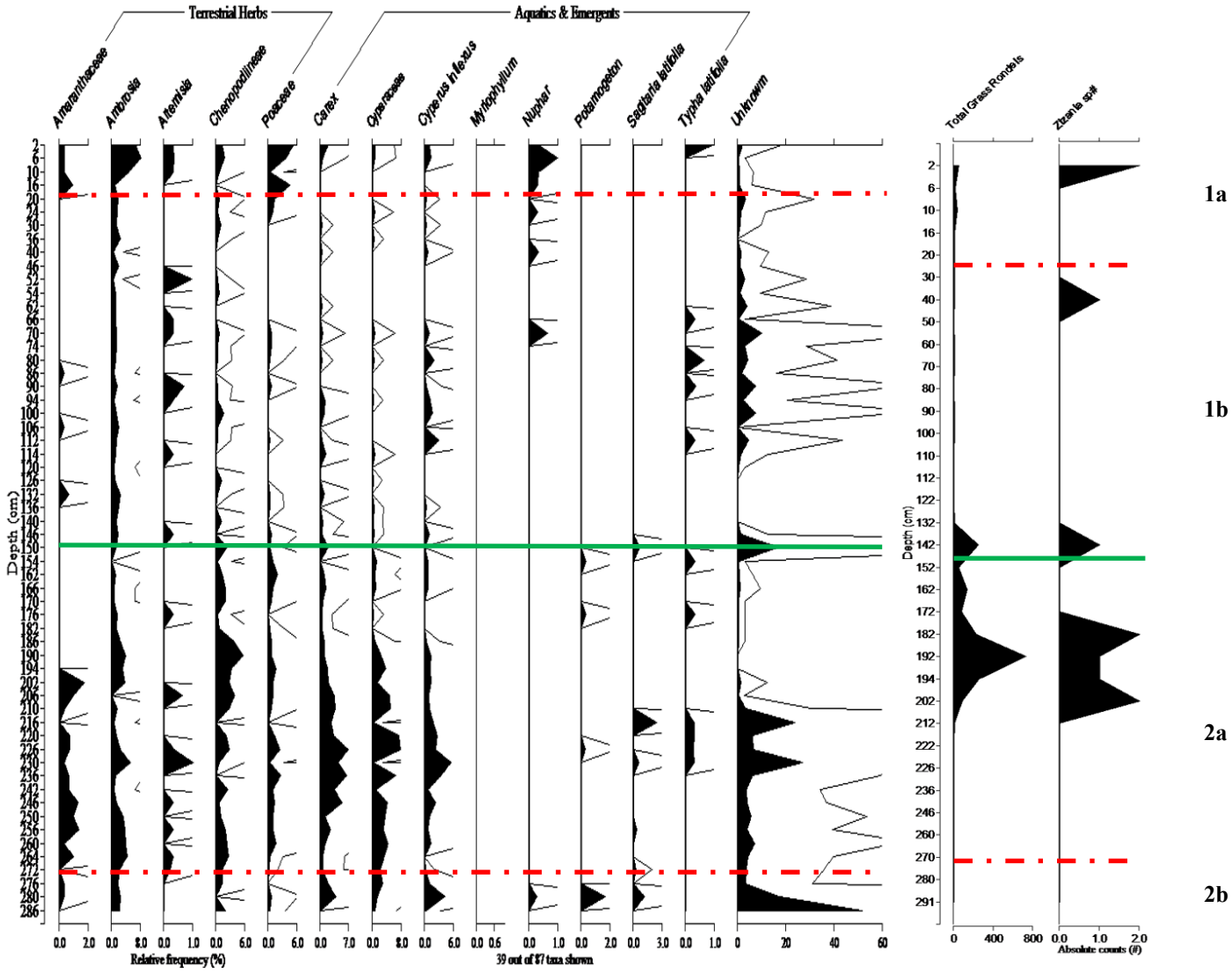

Figure 6.4 (continue from page 80) Core WTFSH08-01: herbs, aquatics and emergent taxa with phytolith data (phytolith data from Boyd et al., 2013) Green line separates Zone 1 and 2. Red hashed line represents subzones a and b.

6.4.2 Pollen Results

Figure 6.6 illustrates the pollen and phytoliths recovered from core WTFSH08-02 (1 m long) collected in 2008 (figure 6.1). *Picea, Pinus, Alnus,* and *Betula* dominate the pollen sequence with *Betula* forming the dominant taxa. *Picea* dominates the lower part of the core between 100 cm and 78-80 cm at ~ 54%. *Pinus* peaks at the 100 cm depth, representing just over 30% of recoveries (composed of mostly *Pinus banksiana/resinosa* type than the *strobus* type). *Populus, Quercus,* and *Salix* are present as well but play a minor role since they account for less than 10%. *Ambrosia* (ambrosia) and *Poaceae* (grasses) make up the majority of the terrestrial herbs at less than 3% at the bottom. There are very few aquatics present. Sedges comprise only ~1% of the total pollen spectra throughout the core and aquatic plants make up less than 1%. *Nuphar* (yellow pond lily) is only found at the very bottom of the core peaking at level 88-90 cm, and *Sagitario latifolia* (arrowhead) peaks at the interval above (78-80 cm). *Typha latifolia* (cattail) peaks at the same level as *Sagitaria latifolia* and declines at 68-70 cm.

6.4.3 Phytolith Results

Samples were processed for phytolith analysis from the same areas as the pollen samples were obtained. The phytolith data was used to supplement the pollen data with a primary focus on the presence of rondels specific to wild rice (figure 5.1, photo C – Chapter 5 pp. 56). Because pollen grains cannot be easily identified to species, it was important to collect additional data from phytolith analysis. As with pollen analysis, phytoliths were counted up to 300 in order to get a representative sample the taxa that are present. Of the phytolith varieties present, the ones of most interest to this study are the rondel phytoliths identifiable as wild rice (figure 6.5) (Surette, 2008). The data shows a general increase in wild rice phytoliths from the bottom of the core towards the top peaking at 30% at 38 – 40 cm depth before they decrease again.

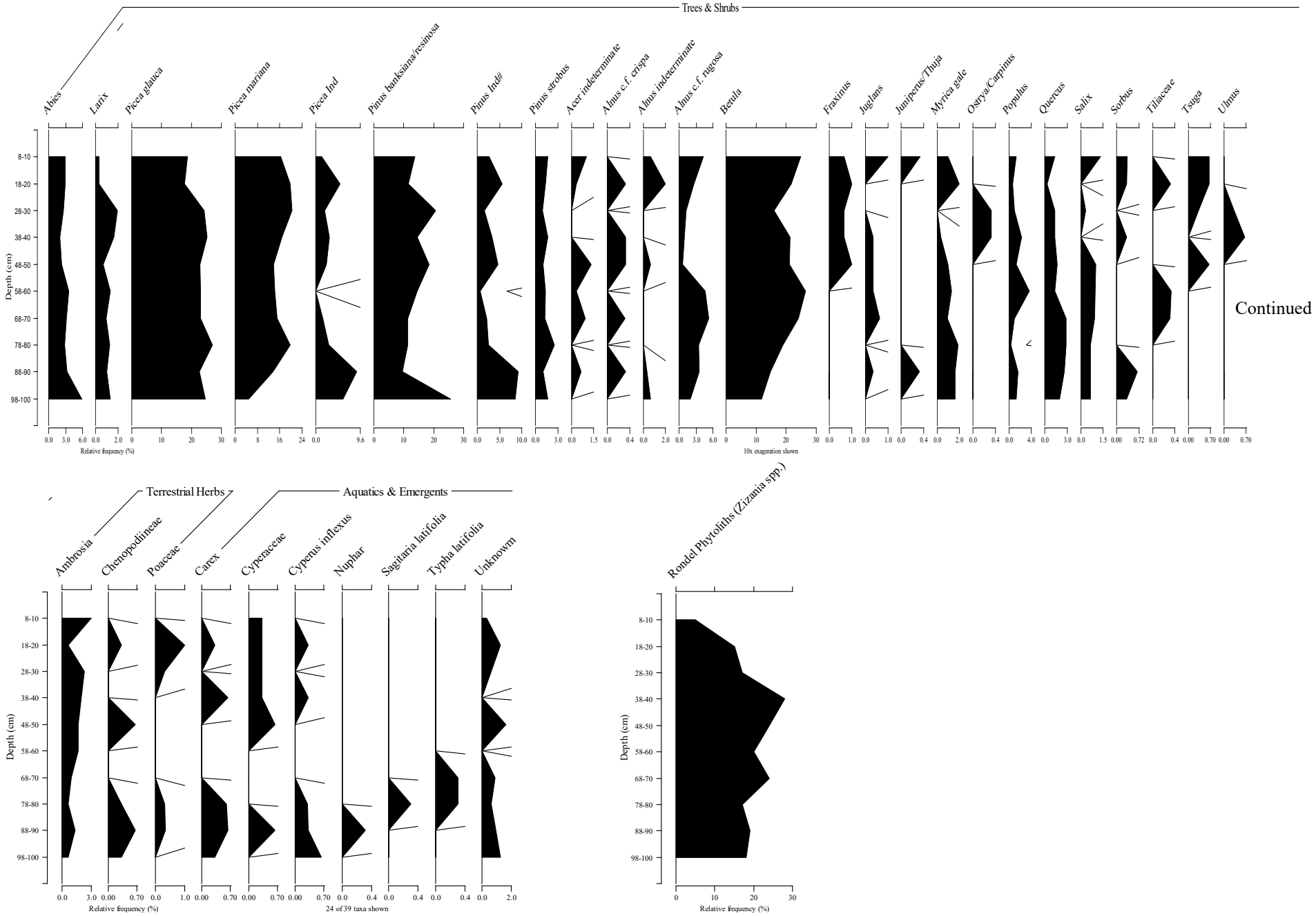

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Figure 6.5 Short core WTFSH08-02

6.4.4 Short Cores WTFSH 2016-01-RC and WTFSH 2016-02-RC

During the 2016 field season, two short lake cores were taken using a Russian Corer. These cores were taken to compare to those collected in 2008 (WTFSH08-01 and WTFSH08-02). Figures 6.6 and 6.7 represent the pollen analyzed from both cores, WTFSH 2016-01 RC and WTFSH 2016-02 RC respectively.

Core WTFSH16-01 RC (figure 6.6) was taken from a wild rice stand on the west side of the lake. The pollen spectra is dominated by *Betula* (representing 36%), *Pinus* (representing ~30%), and *Picea* (representing ~25%). *Alnus* is present at ~8%, and the presence of *Abies* is minor at ~3%. *Quercus* is present and remains steady at ~4% throughout the sequence. *Populus* increases and peaks at ~ 4% at 10-15 cm depth before it declines slightly and *Salix* declines from ~2%. *Ambrosia* increases to ~ 4% toward the top of the core peaking at 5-10 cm depth. *Poaceae* increases at 15-20 cm to 12%.

Core WTFSH16-02 RC was taken from a wild rice stand to the southwest of the island. The pollen sequence (figure 6.7) is dominated by *Betula*, which remains constant at 36% throughout the sequence. *Picea* and *Pinus* are also dominate making up ~20% and ~35% respectively. *Alnus, Populus, Quercus*, and *Salix* are all present in minor quantities. *Alnus* rises to ~ 8% and remains there for most of the sequence. *Quercus* and *Populus* presence remain minor at ~ 4% with *Populus,* peaking at 10-15 cm and falls again to about 2%. As for terrestrial herbs, *Ambrosia* is present and increases to ~ 4%. *Chenopodiinaceae* is present in very sparse quantities, less than 2%, and appears to disappear after the 5 cm depth. *Poaceae* is present and starts to increase between 15 cm and 20 cm to ~12%. Sedges are present, *Carex* being the most prominent, rising to 8% at the 5-10 cm interval. Aquatic plants are also present but in relatively miniscule quantities of ~ 1% or less.

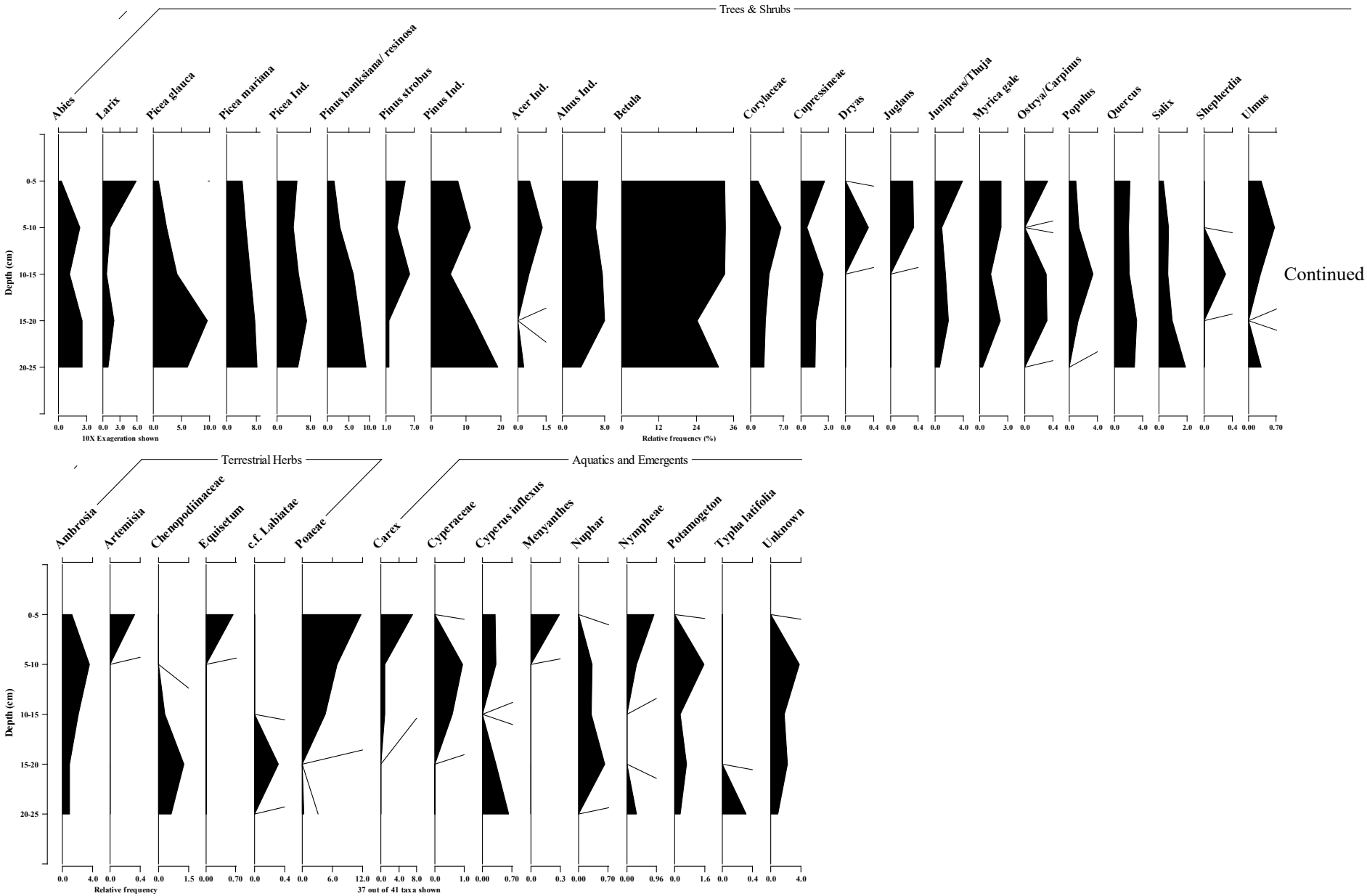

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Figure 6.6 Short core (WTFSH16-01-RC)

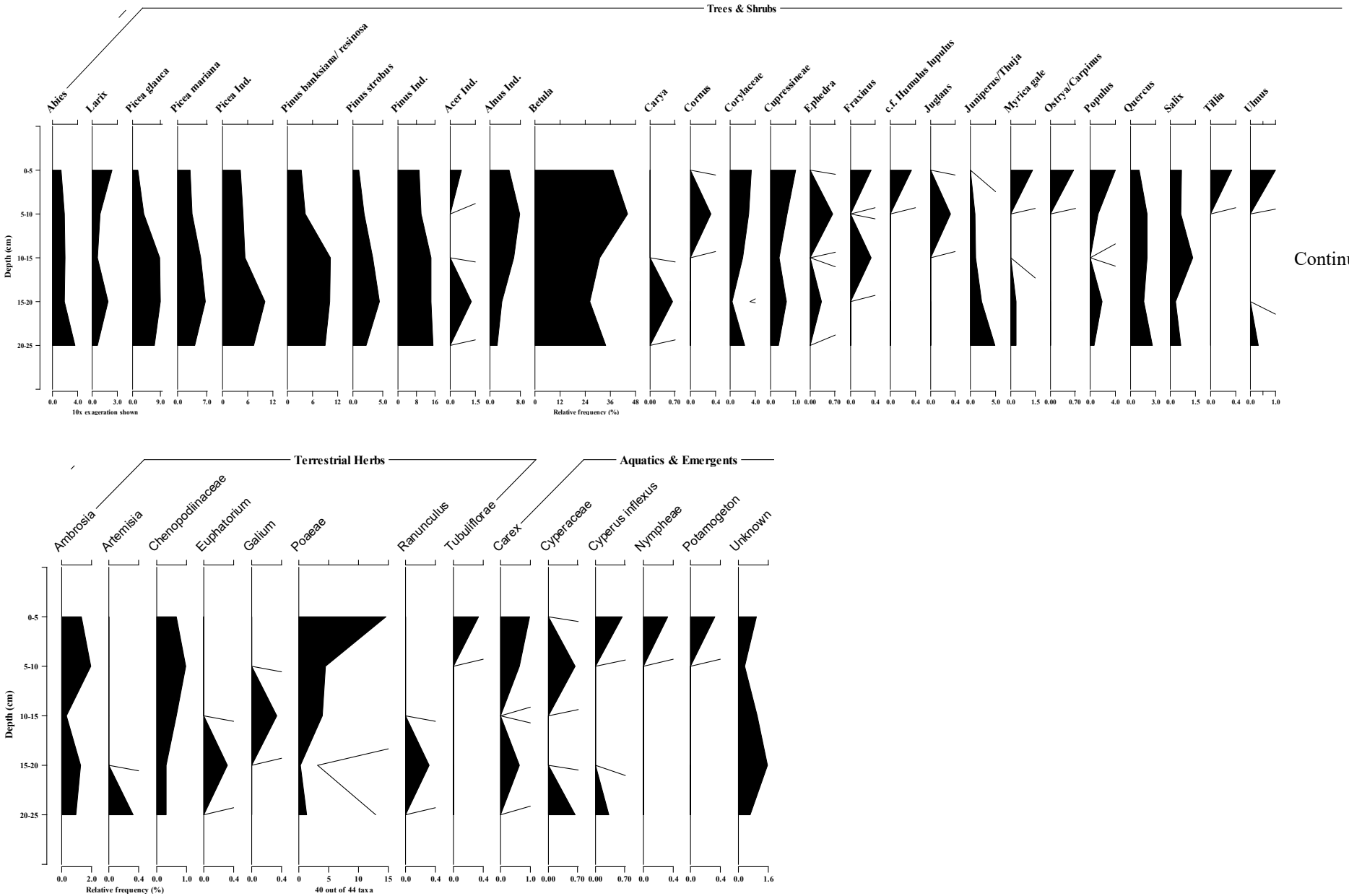

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Figure 6.7 Short core 2 (WTFSH 2016-02)

Chapter 7: Interpretations and Discussion

7.1 Introduction

Four cores were used to determine the paleoecology of Whitefish Lake. The pollen and lithostratigraphic data from the long core, WTFSH 08-01, enables interpretation of regional environmental change since deglaciation. The three additional short cores provide higher-resolution information to document the latter part of the late Holocene. Pollen and phytolith data were obtained from core WTFSH08-02, obtained near the long core (WTFSH08-01), and pollen data was collected from core WTFSH16-01-RC, obtained from a wild rice bed to west of the Macgillivray (Bishop) Island, and core WTFSH16-02-RC, obtained from a wild rice bed to the southwest of the island. This was done to clearly document modern vegetative trends. Three issues are addressed in this analysis: 1) documentation of an early post-glacial deep-water lake phase; 2) delineation of past environmental conditions using changing pollen taxa and sedimentation rates; and 3) using phytolith recoveries in conjunction with pollen to address the possible antiquity of wild rice in the area.

7.2 Interpretations

7.2.1 Unit D

The lowest 1.5 m (461.5 cm – 289 cm) of core WTFSH 08-01, labelled unit D, appears to be rhythmically laminated silt and clay layers interpreted as varves (Boyd et al., 2013). The counts suggest that there was approximately 265 yrs of uninterrupted sedimentation at a rate of nearly 0.60 cm annually in a deep-water environment (figure 6.4 chapter 6) (Boyd et al., 2013). The age-depth model below (figure 7.1) shows an approximate rate of sedimentation for the western basin of Whitefish Lake. Figure 7.1 based on the radiocarbon dates obtained from core WTFSH08-01 and when the area was estimated to be occupied by a proglacial lake (Boyd et al.,

2013; Loope, 2006). During the time when glacial meltwater was draining into the area the rate of sediment influx averaged ~0.55 cm/yr for about 500 years in unit D.

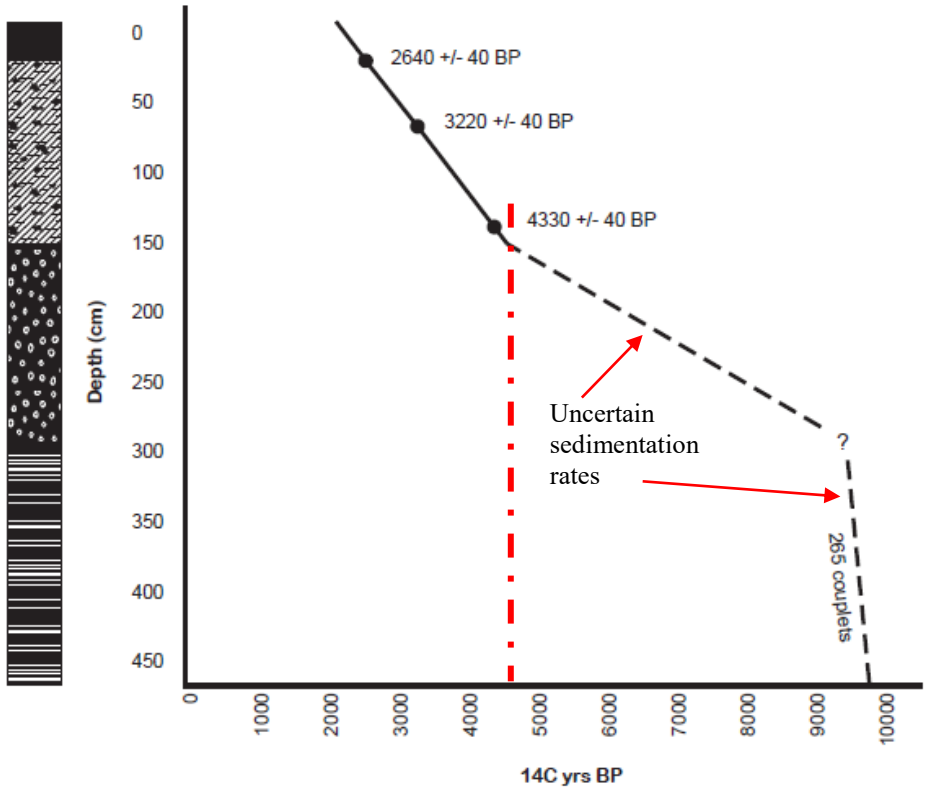


Figure 7.1 Age-depth model representing the approximate rate of sedimentation and rough timeline (as there are no dates for unit C and D) for all four stratigraphic units. Red broken line separates known from unknown sedimentation rates. NOTE: the model represented here is merely a visual showing an estimate of different sedimentation rates and inaccuracies are to be expected especially for the older deposits that have no dates corresponding to them.

The pollen profile begins at ~ 286 cm where unit C begins. The pollen profile suggests that the early postglacial environment at about 9400 ^{14}C yr BP in the general Whitefish Lake area was wet with cool temperatures. The sequence begins with the presence of *Abies* (balsam fir) that peaks very early on (figure 7.2). The presence of *Abies* is significant because it prefers cool temperatures, around 4 ^{o}C, and soils that are swampy. *Picea mariana* is another species that prefers wet, organic soils and is often a pioneer species that invades the sedge mat in filled-lake bogs**.** *Larix* **(**tamarack**)** is a cold tolerant species that can survive temperatures as low as -65 ^{0}C.

They prefer moist soils like swamps, bogs, and muskegs and are commonly found at the arctic tree line.

However, thermophilous deciduous trees where also found in this zone, between 286 cm and 272 cm, in small but notable quantities of 10% or less, which includes *Betula* (birch), *Quercus* (oak), *Fraxinus* (ash), and *Alnus* (alder) (figure 7.2). Although these species are present in relatively small quantities, they represent warm temperate species inhabiting a cold northern environment. One possibility is that the pollen grains from these warm temperate species were transported into the area from long distances by rivers and streams (Bjork, 1985). Another possibility is that the nearby glaciers provided shelter for these thermophilous species blocking the harsh arctic wind (Crawford, 2013). It is likely that this area of the pollen sequence represents a transitional zone that was not visually distinguishable in the sediments or perhaps overlooked during the initial inspection.

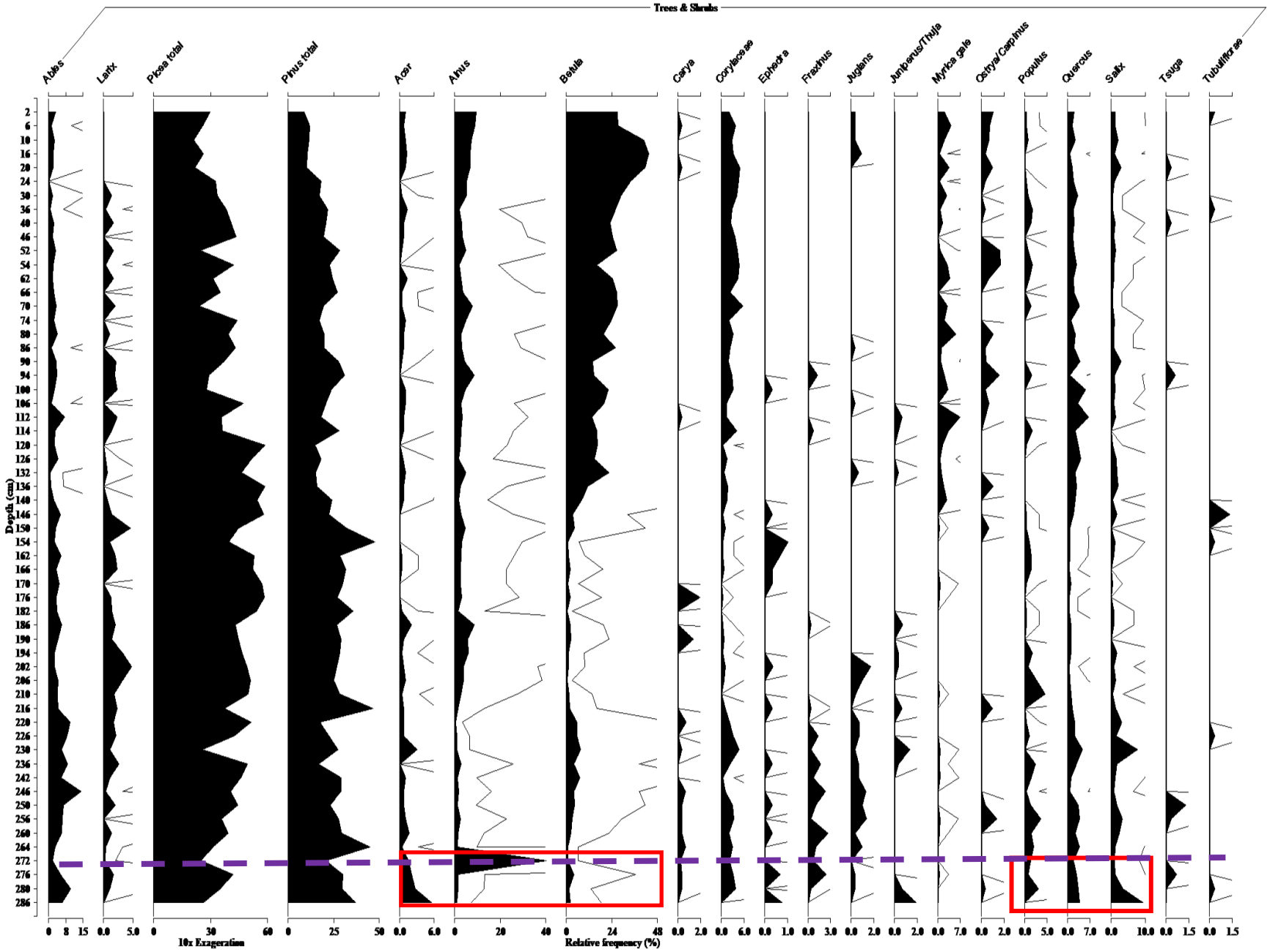


Figure 7.2 Pollen profile core WTFSH08-01. Red rectangles indicate thermophilous species present postglacially at 5% or more.

7.2.2 Unit C

Unit C starts at ~ 290 cm and ends at ~110 cm during the middle Holocene. The sediment structure changes from that of clay and silt varves to that of platy and prismatic ped-like structures at roughly 290 cm. These ped structures occur as part of the pedogenic process as the soil forms beginning sometime before 9,000 ^{14}C (figure 6.4, chapter 6). At the lower boundary of unit C (290 cm – 260 cm) the peds appear platy and they gradually become more angular and prismatic up to 110 cm. The presence of ped-like structures and lower water content suggests that a very shallow (and perhaps periodically dry) lake existed in the Whitefish Lake area or at least encompassed the western basin following drainage of the proglacial lake but before ~ 4300 ^{14}C BP.

Pollen zone 2 (figure 6.3) correlates with unit C of the lithostratigraphy (figure 6.2) around 9,000 – 9,200 ^{14}C yr BP. In subzone 2b, there appears to be a short period of early boreal forest dominated by spruce. The environmental indicators appear to shift at 272 cm. Figure 7.3 shows the non-arboreal pollen starts to increase at this point, ~8900 ^{14}C yr BP, including *Amaranthaceae* (amaranth), *Ambrosia* (ragweed, goldenrod), *Chenopodiineae* (goosefoot), and *Poaceae* (grass). *Ambrosia* is a drought tolerant plant that does well in a variety of disturbed areas like upland prairies where topsoil is exposed. *Chenopodiineae* is a weedy species that typically grows in a variety of soil types preferring disturbed areas that are well drained. Collectively these arboreal plants suggest an open landscape developing such as an open parkland-forest. Sedges are most abundant in subzone 2a (figure 7.3). Sedges (e.g. *Cyperaceae, Scirpus*), in general prefer water saturated soil and are commonly found in sunny areas around ponds and lakes, meadows, bogs, fens and marshy areas. Aquatic plants have a very small and short-lived presence postglacially, disappearing or decreasing substantially at 276 cm (~8900 ^{14}C

yr BP). The overall presence of arboreal pollen shows a decline (fig. 7.2). The coniferous tree assemblage shifts from *Picea* dominant to *Pinus* dominant and the deciduous trees persist but decline as well (figure 7.2). This change is consistent with a drier and more open savannah vegetation. The prolonged arid conditions were likely more susceptible to fire, as indicated by the presence of oak (Randall and Harr, 2014), and periods of drought, as indicated by the shift to pine (drought tolerant) dominated forests.

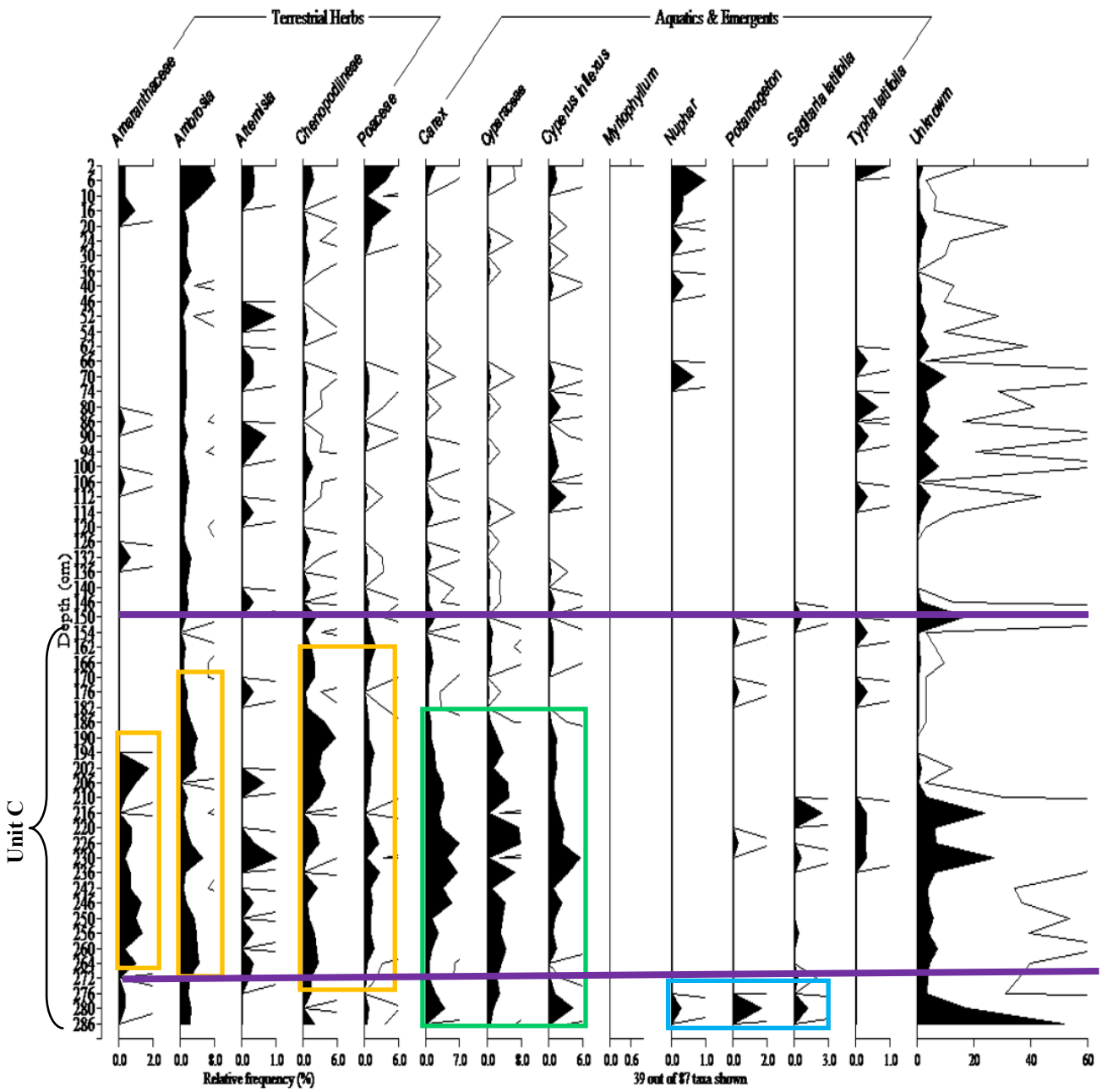


Figure 7.3 Pollen profile of of terrestrial herbs, aquatics and emergents. The rectangles demonstrate notable relative ecological changes among certain plants. The purple line represents general vegetation changes across all vegetation zones.

Phytolith samples were also analysed from this zone in order to clarify the implications of increased grass pollen (figure 7.4). The purpose of the additional analysis was to determine if the increased presence of grass in the area could be linked to colonization of wild rice. Although, the phytoliths counted were small in number they provide evidence that wild rice established itself in the lake at some point around 6,000 ^{14}C yr BP and definitely before 4,330 ^{14}C yr BP. Whether it had arrived before the mid Holocene began or after has yet to be determined, the evidence does point to it being present locally early during the mid Holocene.

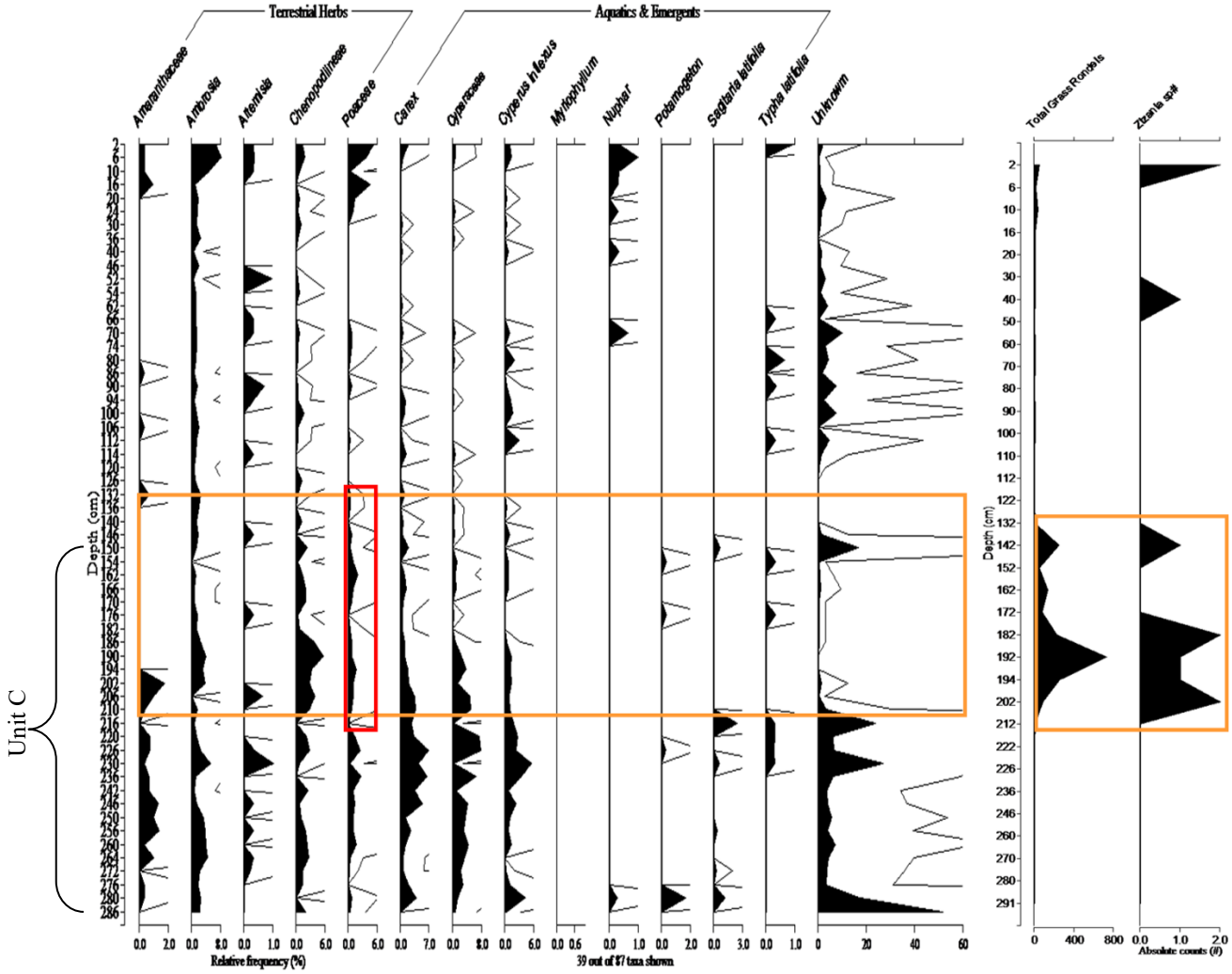


Figure 7.4 Grass and *Zizania spp* phytoliths compared to NAP (non-arboreal pollen). The red box is the highlights the *Poaceae* pollen. The orange box compares the phytolith data to the herb and aquatic vegetation in general.

7.2.3 Unit B

Unit B lithostratigraphy begins at 150 cm, sometime around or just before 4,905 cal (4,330 $\pm$ 40 ^{14}C) yr BP, where the ped-like structures stop and the water content increases substantially. This also coincides with the appearance of fibrous plant debris. This demonstrates that the climate shifted from dry conditions to wetter ones as the lake water level started to rise. Sedimentation increases again in the beginning of this unit as water flow begins to increase into the basin.

The pollen data suggests a climatic change as well. *Betula*, which had been present in small quantities of less than ~ 6%, begins to increase sometime before ~ 4,905 cal (4,330 $\pm$ 40 ^{14}C) yr BP at ~ 150 cm. Other thermophilous deciduous trees increase as well including *Quercus*, *Salix*, and *Alnus.* The increasing presence of *Quercus* is particularly interesting because it requires intense heat from fire to regenerate (Randall and Harr, 2014). Both *Pinus* and *Picea* decrease but remain present. There is a shift in the non-arboreal pollen sequence as well. The grass pollen appears to decrease as *Ambrosia* rises gradually. This observation may be demonstrating an increase in productivity, both within the lake basin and the surrounding area. As noted before, there is an increase in thermophilous trees and an overall increase in AP (arboreal pollen) during this time, leading to the formation of the boreal forest. As seen in figure 7.6, the pollen sequence changes at roughly the same time as the sediments change. The AP sequence tends to encompass both lithostratigraphic unit A and B.

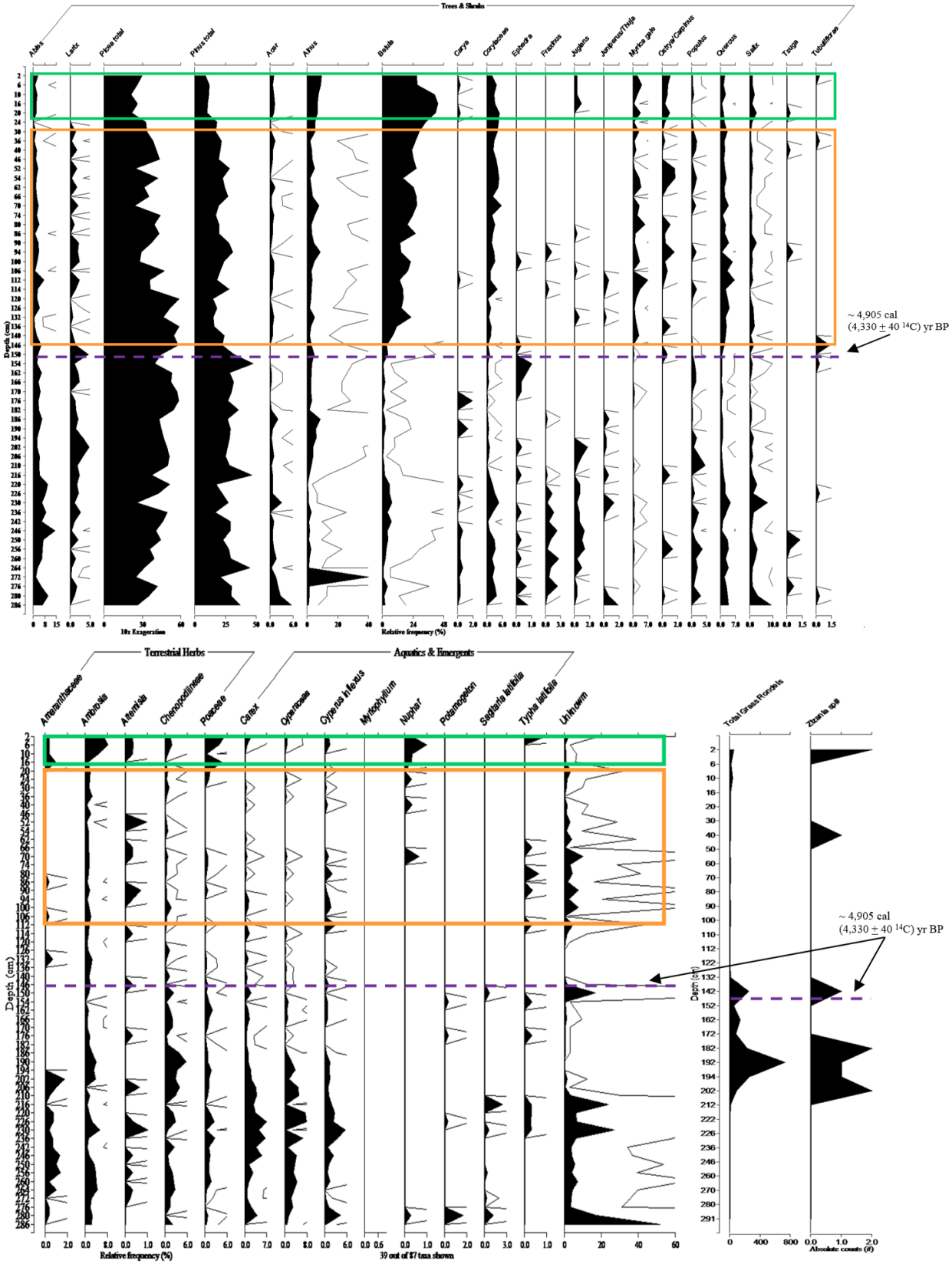


Figure 7.5 AP, NAP and phytolith sequence showing oldest reliable radiocarbon date obtained from core WTFHS08-01. Green box represents unit A. Orange box represents unit B.

7.2.4 Unit A

Unit A begins at 20 cm and continues to the top of the core, with a date of ~ 2,760 cal (2,640 $\pm$ 40) yr BP at the AB boundary (figure 7.4 and 7.5). One major difference observed in this unit is the gelatinous texture that is present. This indicates an increase in productivity in the lake as gelatinous sapropel is produced from algae and fungal ooze (Leeder, 2010). In figure 7.4, there is a significant increase in *Alnus* and *Betula* as well as an increase in *Ambrosia* (up to 8%), Poaceae (up to 6%), and *Nuphar* (1%). There is a slight discrepancy between the AP and the NAP sequences. The AP trends appear to shift slightly earlier than the NAP. This could be due the trees and shrubs responding faster to climate changes or that the local vegetation nearest the lake basin is affected differently.

The short cores contain sediments that appear to be the same to one another with gelatinous sapropel. This observation suggests that they could all belong to the same time line representing the same or portions of the same sequence of events. Because no radiocarbon dates are directly associated with any of the short cores, it is difficult to know for sure if the short cores represent all of the missing modern vegetation for the long core or if there are more sediments missing. Inferences will be made by observations of the pollen sequences and an attempt will be made to place the short core sequences within the long core.

Short cores WTFSH16-01-RC and WTFSH 16-02-RC (figures 7.6 and 7.7) show definite similarities. For example, the green line in both figure 7.6 and 7.7 show a general increase in AP, particularly *Betula* and *Alnus*. *Quercus* remains steady with only subtle fluctuation and *Picea* and *Pinus* decrease slightly in both graphs. The AP observations that the pollen sequence in both cores is recent. They could be placed in the upper zone of core WTFSH08-01 (figure 7.8) (marked with a green rectangle) or they may represent a more modern vegetation beginning

in the top 10 cm of the long core. There is also the possibility that they may not be represented in the long core at all. The green line in both figures (7.6 and 7.7) demonstrate a similar trend happening with the NAP sequence.

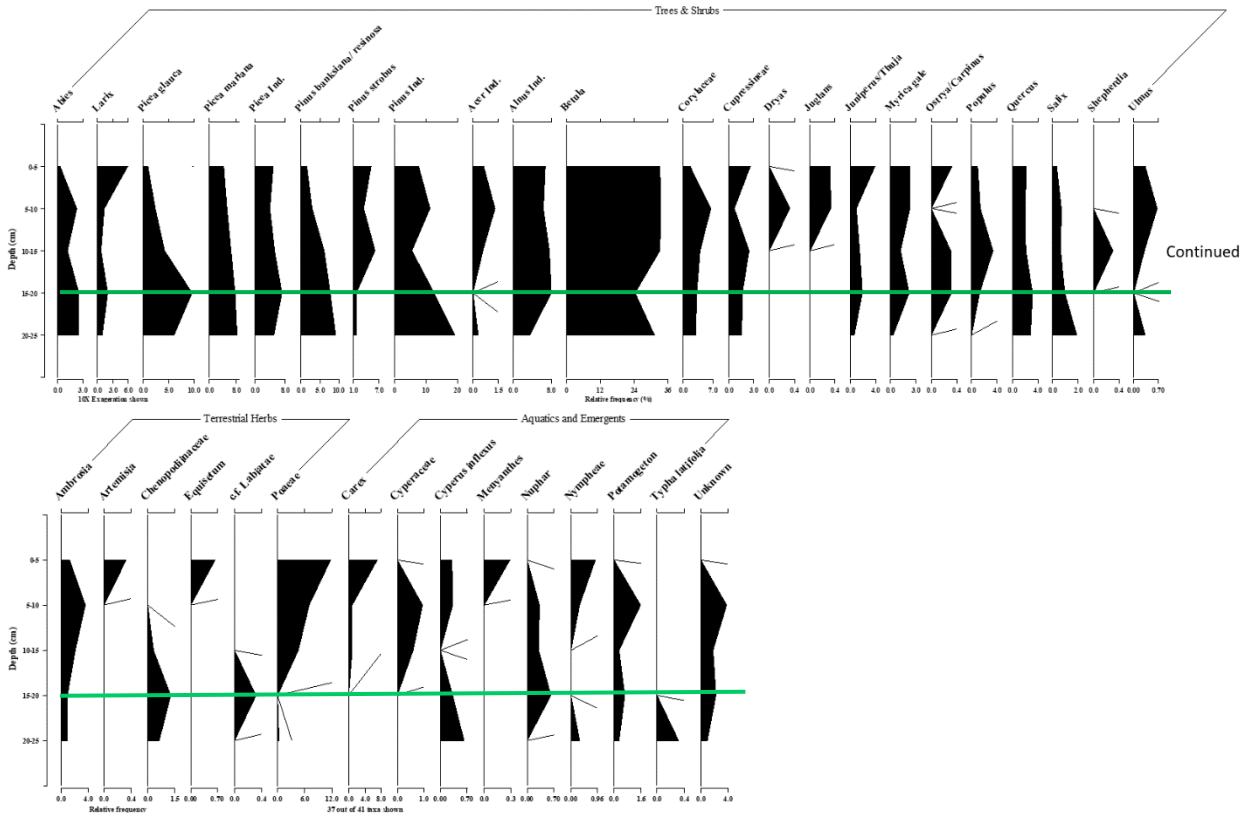


Figure 7.6 Short core WTFSH16-01-RC. Green line represents 15-20 cm depth interval.

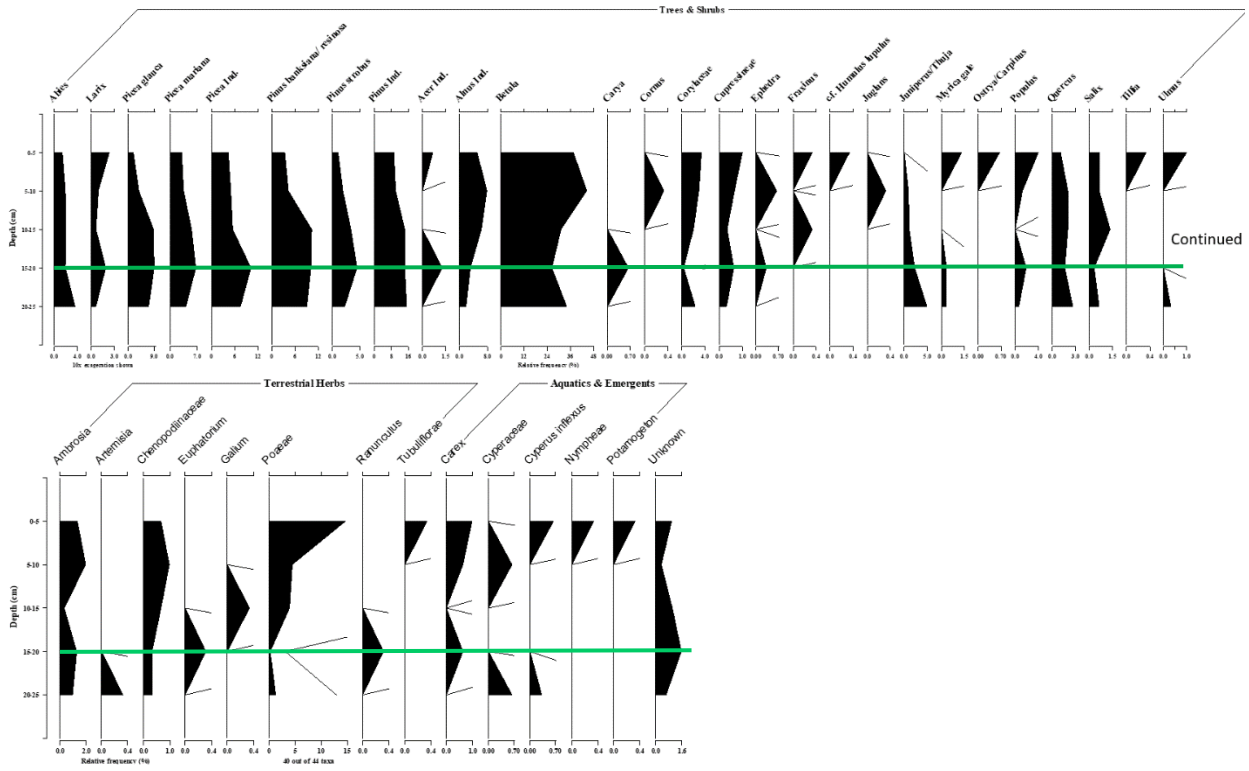


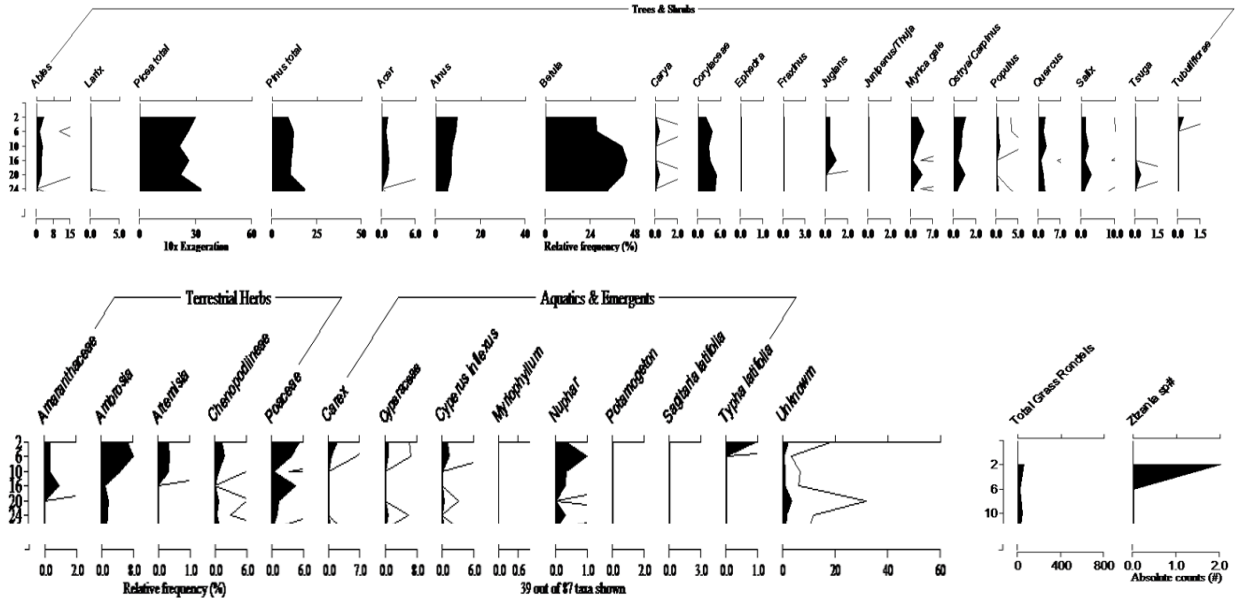
Figure 7.7 Short core WTFSH16-02-RC. Green line indicates 15-20 cm depth interval.

However, there are some additional differences between the two cores. There is a greater variety of terrestrial herbs in core WTFSH16-02-RC (figure 7.7) and core WTFSH16-02 contains a larger variety of aquatic and emergent plants. These differences could be due to sampling biases based on the specific locations the cores were retrieved from or biases in the sampling techniques. Because only 3 cc were processed from each sample, the pollen could have been easily missed. Another, more likely cause of the differences is the local vegetation. It could be that more aquatic and emergent plants are present at the site of WTFSH16-01-RC. Water levels and nutrients may vary slightly between the two areas causing differing growing conditions. It is difficult to determine the cause of the differences without doing additional sampling and testing.

Core WTFSH08-02 shows the analysis of pollen and wild rice phytoliths (figure 7.8). The red and green lines drawn over the WTFSH08-02 sequence gives two possible areas of

overlap. The short core could overlap with the larger core at the 28-30 cm depth interval (red line, figure 7.8). This would indicate that the vibracorer managed to capture a fair bit of the modern sedimentation sequence. The green line is another possible area where the short core could begin showing a much smaller area of overlap. Given the softness of the gelatinous sapropel, it is more likely that the green line (15-20 cm depth) shows the area of overlap assuming the two cores correlate at all.

Long Core WTFSH08-01



Short Core WTFSH08-02

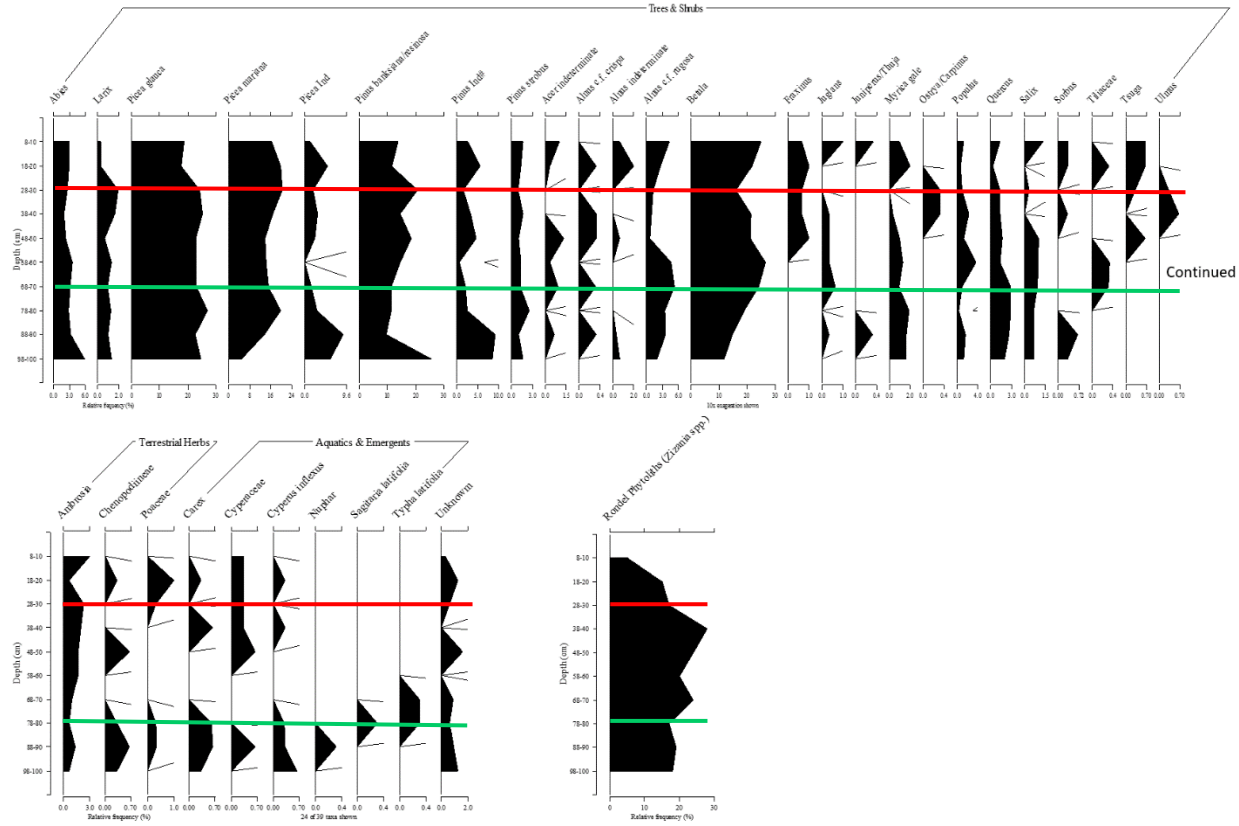


Figure 7.8 Core WTFSH08-01 compared to core WTFSH08-02 pollen and phytolith profiles. Red line is 28-30 cm and the green line shows the 78-80 cm depth.

When comparing the grass data from all the cores collected (figure 7.9) similarities are observed between them. For example, they all show an increase in grass to roughly the same percentage: between 10 % – 15 %. An interesting observation in core WTFSH08-02 is there appears to be a hiatus in grass pollen but not in the phytolith data. Figure 7.9 shows an increase in *Betula*, *Pinus*, *Populus*, *Ambrosia*, and in the sedges in general. The relative increase in pollen influx from other plants could be overshadowing the presence of grass pollen, and not that wild rice temporarily disappeared from the basin. The phytolith data demonstrates the continued presence of wild rice, representing up to 30 % of the overall grass phytoliths present (not shown here). The presence of *Zizania* phytoliths directly contradicts the missing pollen data, suggesting that wild rice was present (phytoliths accumulated in situ) and therefore pollen is not always a reliable source of information. However, pollen together with phytolith data provide a more comprehensive multiproxy analysis of local vegetation at the coring site.

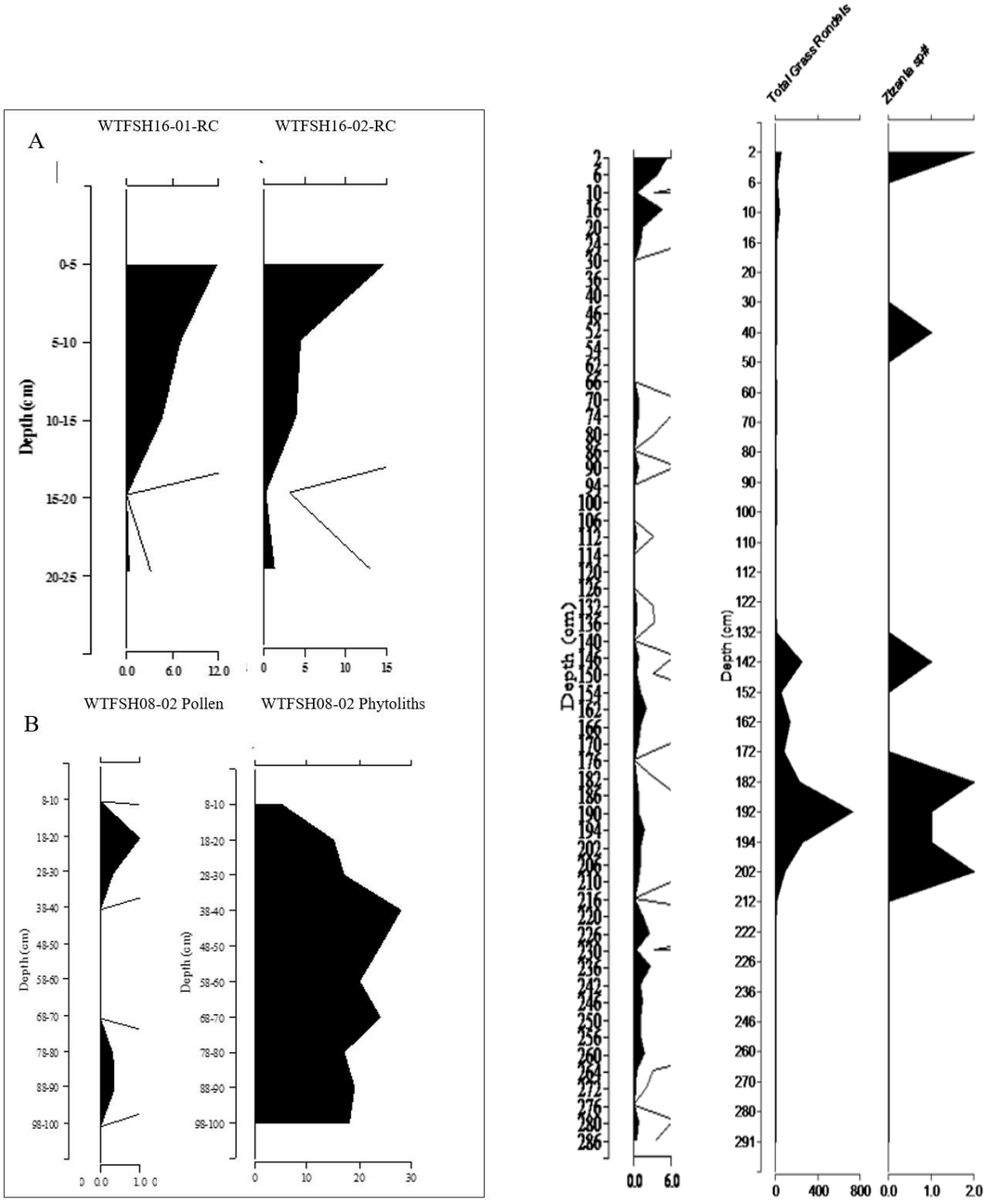


Figure 7.9 Graphs showing grass pollen and phytoliths analyzed for all cores collected for this study. Left) the short core profile, Right) Long core profiles (WTFSH08-01) (Phytolith data taken from Boyd et al., 2013). The shaded areas are the actual percentages and the lines represent a 10x exaggeration.

7.3 Discussion

Whitefish Lake was once part of a larger water body before it became a discrete headwater lake. The lithostratigraphic, pollen and phytolith analysis presented in this thesis point to a long history of vegetation activity in the area following the retreat of the LIS roughly 10,000 ^{14}C yr BP (Bajc et al., 2000; Dyke, 2005; McAndrews, 1982). This section summarizes the previous interpretations as they pertain to the ecological and climatic trends that occurred throughout northwestern Ontario.

The varved sediments from Whitefish Lake basin indicate that there was once a deep-water environment, perhaps a proglacial lake, occupying the area. The light and dark rhythmites are consistent with those recovered from Mokomon Lake, which date to between 9,345-9,510 $\pm$75 ^{14}C yr BP (Loope, 2006), and those described from Lake Superior dating to its proglacial lake phase (Dell, 1973). In Loope's (2006) study, Whitefish Lake appears to form part of glacial Lake O'Connor, which was fed by glacial melt-water from the Superior Lobe (figure 7.10). Although glacial Lake O'Connor shorelines have not been identified yet, it is likely that Whitefish Lake was part of glacial Lake O'Connor due to its elevation (Loope, 2006). Echo Lake, in northwestern Ontario, also revealed varved sediment (Thunell et al., 1995; Zolitschka, 1996; Zolitschka et al., 2015), suggesting a proglacial lake once existing there. The Echo Lake varved sediments offer similar dates to those from Lake Mokomon (9,360$\pm$90 ^{14}C) yr BP. The data from both dates concur with the drainage timeline for proglacial Lake Kaministiquia, a glacial lake that existed after Lake O'Connor (Loope, 2006). The bioturbation noted within the Whitefish Lake core, WTFSH08-01, appear similar to those found in the Harstone Cut rhythmites, glacial Lake Minong (northeast of Thunder Bay), and glacial Lake O'Connor (figure 7.10). Loope (2006) proposes that the bioturbation within the winter beds may represent a slide

or slump generated turbidity caused by decreasing lake levels during the winter season (Shaw, 1977; Shaw et al., 1978). Sometime after ~ 9,700 ^{14}C yr BP, glacial Lake O'Connor no longer existed. Instead, glacial Lake Kaministiquia formed to the north and glacial Lake Kakabeka to the east of Whitefish Lake (figure 7.11) (Loope, 2006).

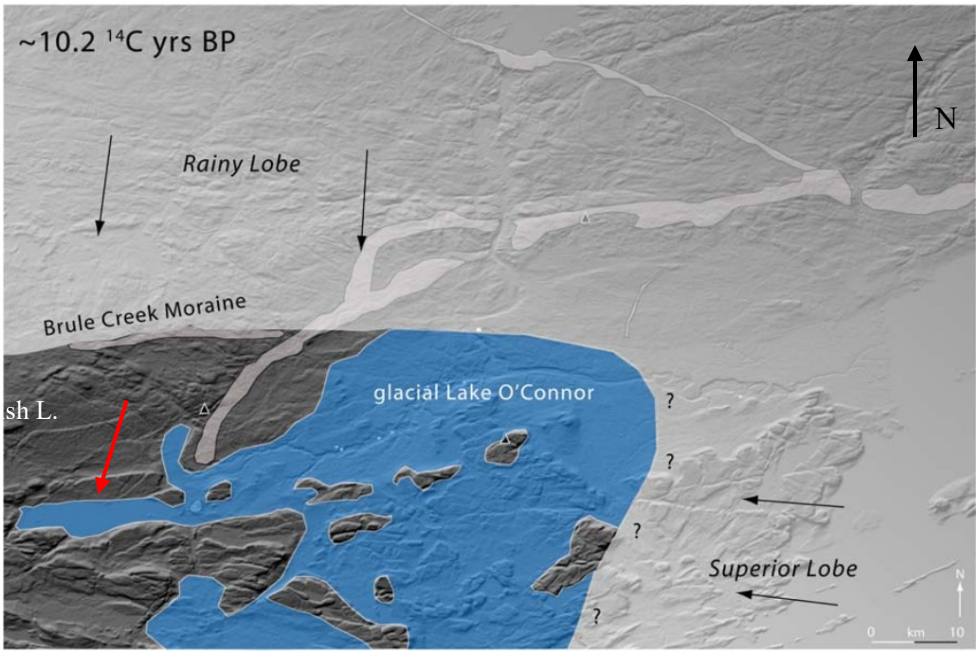


Figure 7.10 Glacial Lake O'Connor. Red arrow represents Whitefish Lake (from Loope, 2006: figure 15).

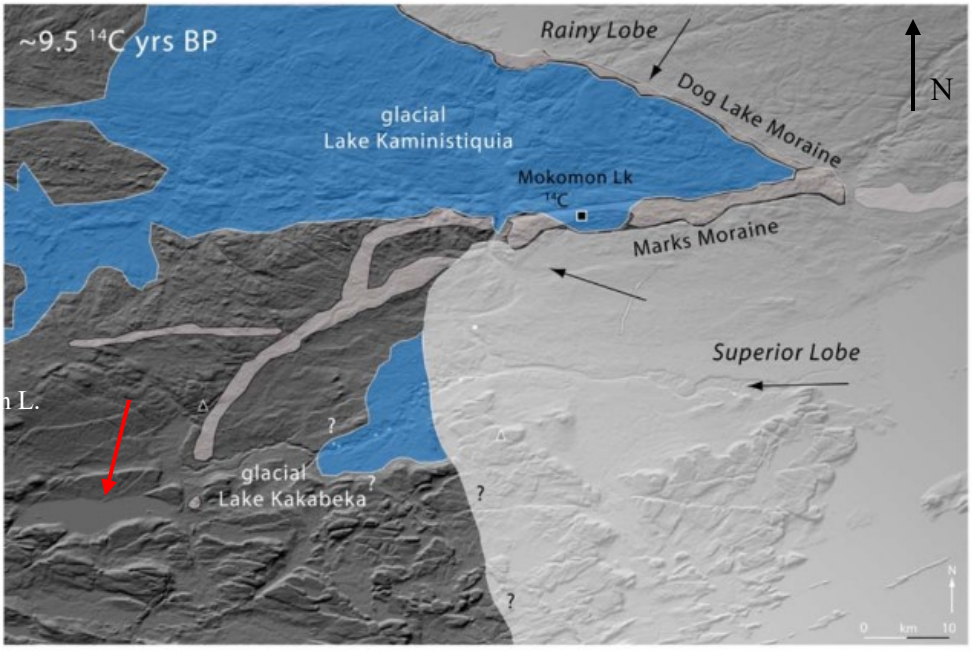


Figure 7.11 Glacial Lake Kaministiquia. Red arrow represents Whitefish Lake (from Loope, 2006: figure 15).

At around the same time that glacial Lake O'Connor ceased to exist (roughly 9,700 ^{14}C yr BP), the hydrology in the Whitefish Lake basin began to change. Figure 7.11 (Loope, 2006) provides a rough estimate as to when the hydrology in the Whitefish Lake basin begins to change after 10,000 ^{14}C yr BP (Dyke, 2005; McAndrews, 1982; Moos, 2011). The boreal forest changes at this time to a more open forest as the climate shifts from cool and moist to warm and drier. Areas to the south and west appear to experience these trends much earlier as they would have been ice-free first. In northern Minnesota, the warming period begins around 11,000 yr BP (Fries, 1962; Huber, 1995; Janssen, 1967; McAndrews, 1966).

The sediment in unit C shows a drop in lake levels as glacial Lake O'Connor drained during the early-mid Holocene. The Houghton Low phase also occurs during this period but is the result of outlet down cutting, the initial cause of lake levels dropping at several sites in the Superior basin (Boyd et al., 2010; Farrand and Drexler, 1985; Saarnisto, 1974; Yu et al., 2010). Reconstructed temperatures from Lake 239 indicate an increase in summer and winter temperatures between 8,600 cal-4,500 cal yr BP (Moos, 2011). The pollen data and lower lake levels at Whitefish Lake suggest a drier and warmer period beginning sometime before 9,000 ^{14}C (10,500 cal) yr BP (Boyd et al., 2013). Moos (2011) and Bjork (1985) also discuss a significant change in the forest structure in northwestern Ontario around 8,600 cal yr BP. Moos (2011) reports a decrease in *Picea* and *Pine* during the middle Holocene with an increase in herbaceous pollen. This pattern has also been observed in the Whitefish Lake core (WTFSH08-01). Among the herbaceous plants that increase during this warming period are *Ambrosia* and *Chenopodium*, which are drought resistant heat tolerant plants. Birch increases slightly as well and Flakne (2003) observed the presence of *Betula*, a pioneering species, on Isle Royal, Michigan, by ~ ca. 8,700 yr BP and Björk (1985) noted that the warmer, drier climate favoured other deciduous

trees like *Fraxinus, Quercus,* and *Ulmus* (elm). Although no *Ulmus* was identified during this study, there are enough similarities to suggest a general shift in vegetation composition to a more open forest across the region. Standing tree trunks have been found preserved upright in the Old Fort William site (cut bank) (Boyd et al., 2010; Boyd et al., 2012; Kingsmill, 2011).

The discovery of a buried forest within the Thunder Bay area (Old Fort William site) dating to 8,900 cal yr BP (Boyd et al., 2010; Kingsmill 2011) provides proof that Glacial Lake Minong levels became extremely low allowing trees to inhabit lake and river basins. At the same time as the newly opened outlets were draining glacial lakes, the warmer and dryer trend had an additional affect on upland systems such as Whitefish Lake. Water levels at Whitefish Lake, as elsewhere, decreased significantly producing the ped-like structures discussed earlier. As water levels decreased, lake and river basins opened up to terrestrial plants. The extended arid climate conditions likely encouraged trees and other terrestrial vegetation to colonize the newly opened areas. The basins remained well drained long enough to allow the terrestrial vegetation to form forest ecotones producing parkland or savannah landscape before the water returned to the area and drowned the forest in a relatively short period.

The long core (WTFSH08-01) from Whitefish Lake also shows evidence for the establishment of wild rice (*Zizania spp.*) in the lake. Grass pollen increases before 4,905 cal (4,330 $\pm$ 40 ^{14}C) yr BP during the mid-Holocene. At 212 cm, ~6,000 ^{14}C yr BP, the phytolith evidence demonstrates that some of the grass pollen derives from wild rice (Boyd et al., 2013). The age-depth model (figure 6.4) suggests that the wild rice may have entered the area as early as 5,000 ^{14}C (6,100 cal) yr BP (Boyd et al., 2013). Huber (1995) discusses a similar pollen trend in Lake Gegoka estimating the establishment of wild rice to occur sometime between 6,000-7,000 BP and even earlier appearance of wild rice at Wolf Creek around 9,000 yr BP (Huber,

2000). The short core (WTFSH08-02) supports the interpretation of the long core (WTFSH08-01), demonstrating that wild rice flourished during the late Holocene sometime around 2,760 cal (2640 $\pm$40 ^{14}C) yr BP. Whitefish Lake appears to have become intensely occupied by humans at this time. It remains difficult to determine whether shifting climatic conditions favoured the local development of wild rice, or if more intensive human intervention contributed to the success of wild rice.

Units A and B represent the Late Holocene. During the early part of the Late Holocene thermophilous trees increased including *Betula, Quercus*, *Salix* and *Alnus*. However, the NAP suggests a decrease in temperature and increase in available water. This phenomenon may suggest anthropogenic involvement as opposed to natural climatic and environmental events.

Although, *Pinus* and *Picea* decrease slightly they remain constant suggesting a return to boreal forest conditions. There is an overall cooling effect, suggested by the decrease in NAP. This is in agreement with other data collected by McAndrews (1982), Björk (1985), and Moos and Cummin (2011) and remains stable to the present.

7.4 CONCLUSION

The sediments and botanical microfossils addressed in the cores through this study reveal several events following the retreat of the Laurentide Ice Sheet (LIS). These events include: 1) a deep-water proglacial lake occupied the study area (likely glacial Lake O'Connor as documented by Loope 2006); 2) a subsequent prolonged warm, arid phase indicated by the observation of ped-like structures in the sediment sequence of Unit C. There is also increased presence of drought resistant herbs and sedge vegetation; 3) the establishment of wild rice (*Zizania spp*) in

the lake; 4) an increase in lake productivity beginning in the late Holocene and continuing to the present.

The presence of thermophilous deciduous trees (*Fraxius, Quercus, Alnus,* and *Betula*) early in the sequence suggests the early Holocene supported a variety of vegetation that has no analogue in the modern northern boreal environment, possibly due to shelter provided by the glaciers from the arctic winds (Crawford, 2013). The increased presence of herbaceous plants (*Ambrosia, Chenopodiineae,* and *Poaceae*) in the pollen sequence also indicates a warmer and drier period (Björk, 1985; Huber, 1995; McAndrews, 1966; Moos and Cummins 2010).

The overall lack of grass pollen in the sediment of Whitefish Lake was probably due to the location chosen to core, the large size and shallow nature of the lake, which would have caused an under-representation of non-arboreal pollen and other typically 'weak flyers'. Thus, pollen-based methods to identify the presence of wild rice (e.g., Huber 2000; Lee et al. 2004; McAdrews 1969) were inappropriate for Whitefish Lake. In contrast, the successful recovery of wild rice phytoliths from the lake sediment in this basin indicates that phytoliths should be routinely employed to identify wild rice in similar depositional contexts. However, as the lake is biologically active the additional use of nitex cloth to filter out the abundant presence of diatoms is necessary in order to collect and analyze the phytolith data of interest.

Based on the phytolith record at Whitefish Lake, it is apparent that wild rice was locally present by as early as ~6,000 ^{14}C yr BP and possibly earlier. It is not known if wild rice spread naturally (McAndrews, 1969) or due to human involvement (Buchner 1979; Johnson, 1969a). However, wild rice has been shown to thrive better with human intervention. It is noted that the occurrence of this plant in Whitefish Lake corresponds to a climate shift and an increase in lake productivity. This suggests that wild rice colonization was controlled by environmental factors;

growth of this plant in the lake would probably not have been possible during the middle Holocene at Whitefish Lake if the basin was periodically dry. With climatic amelioration in the Late Holocene and the establishment and stabilization of the modern lake configuration, wild rice colonization would have created a large and stable food supply for resident human populations**.**

Others have suggested a connection between the appearance of Laurel (the first pottery-producing culture in the boreal forest) and wild rice. It was believed that the adoption of pottery might have been necessary for the processing and storage of large quantities of wild rice in the Upper Great Lakes. This economic shift has been used to explain the advent of burial mound ceremonialism and other indications of greater social complexity in the middle Woodland period (Johnson, 1969a; Gibbon and Caine, 1980; Buchner, 1979; Stoltman, 1973; Rajnovich 1984). Food residue analysis from sites surrounding Whitefish Lake show that wild rice was consumed by Middle and Late Woodland peoples. However, our study indicates that wild rice was present well before Middle Woodland cultures established themselves in the area. These findings indicating that late Middle Period peoples (Archaic) could have exploited this resource in northern Ontario, as they have in the upper United States (figure 3.4, table 1; chapter 2), but have yet to be discovered. The lack of Middle Period archaeological sites in Northwestern Ontario may be due to site visibility for two reasons; 1) the large number of Late Period Woodland sites and artifacts may over shadow Middle Period sites in the area; 2) environmental changes are also factors that need to be considered. The period in which the Middle Period cultures would have inhabited the area would have been during the Middle Holocene when water levels were much lower. This suggests that Middle Period archaeological sites are under water, out of sight and out of reach for researchers.

Whitefish Lake and the surrounding area has been important to First Nations People, particularly the Seine River First Nation, for over 2000 yrs. Archaeologically, several Middle and Late Woodland sites have been reported on Whitefish Lake with Paleo sites in the surrounding area. Whitefish Lake appears to be culturally and economically important as several sites contain some evidence of wild rice consumption. Although no Middle Period sites have been reported, recent excavations at the Macgillivray site (field season 2017) have produced an unconfirmed Archaic biface (Surette, 2017 Pers. Comm.), adding to the strong possibility that they occupied the area as well, taking advantage of the abundant food resources, in particular wild rice, that was and continues to be available in the area. The question remains of whether or not wild rice was brought into the area by Middle Period cultures or were they attracted to the area by already established stands of wild rice.

If indeed, people brought wild rice into the area it would have been by Middle Period cultures given that it pre-dates the Late Period Woodland cultures. If it did establish itself naturally, it would be dependent on animal migrations and waterways. It would be beneficial to examine river systems that drain through Whitefish Lake and nearby lakes to look for indications that wild rice existed earlier during the late Early Holocene or the early Middle Holocene. If none exists then it pushes the likelihood that people brought it with them from the south and seeded the lakes in more northern areas.

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Appendix A

WTFSH08-01 POLLEN DATA (N 48 13.506', W 90 03.882', +/- 8 m)

Depth	Abies	Larix	Picea glauca	Picea mariana	Picea Ind	Pinus banksiana/ resinosa	Pinus strobus	Pinus Ind.	Acer cf. negundo	Acer cf. saccharum	Acer cf. saccharinum	Acer ind.	Alnus cf. crispa	Alnus cf. rugosa	Alnus ind.	Aquifoliaceae	Betula	Carya	Cornaceae	Corylaceae	Cupressaceae	Eleagnaceae	Ephedra	Fraxinus	Juglans	Juniperus/ Thuja	Myrica gale	Morus	Ostrya/ Carpinus	Populus	Potentilla	Quercus	Rosaceae	Salix	Sorbus	Tiliaceae	Tsuga	Tubuliflorae	Ulmus
2 cm	9	0	67	21	2	23	0	3	0	0	0	3	2	26	0		81	0	0	6	0	0	0	0	1	0	6	0	3	1	0	6	0	3	0	0	0	1	0
6 cm	3	0	59	18	0	30	0	5	0	0	0	2	1	23	2	0	81	1	0	11	0	0	0	0	1	0	12	0	2	1	0	4	0	3	0	0	0	0	0
10 cm	7	0	43	18	3	34	0	0	0	0	0	3	0	22	0	0	124	0	0	8	0	0	0	0	1	0	6	0	2	2	0	7	0	6	0	0	0	0	0
16 cm	6	0	72	15	0	33	1	0	1	0	0	3	3	19	0	0	145	0	0	10	0	0	0	0	3	0	1	0	1	0	0	2	0	3	0	0	0	0	0
20 cm	6	0	47	16	5	26	2	3	0	0	0	3	1	20	0	0	130	1	0	15	0	0	0	0	0	0	11	0	3	0	0	4	0	9	0	0	1	0	0
24 cm	0	0	88	21	0	60	0	0	0	0	0	0	2	14	1	0	113	0	0	15	0	0	0	0	0	0	1	0	1	1	0	6	0	3	0	0	0	0	0
30 cm	5	4	76	22	3	49	1	1	0	0	0	1	1	14	0	0	86	0	0	12	0	0	0	0	0	0	8	0	0	2	0	9	0	1	0	0	0	0	0
36 cm	2	1	103	9	4	65	0	1	0	0	0	4	1	3	2	0	79	0	0	8	0	0	0	0	0	0	2	0	1	5	0	5	0	1	0	0	0	1	0
40 cm	6	5	91	20	13	56	1	5	1	0	0	1	2	7	0	0	70	0	0	7	0	0	0	0	0	0	4	0	0	4	0	6	0	3	0	0	1	0	0
46 cm	5	0	116	16	3	56	2	2	0	0	0	2	2	7	1	0	75	0	0	11	0	0	0	0	0	0	0	0	0	0	0	5	0	2	0	1	0	0	0
52 cm	9	5	39	19	19	64	1	24	0	0	0	1	3	10	2	0	83	0	0	13	0	0	0	0	0	0	2	0	5	2	0	6	0	4	0	0	0	0	0
54 cm	6	1	84	21	25	56	1	13	0	0	0	0	0	6	0	0	49	0	0	14	0	0	0	0	0	0	9	0	5	5	0	8	0	2	0	0	0	0	0
62 cm	5	5	38	25	33	42	2	31	0	0	2	2	1	6	1	0	75	0	0	13	0	0	0	0	0	0	11	0	2	3	0	5	0	2	0	0	0	0	0
66 cm	7	0	82	23	4	78	1	5	0	0	0	1	1	10	0	0	83	0	0	7	0	0	0	0	0	0	0	0	0	0	0	6	0	1	0	0	0	0	0
70 cm	10	6	39	15	20	32	0	28	0	0	1	0	1	17	6	0	83	0	0	17	0	0	0	0	0	0	9	0	0	4	1	11	0	1	0	1	0	0	0
74 cm	7	0	##	13	7	48	0	5	0	0	0	3	1	13	1	0	74	0	0	6	0	0	0	0	0	0	6	0	0	0	0	3	0	3	0	0	0	0	0
80 cm	11	3	78	23	18	27	1	32	0	1	0	1	0	7	1	0	59	0	0	9	0	0	0	0	0	0	17	0	3	0	0	7	0	2	0	0	0	0	0
86 cm	3	0	78	22	32	53	0	7	0	0	0	2	2	7	0	0	79	0	0	7	0	0	0	0	1	0	3	0	1	0	0	6	0	2	0	1	0	0	0
90 cm	9	6	76	22	9	49	1	30	0	0	0	1	1	10	1	0	40	0	0	5	0	0	0	0	0	0	2	0	1	0	0	11	0	8	0	0	0	0	0
94 cm	11	6	62	20	13	60	8	33	0	0	0	0	6	19	3	0	47	0	0	9	0	0	0	4	0	0	6	0	5	5	0	2	0	3	0	0	2	0	0
100 cm	7	7	49	21	14	41	4	27	0	0	1	2	0	11	3	0	67	0	0	9	1	0	1	0	0	0	9	0	1	0	0	17	0	3	0	0	0	0	0
106 cm	3	0	##	15	6	55	2	6	0	0	0	3	1	5	2	0	60	0	0	4	0	0	0	0	1	0	0	0	2	0	0	9	0	2	0	0	0	0	0
112 cm	21	7	55	34	21	25	8	22	0	0	0	2	2	6	2	0	41	1	0	4	3	0	0	0	0	2	21	0	1	0	0	20	0	4	0	1	0	0	0
114 cm	8	4	68	29	13	57	8	20	0	0	1	1	1	7	0	0	49	0	0	12	0	0	0	2	0	1	10	0	0	5	0	7	0	0	0	0	0	0	0
120 cm	7	0	##	22	1	40	1	3	0	0	0	0	1	6	0	0	49	0	0	1	0	0	0	0	0	0	4	0	0	1	0	10	0	1	0	0	0	0	0
126 cm	14	1	##	26	29	49	0	14	0	0	0	2	0	6	0	0	52	0	0	5	0	0	0	0	0	0	2	0	0	0	0	14	0	5	0	0	0	0	0
132 cm	2	2	##	9	7	35	1	11	0	0	0	3	2	13	0	0	70	0	0	2	0	1	0	0	2	1	3	0	0	0	0	7	0	5	0	0	0	0	0
136 cm	2	0	##	18	54	26	0	21	0	0	0	2	2	3	2	0	34	0	0	5	0	0	0	0	0	0	5	0	3	0	0	8	0	6	0	0	0	0	0
140 cm	7	2	##	28	32	50	0	31	0	0	0	2	0	1	4	0	27	0	0	5	0	0	0	0	0	0	9	0	0	0	0	8	0	1	0	0	0	0	0
146 cm	15	4	##	18	45	41	0	27	0	0	0	0	2	6	0	0	10	0	0	1	0	0	1	0	0	0	0	0	0	1	0	5	0	5	0	0	0	4	0
150 cm	9	14	93	28	18	57	6	36	0	0	0	0	4	3	7	0	13	0	0	3	2	0	0	0	0	0	1	0	2	1	0	2	0	0	0	0	0	0	0
154 cm	7	3	78	24	17	113	0	30	0	0	0	0	1	8	0	0	2	0	0	1	0	0	3	0	0	0	0	0	0	3	0	2	0	3	1	0	0	1	0
162 cm	16	6	##	35	21	70	0	16	0	0	0	1	0	8	0	0	3	0	0	1	0	0	2	0	0	0	0	0	0	4	0	2	0	2	0	0	0	0	0
166 cm	10	7	##	36	24	81	1	15	0	0	0	1	0	6	1	0	6	0	0	2	0	0	1	0	0	0	0	0	0	4	0	1	0	0	0	0	0	0	0
170 cm	14	0	##	32	15	67	2	23	0	0	0	0	1	6	0	0	2	0	0	0	0	0	1	0	0	0	2	0	0	1	0	3	0	1	0	0	0	0	0
176 cm	10	4	##	33	4	77	3	6	0	0	0	0	3	6	0	0	6	6	1	1	0	0	0	0	0	0	1	0	0	0	0	1	0	0	1	0	0	0	0
182 cm	10	4	##	18	3	98	3	7	0	0	1	0	0	4	0	0	1	0	0	0	0	0	0	0	0	0	0	1	0	1	0	1	0	2	0	0	0	0	0
186 cm	17	6	##	22	2	69	2	10	1	3	0	2	0	26	0	0	6	0	0	1	0	0	0	1	0	2	0	0	0	1	0	3	0	2	1	1	0	0	0
190 cm	12	4	##	18	3	84	4	1	0	0	0	2	1	14	2	0	7	4	0	2	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0
194 cm	7	10	##	32	3	77	3	8	0	0	0	1	0	18	0	0	3	0	0	1	1	0	0	0	0	1	0	0	0	5	0	3	0	5	0	0	0	0	0
202 cm	7	14	##	24	18	50	8	21	0	0	1	1	1	10	0	0	3	0	0	3	0	0	1	0	5	1	0	0	0	2	0	1	0	2	0	0	0	0	0
206 cm	12	10	##	26	7	53	4	21	0	0	0	3	1	11	0	0	1	0	0	2	0	0	0	0	3	0	0	0	0	8	0	2	0	4	0	0	0	0	1
210 cm	11	5	95	19	30	50	7	25	0	0	1	0	0	7	1	0	4	0	0	0	1	0	0	0	1	0	1	0	0	13	0	3	0	1	1	0	0	0	0
216 cm	12	7	52	39	25	6	65	73	0	0	1	1	2	2	0	0	5	0	0	3	0	0	1	1	0	2	0	0	3	0	0	4	0	4	0	0	0	0	0
222 cm	28	5	85	14	54	31	1	20	0	0	0	2	0	1	0	0	16	2	0	6	0	0	0	0	2	0	0	0	0	1	0	6	1	9	2	0	0	0	0
226 cm	24	6	69	32	26	50	4	13	0	0	1	1	0	1	1	0	16	0	0	9	4	0	0	4	2	0	0	0	0	3	0	6	0	4	1	0	0	1	0
230 cm	17	3	36	19	22	27	1	54	0	0	0	9	0	2	0	0	22	1	0	14	7	0	0	1	1	4	2	0	0	0	0	14	0	23	0	1	0	0	0
236 cm	25	8	82	37	34	37	1	13	0	0	0	0	1	6	1	0	12	0	0	7	4	0	1	5	2	1	1	0	0	7	0	8	0	5	1	0	0	0	0
242 cm	16	3	83	34	22	68	5	15	2	0	1	0	0	3	0	0	21	0	0	1	0	0	0	2	2	0	2	0	0	4	0	3	0	3	2	0	0	0	0
246 cm	43	1	73	31	21	61	1	28	1	0	0	1	0	3	2	0	12	2	0	3	0	0	0	7	4	0	0	0	0	1	0	2	0	2	1	0	0	0	0
250 cm	20	6	76	27	35	61	0	10	0	0	0	2	0	2	1	0	13	1	0	9	2	0	1	3	3	0	0	0	1	4	0	10	0	5	0	0	4	0	0
256 cm	18	0	56	22	32	53	3	29	0	1	0	2	1	5	1	1	9	1	0	10	0	0	0	1	4	0	2	0	4	11	0	11	0	10	0	0	1	0	0
260 cm	17	4	76	10	35	67	1	22	0	0	0	5	0	3	1	0	7	1	0	6	0	0	1	8	1	0	1	0	0	4	0	7	2	7	0	0	0	0	0
264 cm	8	1	55	18	23	123	3	13	0	0	0	1	0	3	0	0	2	2	0	9	0	0	0	3	3	0	0	0	0	6	0	11	0	3	0	0	0	0	0
272 cm	8	1	71	16	32	78	3	18	1	0	0	6	##	3	10	0	3	1	0	10	0	0	0	3	0	0	0	0	0	6	1	8	0	4	1	0	0	0	0
276 cm	15	5	78	13	34	59	4	26	0	0	0	6	0	4	0	0	11	1	0	9	0	0	2	7	1	0	1	0	0	2	0	8	0	3	0	0	2	0	0
280 cm	29	3	55	27	26	25	12	54	0	1	1	6	0	2	2	0	4	1	0	11	2	1	0	1	1	2	0	0	1	9	0	10	0	10	0	1	0	1	0
286 cm	16	0	16	27	28	25	15	60	1	0	0	14	1	1	0	0	5	0	0	0	2	0	2	0	0	5	0	0	0	0	0	10	3	25	0	1	0	0	0

Depth	Agoseris	Amaranthaceae	Ambrosia	Artemisia	Asteraceae	Caltha	Chenopodiineae	Cruciferae	Dryas integrifolia	Ericaceae	Fabaceae/ Leguminosae	Galium	Gramineae/ Poaceae	Heliathus	Iva ciliata	Petalostemum purpureum	Thalictrum	Urtica	Urticaceae	Epilobium latifolium	Eupatorium perfoliatum	Polygonum	Polygonaceae	Carex	Cyperaceae	Cyperus	Hippuridaceae	Myriophyllum (exalbescens)	Nuphar	Nymphaeaceae	Potamogeton	Rumex	Typhaceae	Typha latifolia	Sagitaria	Zosteraceae	Unknown	Lycopodium Spike
2 cm	0	0	20	1	0	0	4	0	0	0	0	0	16	0	0	0	0	0	0	0	0	0	0	6	2	3	0	0	1	0	0	0	0	3	0	0	6	24
6 cm	0	0	24	1	0	0	5	0	0	0	0	0	11	0	0	0	0	0	0	0	0	0	0	2	2	4	0	0	3	0	0	0	0	0	0	0	1	13
10 cm	0	0	14	1	0	0	2	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	2	23
16 cm	0	0	3	0	0	0	0	0	0	0	0	0	15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	1	0	0	0	0	0	0	0	2	33
20 cm	1	0	5	0	0	0	2	0	0	0	0	0	4	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	10	12
24 cm	0	0	5	0	0	0	1	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	1	0	0	0	0	0	0	0	4	29
30 cm	0	0	4	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	3	4
36 cm	0	0	7	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0	6
40 cm	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	2	0	0	1	0	0	1	0	0	0	0	4	20
46 cm	0	0	6	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	0	0	0	0	0	3	16
52 cm	0	0	1	3	0	0	1	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	0	9	12
54 cm	0	0	3	0	0	0	2	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	0	3	14
62 cm	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	12	5
66 cm	0	0	3	1	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	0	1	0	0	1	2
70 cm	0	0	4	1	0	0	2	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	2	2	3	0	0	2	0	0	0	0	0	0	0	31	6
74 cm	0	0	4	0	0	0	1	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	9	12
80 cm	0	0	3	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1	1	6	0	0	0	0	0	0	0	2	0	0	13	21
86 cm	0	0	2	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	0	0	0	0	0	5	9
90 cm	0	0	4	2	0	0	1	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	21	8
94 cm	0	0	2	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	1	4	0	1	0	0	0	0	0	0	0	0	7	10
100 cm	0	0	4	0	0	0	5	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	3	0	5	0	1	0	0	0	0	0	0	0	0	23	6
106 cm	0	0	6	0	0	0	1	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	0	0	6
112 cm	0	0	4	0	0	0	1	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	1	0	9	0	0	0	0	0	0	0	1	0	0	14	7
114 cm	0	0	3	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	2	0	0	1	0	0	0	0	0	0	0	0	4	7
120 cm	0	0	2	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1
126 cm	0	0	3	0	0	0	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	6
132 cm	0	0	7	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	7
136 cm	0	0	6	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	4
140 cm	0	0	4	0	0	0	4	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	2	1	0	0	0	0	0	0	0	0	0	0	0	0	15
146 cm	0	0	5	1	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	1	1	3	0	0	0	0	0	0	0	0	0	0	4	13
150 cm	0	0	4	0	0	0	7	0	0	2	0	0	1	0	0	0	0	0	0	0	0	0	0	6	0	0	0	0	0	0	0	0	0	0	2	0	53	18
154 cm	0	0	0	0	0	0	1	0	0	0	0	0	3	1	0	0	0	0	0	0	0	1	0	0	3	2	0	0	0	0	1	0	1	1	0	0	1	43
162 cm	0	0	3	0	0	0	4	0	0	0	0	0	6	0	0	1	0	0	0	0	0	0	0	3	2	2	0	0	0	0	0	0	0	0	0	0	2	14
166 cm	0	0	2	0	0	0	6	0	0	0	1	0	3	0	0	0	0	0	0	0	0	0	0	4	3	2	0	0	0	0	0	0	0	0	0	0	3	10
170 cm	0	0	2	0	0	0	6	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	1	8
176 cm	0	0	5	1	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	1	0	0	1	0	0	1	7
182 cm	0	0	4	0	0	0	2	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	17
186 cm	0	0	7	0	0	0	11	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	3	2	1	0	0	0	0	0	0	0	0	0	0	1	32
190 cm	0	0	12	0	0	0	17	0	0	0	0	0	2	0	0	0	0	0	0	0	1	0	0	3	8	4	0	0	0	0	0	0	0	0	0	0	0	46
194 cm	0	0	9	0	0	0	10	0	0	0	0	0	5	0	0	0	0	0	0	0	0	0	0	6	12	4	0	0	0	0	0	0	0	0	0	0	0	46
202 cm	0	0	11	0	0	0	8	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	6	4	4	0	0	0	0	0	0	0	0	0	0	4	81
206 cm	0	0	0	2	0	0	12	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	1	12	16	3	0	0	0	0	0	0	0	0	0	0	1	91
210 cm	0	0	4	0	0	0	8	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	12	16	3	0	0	0	0	0	0	0	0	0	0	10	101
216 cm	0	0	2	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	9	1	6	0	1	0	0	0	0	0	1	8	0	80	76
222 cm	0	0	4	0	0	0	6	0	0	0	0	0	4	0	0	0	0	0	0	0	0	0	0	11	25	9	0	0	0	0	0	0	0	1	0	0	21	655
226 cm	0	0	7	1	0	0	8	0	0	0	0	0	7	0	0	0	0	0	0	0	0	0	0	25	28	8	0	0	0	1	1	0	0	1	0	0	23	1412
230 cm	0	0	15	3	0	0	2	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	15	1	19	0	0	0	0	0	0	0	1	2	0	93	1717
236 cm	1	0	3	0	0	0	0	0	0	0	0	0	8	0	0	0	0	0	0	0	0	0	0	24	23	12	0	0	0	0	0	0	0	0	0	0	22	1172
242 cm	0	0	2	0	0	0	7	0	0	0	0	0	3	0	0	0	0	0	1	0	0	0	0	11	3	2	0	0	0	0	0	0	0	0	0	0	11	723
246 cm	0	0	4	1	0	0	2	0	0	0	0	0	4	0	0	0	0	0	0	0	0	0	0	19	14	8	0	0	0	0	0	0	0	0	0	0	13	926
250 cm	0		10	0	0	0	3	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	4	11	3	0	0	0	0	0	0	0	0	0	1	18	959
256 cm	0	0	11	1	0	0	6	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	8	10	2	0	0	0	0	0	0	0	0	1	0	13	668
260 cm	0	0	12	0	0	0	7	0	0	0	0	0	5	0	0	0	0	0	0	0	0	0	0	4	14	4	0	0	0	0	0	0	0	0	0	0	23	1160
264 cm	0	0	13	1	0	0	8	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	2	10	0	0	0	0	0	0	0	0	0	0	0	13	1003
272 cm	0	0	10	1	0	0	6	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	3	11	1	0	0	0	0	0	0	0	0	1	0	18	867
276 cm	0	0	5	0	0	0	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6	9	3	0	0	0	1	0	0	0	0	0	0	10	1493
280 cm	0	0	7	0	0	1	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	14	5	15	0	1	1	0	6	0	0	0	4	0	63	1374
286 cm	1	0	6	0	1	0	5	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0	2	1	1	1	0	0	0	0	0	0	0	0	##	671

APPENDIX B

WTFHS08-02 POLLEN DATA (N 48 13.506', W 90 03.882', +/- 8 m)

Depth (cm)	Abies	Larix	Picea glauca	Picea Ind	Picea mariana	Pinus banksiana/resinosa	Pinus Ind.	Pinus strobus	Acer indeterminate	Acer cf. negundo	Acer cf. saccharum	Acer cf. saccharinum	Alnus cf. crispa	Alnus indeterminate	Alnus cf. rugosa	Betula	Carya	Cornaceae	Corylaceae	Cupressaceae	Fraxinus	Juglans	Juniperus	Myrica gale	Ostrya/Carpinus	Populus	Quercus	Salix	Sorbus	Thuja	Tiliaceae	Tsuga	Ulmus
8-10 cm	9	1	56	4	49	41	8	5	3	0	0	0	0	2	13	75	0	0	2	0	2	3	1	3	0	4	4	4	1	0	0	2	0
18-20 cm	9	1	54	16	60	35	17	4	1	0	0	0	1	6	8	66	0	0	4	0	3	0	0	6	0	2	1	0	1	0	1	2	0
28-30 cm	8	6	74	6	62	63	5	3	0	0	0	0	0	0	4	49	0	0	4	0	2	0	0	0	1	3	4	1	0	0	0	1	1
38-40 cm	6	5	77	9	51	44	10	5	0	0	0	0	1	0	3	65	0	0	3	0	2	1	0	1	1	7	4	0	1	0	0	0	2
48-50 cm	7	2	69	7	42	56	14	3	4	0	0	0	1	2	2	64	0	0	1	0	3	1	0	3	0	4	5	3	0	0	0	2	0
58-60 cm	11	4	70	0	43	44	2	4	1	0	0	0	0	0	14	80	0	0	1	0	0	1	0	4	0	11	4	3	0	0	1	0	0
68-70 cm	10	3	74	5	48	36	7	4	3	0	0	0	1	0	17	77	0	0	9	0	0	2	0	3	0	3	9	3	0	0	1	0	0
78-80 cm	9	4	86	9	63	36	8	8	0	0	0	0	0	0	11	60	0	0	2	0	0	0	0	6	0	1	9	2	0	0	0	0	0
88-90 cm	10	3	69	27	41	29	28	3	2	0	0	0	1	1	11	45	0	0	3	0	0	1	1	5	0	5	8	2	2	0	0	0	0
98-100 cm	18	4	75	18	15	78	26	5	0	0	0	0	0	2	6	36	0	0	0	0	0	0	0	5	0	4	6	2	1	0	0	0	0

Depth (cm)	Ambrosia	Chenopodiineae	Gramineae/Poaceae	Humulus	Carex	Cyperaceae	Cyperus inflexus	Nuphar	Myriophyllum (exalbescens type)	Typha latifolia	Sagitaria latifolia	Unknown
8-10 cm	9	0	0	0	0	1	0	0	0	0	0	1
18-20 cm	2	1	3	0	1	1	1	0	0	0	0	4
28-30 cm	7	0	1	0	0	1	0	0	0	0	0	2
38-40 cm	6	0	0	0	2	1	1	0	2	0	0	0
48-50 cm	5	2	0	0	0	2	0	0	0	0	0	5
58-60 cm	5	0	0	0	0	0	0	0	0	0	0	0
68-70 cm	3	0	0	2	0	0	0	0	2	1	0	3
78-80 cm	2	1	1	0	2	0	1	0	0	1	1	2
88-90 cm	4	2	1	0	2	2	1	1	0	0	0	3
98-100 cm	2	1	0	0	1	0	2	0	0	0	0	4

WTFSH08-02 PHYTOLITH DATA

Depth cm	Elongate Plates (gramineae)	Elongate Plates (smooth)	Elongate Plates (other)	Short Plates	Trichomes	Double Outlines	Saddles	Long Sinuous Trapezoids	Short Sinuous Trapezoids	Long Non Sinuous Trapezoid	Short Non Sinuous Trapezoid	Bilobates	Polylobates	Crosses	Bulliforms	Phytoliths unknown	Zea Mais Starch	Possible Bean Starch	Starch Unknown	Spike	1.A.I.a.i.	1.A.I.a.ii.	1.A.i.a.i.a.	1.A.I.b.i.	1.A.I.b.ii.	1.A.II.a.i.b.i.	1.A.II.a.ii.b.	1.A.III	1.B.II.	1.C.I.	2.A.I.a.	2.A.I.b.i.	2.C.I.b.1.a.i.	2.C.VII.a.ii.	3.A.I.a.	3.A.VI.a.	3.B.I.a.	3.B.IV.a.i.a.	3.B.IV.a.i.b.	3.B.IV.c.ii	3.C.I.a.i.b.	3.D.I.a.ii.	3.D.I.b.i.b.ii.	3.D.I.c.ii.	4.B.I.a.ii.
8-10 cm	116	29	36	12	37	4	16	14	10	19	7	0	1	0		2	0	0	0	2	0	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
18-20 cm	25	40	24	23	11	10	58	34	21	16	17	7	2	0	0	0	0	0	0	1	1	0	0	0	4	0	0	0	1	1	0	0	1	0	0	0	1	2	4	0	0	0	0	0
28-30 cm	32	45	25	21	7	2	95	20	23	9	9	13	2	1	0	1	0	0	0	0	0	4	0	6	0	0	0	0	0	0	0	0	0	1	0	0	0	0	5	0	0	0	1	0
38-40 cm	35	32	21	8	15	8	90	25	26	9	7	11	3	1	0	0	0	0	0	0	2	12	0	1	0	6	1	2	0	0	0	0	0	0	0	0	0	1	2	0	1	0	0	0
48-50 cm	36	43	30	14	22	9	60	18	19	11	4	11	4	1	0	0	0	0	0	0	6	4	0	0	2	1	0	5	0	0	0	0	0	0	0	0	0	0	0	5	1	0	0	0
58-60 cm	69	43	16	17	16	8	64	11	18	0	5	13	1	1	0	3	0	0	0	0	1	8	0	0	1	0	0	3	0	0	1	1	0	0	0	0	0	2	0	1	0	0	0	1	1
68-70 cm	37	42	9	24	21	4	63	16	23	7	5	24	2	0	0	1	0	0	0	0	0	8	1	0	7	0	0	3	0	0	0	1	0	0	0	0	0	1	0	2	0	1	0	0	0
78-80 cm	37	38	7	16	12	2	54	26	22	8	5	57	4	1	0	0	0	0	0	0	0	10	0	0	4	0	0	0	0	0	0	0	0	0	0	0	0	1	0	2	0	0	0	0	0
88-90 cm	54	38	7	19	31	6	49	19	20	5	8	30	3	0	0	0	0	0	0	0	0	6	2	0	6	0	0	0	0	0	0	0	0	1	1	0	0	1	2	0	0	0	0	0
98-100 cm	37	61	19	19	20	0	43	20	11	12	5	31	3	1	0	3	0	0	0	3	0	1	6	4	0	0	0	0	0	0	0	0	0	1	0	0	1	2	2	1	0	0	0	0

APPENDIX C

WTFSH16-01 POLLEN DATA

Depth (cm)	Abies	Larix	Picea glauca	Picea mariana	Picea Ind.	Pinus banksiana/ resinosa	Pinus strobus	Pinus Ind.	Acer Ind.	Acer c.f. A. saccharum	Alnus c.f. A. crispa	Alnus Ind.	Alnus c.f. A. rugosa	Betula	Corylaceae	Cupressineae	Dryas	Fraxinus	Juglans	Juniperus/Thuja	Myrica gale	Ostrya/Carpinus	Populus	Quercus	Rosaceae	Salix	Shepherdia	Ulmus	Ambrosia	Artemisia	Chenopodiinaceae	Equisetum	c.f. Labiatae	Poaeae	Carex	Cyperaceae	Cyperus inflexus	Menyanthes	Myriophyllum	Nuphar	Nympheae	Potamogeton	Typha latifolia	Unknown	Spike
0-5 cm	1	18	3	13	15	5	16	24	0	2	7	3	11	103	5	8	0	0	1	12	7	1	3	7	0	1	0	1	4	1	0	2	0	36	24	0	1	1	0	0	3	0	0	0	10
5-10 cm	7	4	7	16	12	9	10	34	4	0	7	0	12	101	20	2	1	0	1	3	7	0	4	6	0	2	0	2	11	0	0	0	0	21	3	3	1	0	0	1	1	5	0	12	11
10-15 cm	4	2	14	21	17	20	20	18	2	0	12	0	13	109	13	8	0	0	0	5	4	1	11	7	0	2	1	1	7	0	1	0	0	15	3	2	0	0	0	1	0	1	0	6	10
15-20 cm	8	6	30	24	22	24	5	39	0	0	6	0	19	76	10	5	0	0	0	6	7	1	4	10	0	3	0	0	3	0	4	0	1	0	0	0	1	0	0	2	0	2	0	7	13
20-25 cm	8	3	19	26	16	29	5	61	1	0	6	0	5	99	9	5	0	0	0	2	1	0	0	9	0	6	0	1	3	0	2	0	0	1	0	0	2	0	0	0	1	1	1	3	4

WTFSH16-02 POLLEN DATA

Depth (cm)	Abies	Larix	Picea glauca	Picea mariana	Picea Ind.	Pinus banksiana/ resinosa	Pinus strobus	Pinus Ind.	Acer Ind.	Alnus c.f. A. crispa	Alnus Ind.	Alnus c.f. A. rugosa	Betula	Carya	Cornus	Corylaceae	Cupressineae	Dryas	Ephedra	Fraxinus	c.f. Humulus lupulus	Juglans	Juniperus/Thuja	Myrica gale	Ostrya/Carpinus	Populus	Quercus	Rosaceae	Salix	Shepherdia	Tillia	Ulmus	Ambrosia	Artemisia	Chenopodinaceae	Equisetum	Euphatorium	Galium	Iva xanthifolia	c.f. Labiatae	Poaeae	Ranunculus	Tubuliflorae	Carex	Cyperaceae	Cyperus inflexus	Menyanthes	Myriophyllum	Nuphar	Nympheae	Potamogeton	Typha latifolia	Unknown	Spike
0-5 cm	4	7	5	9	13	10	3	27	2	7	0	8	112	0	0	10	3	0	0	1	1	0	0	4	2	12	3	0	2	0	1	3	4	0	2	0	0	0	0	0	44	0	1	3	0	2	0	0	0	1	0	3	15
5-10 cm	6	3	11	11	15	13	6	31	0	11	1	12	137	0	1	9	2	0	2	0	0	1	3	0	0	4	6	0	2	0	0	0	6	0	3	0	0	0	0	0	0	14	0	0	2	2	0	0	0	0	0	1	12
10-15 cm	6	2	26	17	16	31	10	43	0	0	19	0	93	0	0	6	1	0	0	1	0	0	3	0	0	0	6	0	4	0	0	0	1	0	2	0	0	1	0	0	12	0	0	0	0	0	0	0	0	0	0	3	18
15-20 cm	6	6	28	21	32	32	14	45	4	0	10	0	83	2	0	1	2	0	1	0	0	0	7	1	0	6	5	0	1	0	0	0	4	0	1	0	1	0	0	0	1	1	0	2	0	0	0	0	0	0	0	5	12
20-25 cm	11	2	22	13	23	28	7	47	0	0	6	0	104	0	0	7	1	0	0	0	0	0	15	1	0	2	8	0	2	0	0	1	3	1	1	0	0	0	0	0	4	0	0	0	2	1	0	0	0	0	0	2	19