POSTGLACIAL VEGETATION HISTORY OF THE OAK PLAINS IN SOUTHERN ONTARIO

POSTGLACIAL VEGETATION HISTORY OF THE OAK PLAINS IN SOUTHERN ONTARIO

by

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ABSTRACT

An open *Quercus*-dominated vegetation association, known locally as the oak plains, was found at a number of locations in southern Ontario until disturbance by European settlers in the late 18th and early 19th centuries. Two contrasting theories have been suggested in the literature regarding the origin of the oak plains. One suggests they developed as the result of burning by pre-European natives, while the other considers them to be relics of a warmer, drier mid-Holocene climate. In this paper, the factors which led to the development of the oak plains are examined. The hypothesis that the oak plains resulted from native burning of the natural vegetation was tested by pollen analysis of a 5 m sediment core from Decoy Lake, a small kettle basin near Paris, Ontario located in an area mapped by early surveyors as oak plains. The Decoy Lake record was then compared to those of two nearby lakes supporting mesic forests. This palaeoecological analysis was supported by an investigation of physical factors controlling the historical distribution of the oak plains in a study area between Cambridge and Long Point on Lake Erie.

The distribution of the oak plains and other vegetation associations in pre-settlement times, reconstructed from early survey records, correlated fairly well with the texture of soils and underlying Quaternary parent materials. Within the defined study area, the oak plains were restricted almost exclusively to well-drained soils overlying coarse-textured till and sandy outwash and deltaic deposits. Climatic factors and topography varied within the study area, but showed little correlation with the distribution of vegetation associations.

The fossil pollen record at Decoy Lake indicates that a Quercus-Pinus-herb pollen assemblage, unique to southern Ontario, was found from 4000 yr BP until pre-settlement times. This suggests that the oak plains have existed in the area for at least 4000 years. The oak plains replaced an assemblage dominated by Pinus strobus. The warm, dry Hypsithermal appears to have allowed Pinus strobus to remain dominant on the well drained soils around Decoy Lake until after 5000 yr BP, 2000 to 3000 years longer than at other southern Ontario sites. The Picea zone (11,800 yr BP to 10,100 yr BP), Pinus banksiana/resinosa zone (10,100 yr BP to c. 9000 yr BP), and the replacement of Pinus banksiana/resinosa by Pinus strobus (c. 9000 yr BP) occurred contemporaneously with other records from southern Ontario.

The hypothesis that anthropogenic factors resulted in the development of the oak plains was rejected since this association developed 2500 years before the onset of agricultural activity by natives in southern Ontario. Instead, it appears post-Hypsithermal increases in moisture, perhaps coupled with an amelioration of winter temperatures, led to the replacement of Pinus strobus by the oak plains in some areas of well-drained soils between 6300 yr BP and 4000 yr BP. The pollen record from Decoy Lake provides the first evidence from southern Ontario for substantial vegetation response to mid to late Holocene climatic change.

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Stealing glimpses of the past
These impressions always last

Bob Mould

CHAPTER 1 - INTRODUCTION

In the 150 to 200 years since widespread European settlement began, the forests of southern Ontario have been fragmented and cleared to a small fraction of their former extent. Many stands and woodlots found today are not remnants of the original forests, but are second-growth forests that have developed following selective or clear cutting. Even large areas of supposedly untouched wilderness, such as Algonquin Park in south-central Ontario, have over the past 150 years been heavily logged and so support very different vegetational associations than they did before disturbance. For the most part, closed canopy mixed or deciduous forest covered southern Ontario until the late 18th and early 19th centuries. However, a number of areas in the most southerly part of the province supported not closed forest but open woodland or even treeless prairie (J.D. Wood, 1961; Maycock, 1963; C.J.B. Wood, 1966; Chanasyk, 1972; MacDonald, 1987a; Bakowsky, 1988). Very few of these areas remain untouched today. The dramatic increase in population of the region has led either to their clearance or their destruction by disturbance.

The majority of these open woodlands were dominated by *Quercus* spp., and are variously referred to as 'oak plains', 'oak savanna', 'oak openings' or 'oak woodland' (for the purposes of this study, savanna will be used as a general term in reference to vegetation dominated by grasses, herbs and scattered trees, whereas 'oak plains' will refer more specifically to the *Quercus*-dominated savanna found in southern Ontario). Similar oak savannas are found in Wisconsin, Minnesota and other mid-western states

(Curtis, 1959; McAndrews, 1966; Jacobson, 1979; Bakowsky, 1988). The origin of Ontario's oak plains has been a topic of considerable debate. There are two basic lines of thought regarding their origin, though they are not mutually exclusive. Repeated burning by natives in order to clear land for agriculture and hunting may have led to destruction of the original forests and their replacement by open grown, fire-tolerant vegetation (J.D. Wood, 1961; C.J.B. Wood, 1966; Bakowsky, 1988). Alternately, a combination of climatic and edaphic factors may have resulted in the development of the oak plains, perhaps through an alteration of natural fire regimes (C.J.B. Wood, 1966; Bakowsky, 1988). Despite the continued interest in the oak plains (MacDonald, 1987a; Bakowsky, 1988), no specific study to resolve their origin has been made. Over twenty years ago, C.J.B. Wood (1966) suggested the problem might be resolved by "several concomitant avenues of investigation":

i) systematic soil analysis;

ii) detailed archaeological study;

iii) detailed pollen analysis of local bogs to establish the evolution of the vegetation pattern in terms of local conditions.

The objective of this research was to determine as accurately as possible the timing and causal factors relating to the origin of the oak plains in southern Ontario, using methods similar to those outlined by Wood (1966) but emphasizing palaeoecological aspects. The methodology necessary to study the postglacial history of a vegetation unit on the scale of the oak plains should also provide new insights into the Holocene palaeoecology of southern Ontario. The research objectives are discussed in greater detail in Section 1.7.

1.1 - The Oak Plains in Southern Ontario

Pre-settlement oak plains or savanna vegetation has been reported from a number of sites in southern Ontario. These include areas between Ingersoll and London, along the lower Thames River in Kent Co., near Paris and Cambridge, north of Turkey Point on Lake Erie, south of Windsor, at Grand Bend on southern Lake Huron, and south and east of Lake St. Clair (J.D. Wood, 1961; Maycock, 1963; C.J.B. Wood, 1966; Chanasyk, 1972; Bakowsky, 1988).

Wood (1961) examined the influence of oak plains vegetation on early settlement patterns in North and South Dumfries townships, between Brantford and Waterloo. The vegetation consisted of single, well-spaced *Quercus* individuals, separated by low herbs and shrubs (Wood, 1961). *Carya, Castanea* and *Populus* were also common. In some areas the oaks and other trees formed scrubby thickets, rather than having normal growth forms. The presence of a small, scattered population of *Quercus ellipsoidalis* in North and South Dumfries townships is noted by Ball (1981). The species reaches its maximum importance on oak savanna in the midwestern U.S., and this population is 200 km east of the nearest localities in Michigan. In some of the locations the trees were associated with herbs which are generally regarded as prairie elements, such as *Andropogon gerardii* and *Lespedeza capitata* (Ball, 1981).

In an extensive study, Bakowsky (1988) examined the floristics and phytosociology of 52 savanna stands throughout southern Ontario covering the soil moisture spectrum from very dry to wet-mesic. The rarity of introduced and weedy species indicated these stands were essentially undisturbed and contained intact floras. Dry, dry-mesic, mesic, and wet-mesic savannas were all dominated by *Quercus* species, and had averages of 33 to 55% canopy cover. Dry-mesic savannas are the most widespread in southern Ontario, and modern examples have been identified in the Brantford and Long Point areas (Bakowsky, 1988). It would appear, then, that the area of oak plains outlined by Wood (1961) would fall into this category. *Quercus velutina* and *Quercus alba* are strong dominants, with *Quercus rubra, Quercus palustris, Quercus macrocarpa, Prunus serotina* and *Carya ovalis* also being important (Bakowsky, 1988). Thirty-two other tree species were recorded at sites of this type. There is also a high diversity in the understorey vegetation; 344 species were recorded. *Carex pennsylvanica*, a sedge, was the most important understorey component and had a mean cover in all stands of over 20%. Both *Poa pratensis*, a grass, and *Pteridium aquilinum*, a fern, had mean covers of over 10%. Other important herbs include *Smilacena racemosa, Aster umbellatus, Helianthus strumosus, Helianthus divaricatus* and *Aster cordifolius*. Important shrubs were *Vitis riparia, Corylus americana* and *Cornus racemosa*, among others.

Savanna sites classified as mesic by Bakowsky (1988) were dominated by similar tree species to dry-mesic sites, with *Quercus rubra* being less common and *Quercus macrocarpa* more common. The understorey composition is fairly similar on a generic or family level, although *Carex pennsylvanica* does not reach as high cover values as in the drier sites. Though still important, it is replaced by *Andropogon gerardii* as the dominant herb.

Fire frequency was found to vary considerably in savanna sites of different soil moisture types (Bakowsky, 1988). Fires were least common on the driest sites, due in part to their sparser vegetation cover.

Most of the savanna sites studied grew on soils with very high sand content (90 to 97% in the A-horizon), even those in mesic and wet-mesic moisture conditions (Bakowsky, 1988). Wood (1966) found that most, but not all, areas in the Long Point region in which survey records indicated oak plains were present had well-drained soils. It was also noted, however, that similar soils also supported *Quercus-Carya-Castanea* forests, and so soils alone may not have accounted for the open vegetation.

1.2 - Oak Savanna in the Midwestern U.S.

In pre-settlement times, open oak vegetation was widespread in Wisconsin, Illinois, Michigan and Minnesota (Cottam, 1949; Ellarson, 1949; Curtis, 1959; McAndrews, 1966, 1968; Wood, 1966; Jacobson, 1979; Grimm, 1983, 1984; Bakowsky, 1988). There are two basic types of savanna noted in this region, though nomenclature varies from region to region. Oak barrens or oak scrub generally refer to savanna with low, stunted, scrubby oaks, whereas savanna with large, open-grown oaks are variously called oak plains, oak woodland, or oak openings. The terminology for the two groups often overlaps; some of these discrepancies in nomenclature apparently result from different interpretations of the land capability by early settlers (Peters, 1972).

For the most part, oak savannas form an ecotone between prairie and forest vegetation types (Grimm, 1983). Oaks, usually *Quercus macrocarpa*, are found towards the margins of the open prairie as shrubs, 1-3 m high. This association gradually gives way to true savanna, oak trees with low-spreading branches being spaced so that the crowns do not touch (McAndrews, 1966). Between and below the trees is a "luxuriant growth of herbs and forbs" (McAndrews, 1966). The principal species found on these savannas are *Quercus macrocarpa* and *Quercus alba*, with *Quercus velutina* also being common (Ellarson, 1949).

Fire is the primary factor maintaining oak savannas in the American midwest (Ellarson, 1949; McAndrews, 1966; Jacobson, 1979; Grimm, 1983, 1984). On the open prairie, fires are widespread and occur frequently. In closed canopy temperate forest, such as the *Acer-Tilia-Ulmus-Quercus* forest of Minnesota, fires are much more infrequent (Grimm, 1984). In the region between the two vegetation types, fires would occur fairly frequently, permitting only fire-adapted vegetation to survive. Oak savannas also occur as islands on the open prairie in localities which are somewhat protected from major fires, such as in the lee of lakes and rivers, or on steep slopes (Ellarson, 1949; Curtis, 1959; Grimm, 1984). Oaks are very tolerant of fire compared to other hardwoods and even many conifers. Of the oaks, *Quercus macrocarpa* is the most fire resistant and also has the ability to sprout vegetatively after a fire (McAndrews, 1966; Jacobson, 1979). *Quercus alba* and *Quercus velutina* can also produce vegetative sprouts, though they are less tolerant of fire (Ellarson, 1949).

Many palynological studies have examined the postglacial history of vegetation, including oak savannas, in the American midwest. Those of McAndrews (1966) and Grimm (1983) were very thorough and of particular interest to the development of oak savannas. McAndrews (1966) examined the fossil pollen records of a number of sites in northwestern Minnesota along an east-west transect from pine-hardwood forest, through mesic deciduous forest, oak savanna and into open prairie. This zonation is partially the result of a steep precipitation gradient, decreasing from east to west. Between 8500 yr BP and about 4000 yr BP, all sites east of the present prairie sites were dominated by a *Quercus*-Gramineae-*Artemisia* assemblage, indicating the presence of oak savanna vegetation (McAndrews, 1966). Following this time, oak savanna remained only in the area in which it is found at present; to the east, it was replaced by hardwood and pine-hardwood forests. These data, supported by a number of other studies, suggest that warmer and drier conditions in the mid-Holocene (the 'Hypsithermal') led to an eastward expansion of prairie and savanna into more mesic forests in the midwest. As the climate cooled and precipitation increased, mesic hardwoods and some conifers were able to invade the most easterly prairie and savanna locations.

In a study of the 'Big Woods' of southern Minnesota, Grimm (1983) found evidence for savanna invasion of prairie sites between 5000 yr BP and 2000 yr BP, following the warmer, drier Hypsithermal. In the last few hundred years, some areas of savanna have in turn been invaded by *Ulmus, Acer, Tilia* and *Ostrya*. Advance of the savanna did not take place continually, but in a series of jumps (Grimm, 1983). Islands of savanna may have developed in prairie in the lee of firebreaks, and then gradually coalesced. Alternately, these islands may have been relics from pre-Hypsithermal conditions. Fire frequency was and is the "primary proximate variable controlling the overall pattern of vegetation in the Big Woods region" (Grimm, 1983).

Both of these studies have shown that the extent of oak savannas has varied considerably during the postglacial as a result of changing climate influencing fire regimes on a large scale. Whether this is true in southern

Ontario is unclear due to the lack of palynological research on oak plains sites up to this point.

1.3 - History of Human Settlement in Southern Ontario

The history of native peoples in southern Ontario has been subdivided into three archaeological periods: the Palaeo-Indian Period (c. 11,000 yr BP to 7000 yr BP), the Archaic Period (c. 7000 yr BP to 3000 yr BP) and the Woodland Period (c. 3000 yr BP to historic contact, c. 350 yr BP) (Wright, 1972). Palaeo-Indians first arrived in southern Ontario between 12,000 and 11,500 yr BP, soon after the local retreat of the Laurentide ice sheet (Jackson, 1983). These peoples were part of the Clovis culture, which has been identified throughout North America east of the Rockies by the distinctive fluted points it produced (Wright, 1972). The Palaeo-Indians were primarily big-game hunters, and would have kept on the move following populations of mammoth, mastodon, bison, elk, caribou, bear, deer and other game. Their numbers are estimated to have been fairly small.

At about 7000 yr BP, the Clovis culture was gradually replaced by Archaic cultures, which displayed a wider range of tools, weapons and ornaments. The earliest well developed Archaic sites in southern Ontario, belonging to a group known as the Laurentian Archaic, date to about 6000 yr BP. The Laurentian Archaic represented the first substantial population to live in southern Ontario, and were found in the region until the beginning of the Woodland Period at about 3000 yr BP (Wright, 1972; Spence and Fox, 1983). As with the Clovis peoples, the Laurentian Archaic were primarily big game hunters, though mammoth and mastodon had by this time disappeared. Their diet would have been supplemented by smaller game, fish, and wild plans. Settlements would probably have been occupied on a seasonal basis. A number of sites from the late Archaic (4000 yr BP to 3000 yr BP) have been excavated, most of them appearing to be warm-season camps (Spence and Fox, 1983). These sites are found for the most part on sand plains in the Deciduous Forest region of the province.

The temporal boundary between the Archaic and Woodland cultures is determined by the first appearance of ceramics, at about 3000 yr BP (Wright, 1972; Spence and Fox, 1983). Early Woodland artifacts from the Meadowood culture have been found throughout much of southern Ontario, though actual sites (villages or encampments) are far fewer in number. These sites are evidence of fall occupation, probably hunting camps; few data are available on activities in the remaining seasons (Spence and Fox, 1983). It appears that people of the Meadowood culture followed lives identical to those of the late Archaic (Wright, 1972).

The Meadowood culture was superseded by two Middle Woodland cultures known as Point Peninsula and Saugeen starting at about 2700 yr BP (Spence and Fox, 1983). Both Point Peninsula and Saugeen sites appear to be concentrated along rivers in the spring and early summer when spawning fish would be available (Wright, 1972; Spence and Fox, 1983). These sites are generally large and show the first evidence of houses in southern Ontario, the earliest dating to about 2500 yr BP (Dodd, 1984). Later in the year groups broke up and dispersed to fall and winter hunting grounds (Spence and Fox, 1983).

Towards the end of the Middle Woodland period, beginning at about AD 500, the Princess Point culture developed at the western end of Lake Ontario and eastern end of Lake Erie (Wright, 1972; Fecteau, 1985). This culture had a great influence on later patterns of subsistence in the area in that it introduced the cultivation of corn to southern Ontario. It is unclear whether the Princess Point Complex represents an actual migration of people or simply a migration of ideas and subsistence techniques (Wright, 1972). Early Princess Point sites seem to indicate that the cultivation of corn initially took place on a developmental-experimental basis in order to supplement hunting and gathering activities (Stothers, 1975). From this base, the use of corn gradually increased over time as techniques improved and more resistant strains developed. The shift from a mobile hunting and gathering lifestyle to a more sedentary agricultural-based society resulted in major changes in the Princess Point culture. By about AD 800, it had developed into the Glen Meyer (Niagara Peninsula and north shore of Lake Erie) and Pickering (north shore of Lake Ontario) branches of the early Iroquois tradition (Dodd, 1984; Fecteau, 1985), marking the beginning of the Late Woodland period. The increase in cultivation led to an increase in territoriality (and thus warfare), increased population, increased trade, and the adoption of palisaded villages (Noble, 1975; Dodd, 1984). The introduction of beans and squash at about AD 1000 gave the natives a 'triad' of cultigens which provided most of the essential nutritional requirements at times when the supply of game was low, such as over the winter. Corn still remained by far the most important cultigen, however (Fecteau, 1985), and hunting and gathering activities would have supplanted the crops whenever possible.

Between AD 1300 and AD 1400, the Glen Meyer and Pickering branches were replaced by the Uren-Middleport culture; this is a period of widespread cultural homogeneity across southern Ontario (Dodd, 1984). Out of this culture developed the Huron, Petun and Neutral tribes of the late Iroquois tradition. The Huron and Petun were found between Georgian Bay and Lake Simcoe, while the Neutral lived at the western end of Lake Ontario, on the Niagara Peninsula, and along the northeast shore of Lake Erie (Fecteau, 1985). It was these three tribes which were encountered by early white explorers and missionaries in the late 16th and early 17th centuries.

Peoples of the Iroquois tradition, from Glen Meyer to Huron, practised slash-and-burn or swidden agriculture (Sykes, 1980). This method of cultivation involves cutting a clearing in the forest, burning the downed trees and debris, cultivating crops for several successive seasons, and then abandoning the field when the soil becomes exhausted. The method is effective on a short-term basis, since the burning introduces calcium, phosphorus, potassium and nitrogen into the soil (Sykes, 1980). After 10-20 years, however, most Iroquois villages appear to have been abandoned. A large population and fairly intensive agricultural techniques probably resulted in the exhaustion of local soils after this period of time.

The cultivation of corn, beans and squash was widespread through most, but not all, of southern Ontario. Only one agricultural site has been recorded north of Lake Simcoe on the Canadian Shield (Fecteau, 1985). The highlands in the centre of the southern Ontario peninsula also show little or no signs of cultivation. The growing seasons in these two areas were apparently too short to support the cultivation of corn (J.H. McAndrews, personal communication, 1987). Additionally, soils on the shield are too thin and acidic to grow many crops. The extreme south-western portion of the province was populated by a tradition distinct from the Iroquois, known as the Younge Tradition (Fecteau, 1985). These people, who appear to have populated the area until at least AD 1500, practised little agriculture.

1.4 - Native Impact on the Environment: Historical and Palynological Evidence

In light of the possibility that native activity, particularly burning, may have been a causal factor behind the development of the oak plains in southern Ontario, this section will review and assess the evidence relating to native disturbance of the environment, with a focus on North America.

The impact of man on the native vegetation of Europe over the last 5000 years has been well documented, based on extensive palaeoecological analyses (Delcourt, 1987). In eastern North America, however, native impact has been fairly poorly documented, and its extent is still a matter of debate. Day (1953) concluded that Indians had a large impact on the forests of northeastern North America, based on historical observations. Clearance around villages would have taken place to permit agriculture and collect firewood. Much of this clearance would have been initiated by burning, with the additional purposes of improving travelling and visibility, driving game, and destroying 'vermin' (Day, 1953). Such activities carried out on a large scale would no doubt destroy or modify large areas of forest.

These suggestions of the widespread use of fire by natives are refuted by Russell (1983) in a re-evaluation of the historical evidence. Natives were unlikely to have initiated large fires on regular occasions, though accidental fires would have augmented the number of natural fires in areas near villages and camps. Some of the accounts of early settlers stated that regular burning of forests by natives had resulted in stately, open-grown trees with little underbrush. Russell (1983) attributes these statements to a desire to attract new settlers to North America; in fact, much of the burning which cleared shrubs and brush was initiated by the settlers themselves.

It is apparent that the extent of burning and disturbance by Indians was highly variable in both space and time; it was unlikely to have been universally widespread as Day (1953) suggests. On a small scale, disturbance may have occurred continuously for extended periods of time. Reznicek (1983) attributed the presence of several disjunct sites of prairie vegetation near Lake Simcoe in southern Ontario to their location along an important and well-travelled canoe route. The sites may have supported prairie for the several thousand years during which the route was apparently used.

On a larger scale, the extent of disturbance would depend to a large degree on the subsistence activities of the native population. Groups of hunter-gatherers did not generally settle in permanent villages, but kept mobile to exploit changing game populations. Fires set to drive game and for other purposes would not be concentrated in the same small area year after year, if they were set at all (Patterson and Sassaman, 1988). These fires would only have complemented infrequent lightning-set fires. Sedentary agricultural societies were more likely to employ fairly widespread burning in order to clear land for agriculture (Patterson and Sassaman, 1988). In addition, agricultural societies are able to support greater populations than groups of hunter-gatherers. The relatively high population density and permanent villages of these societies could lead to frequent burnings and thus a successional change in forest composition to more fire- or disturbance-tolerant vegetation. Patterson and Sassaman (1988) note that very few native-set fires were recorded by early settlers in northern New England where no agriculture was practised, whereas many more man-made fires occurred to the south, where native agriculture was fairly widespread.

Several methods have been employed to determine the extent of native clearance and agriculture, aside from the examination of historical accounts. In the late 18th century, much *Pinus strobus* was cut in southern Ontario in order to provide masts for the Royal Navy. Using historical records indicating the size of these trees at the time they were cut, Bowman (1980) calculated that a number of even-aged *Pinus* stands along the north shore of Lake Ontario had become established at about AD 1550. Iroquois villages in the area had been abandoned in the early part of that century, according to archaeological and historical evidence (Bowman, 1980). Thus, it was postulated that the original *Acer-Fagus* forests on these sites had been cleared for agriculture, and following abandonment had been replaced by *Pinus strobus*. If this is indeed what took place, it is evidence of Indian disturbance leading to long-term successional changes in the native vegetation.

Palynological records have also been used to study the impact of prehistoric man on vegetation in North America, as they have in Europe. One of the finest examples is the pollen record from the annually laminated sediments of Crawford Lake in southern Ontario (McAndrews, 1976, 1988). The sediments were analyzed for pollen at 5 to 10-year intervals from AD 1970 back to AD 1000; precise dating control was possible due to the annual laminations. Between AD 1350 and AD 1650 and peaking at about AD 1450, there was an increase in Gramineae pollen, some of these grains being identified as *Zea mays*. Soon after corn pollen showed up in the record, the pollen of *Fagus* and *Acer saccharum* began to decline, and was replaced by *Quercus* and eventually *Pinus*. McAndrews (1976, 1988) hypothesized that during the period in which corn pollen was found Iroquoian agriculture was taking place within the lake's watershed. The impact on forest vegetation appears to have been similar to that suggested by Bowman (1980); the original *Acer-Fagus* forests around the lake had been partially cleared, and after agriculture was abandoned had been replaced by first *Quercus* and then *Pinus strobus*. This hypothesis was confirmed by the subsequent discovery of an Iroquoian village within 1 km of the lake, dating to the same period as that in which the corn pollen had been found.

Other pollen-based studies, such as those of Burden *et al.* (1984) and Delcourt *et al.* (1986) have provided information on prehistoric settlement and agriculture in eastern North America. However, the rarity of good sites and the relatively small native population has led to indications of native impact being absent or difficult to interpret. Palynological investigations have been very successful in areas which have long records of human disturbance and supported large populations, such as Europe (Delcourt, 1987; Molloy and O'Connell, 1987; Robinson and Dickson, 1988) and Central and South America (Vaughan *et al.*, 1985; Binford *et al.*, 1987).

For many years, examination of microscopic charcoal in combination with pollen analysis has been used to reconstruct the fire history of forests, with mixed results (Swain, 1973, 1978; Cwynar, 1978; Patterson *et al.*, 1987). This would appear to be a promising method of studying the effects and extent of Indian-set fires. Patterson and Sassaman (1988) examined the charcoal records of several sites in New England, and note that much more charcoal is present in post-settlement levels than in pre-settlement levels.

As of yet, however, there has been no correlation between pre-settlement charcoal influxes and Indian activity. Very recent evidence from a small annually laminated lake in northern Alberta indicates that in certain situations charcoal may not in fact be a reliable indicator of fire, whereas the pollen record will reflect successional changes in vegetation following a fire, and thus is a more reliable indicator (Larsen, 1989).

Although southern Ontario has been occupied by man for more than 10,000 years, human impact has probably influenced vegetation on a scale relevant to this study only during the past 1500 years. Pre-agricultural natives were transient hunter-gatherers and were unlikely to have repeatedly burned or otherwise cleared large areas of forest. The introduction and spread of corn cultivation at about 1500 yr BP, however, led to rapid increases in populations and social organization. The clearance of land for agriculture and village construction by Woodland peoples may have resulted in considerable disturbance to the native vegetation.

1.5 - A Concise History of Postglacial Vegetation and Climate Change in Southern Ontario

The postglacial vegetation history of northeastern North America has been fairly well documented by a large number of pollen and plant macrofossil studies over the past half-century or so (Davis, 1983; MacDonald, 1987a; Ritchie, 1987; Webb *et al.*, 1987). A number of these studies have been carried out at sites in southern Ontario, and the results of these will be combined here to review the changes in vegetation and climate that have taken place in this region over the past 12,000 years. The locations of these sites are shown in Figure 1. Most of the reconstructions of vegetational change are based on pollen data, and the majority of palynological research in this region has been carried out on the sediments of medium-sized lakes (1-100 ha). The data will therefore tend to display regional trends in the vegetation, as opposed to local trends which are evident in the records of smaller lakes, ponds and bogs (Jacobson and Bradshaw, 1981).

Very soon after the time-transgressive retreat of Laurentide ice between about 14,000 yr BP and 12,500 yr BP, open spruce-tundra appears to have become established on the newly exposed land in southern Ontario (Mott and Farley-Gill, 1978; Schwert *et al.*, 1985; Ritchie, 1987; see also summary in Appendix 3). Taxa such as *Picea, Salix, Vaccinium, Empetrum, Dryas, Artemisia* and Cyperaceae, which are common components of the sub-arctic flora, are well represented in the pollen and macrofossil records of Gage Street Bog, near Kitchener, and Maplehurst Lake, near Woodstock, at about 12,500 yr BP (Mott and Farley-Gill, 1978; Schwert *et al.*, 1985). After this, *Picea* percentages increase and herb pollen decreases, indicating the development of a closed-canopy *Picea*-dominated forest similar to that of today's mid-boreal zone (Ritchie, 1987). This period of *Picea* dominance is seen in all records from southern Ontario dating from this time, such as Pond Mills Pond, near London (McAndrews, 1981), Hams Lake, near Paris (Bennett, 1987), Miller Lake, north of Hamilton (McAndrews, unpublished data, 1989), and Edward Lake, near Barrie (McAndrews, 1981). Some tree taxa, such as *Populus*, may have also been important at this time, but are poorly represented in the pollen record due to poor preservation or low levels of pollen production (Mott, 1978; Ritchie, 1987).

Mean annual temperatures during the early postglacial in southern Ontario have been estimated by using the $\delta^{18}O$ record from sediment cores

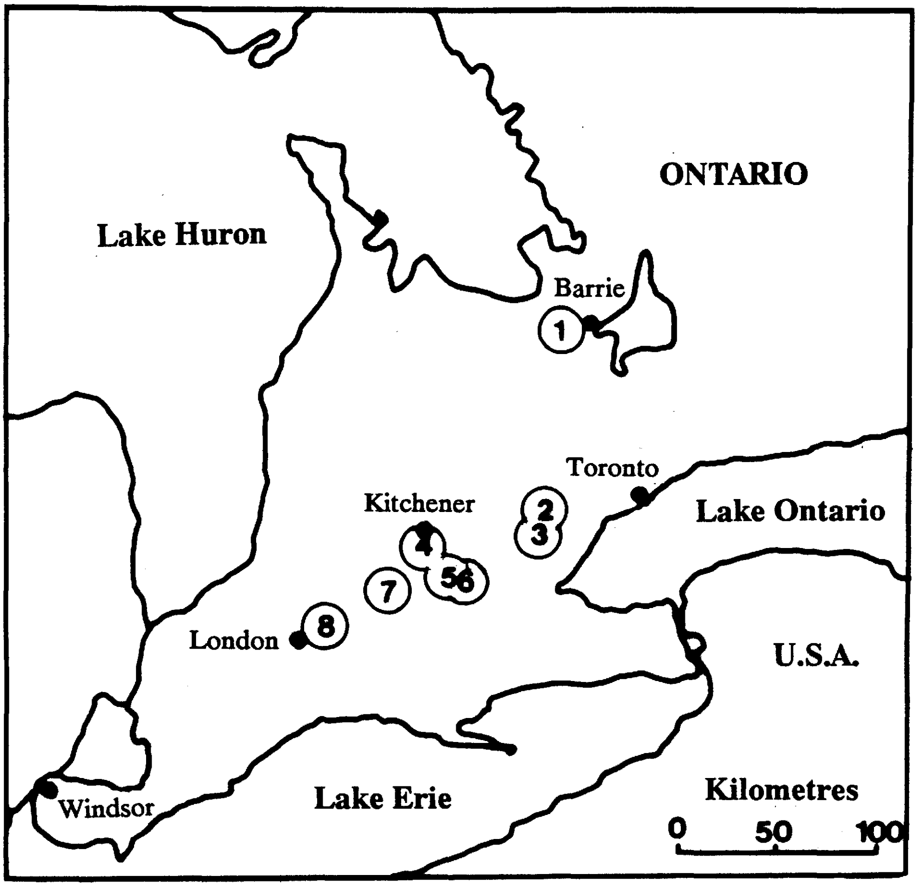


Figure 1: Location of palaeoecological sites mentioned in text

1. Edward Lake (McAndrews, 1981) 2. Crawford Lake (McAndrews, 1976)
3. Miller Lake (McAndrews, unpublished data, 1989)
4. Gage St. Bog (Schwert *et al.*, 1985) 5. Hams Lake (Bennett, 1987)
6. Decoy Lake (this study) 7. Maplehurst Lake (Mott and Farley-Gill, 1978)
8. Pond Mills Pond (McAndrews, 1981)

(Edwards and Fritz, 1988) and by comparison with the climate of the modern forest-tundra (McAndrews, 1981). The results indicate annual temperatures were 10-15^{0}C below those of today, and there was less precipitation.

Following a rapid decline in *Picea* between 10,500 yr BP and 10,000 yr BP, *Pinus banksiana* very rapidly became the dominant arboreal component in the forests throughout southern Ontario (Mott and Farley-Gill, 1978; McAndrews, 1981; Bennett, 1987; MacDonald, 1987a; Ritchie, 1987). Although this species is widespread in the modern boreal forest of eastern and central Canada (Fowells, 1965), it was apparently associated with a number of mixed forest species during the early Holocene. The pollen of *Quercus, Ulmus, Ostrya/Carpinus* (these two genera are indistinguishable in the pollen record) and *Fraxinus* is present in fairly significant quantities during this time (Bennett, 1987). Other trees more typical of the boreal forest, such as *Abies balsamea, Betula, Populus* and *Larix laricina*, were also present.

At about 9000 yr BP, *Pinus strobus* replaced *Pinus banksiana* as the dominant tree in southern Ontario. By about 7500 yr BP it too had declined and was replaced throughout most of the region by mesic temperate taxa. In what is now the mixed forest, *Tsuga canadensis* increased dramatically and reached a peak between 7000 yr BP and 6000 yr BP (McAndrews, 1981). Also increasing at this time were *Acer saccharum, Ulmus* and *Fagus grandifolia*. At about 5000 yr BP, *Tsuga canadensis* populations crashed, and it appears to have been essentially eliminated from the vegetation for over 1000 years (McAndrews, 1981; Bennett, 1987; Ritchie, 1987). Originally, this catastrophic decline was attributed to climatic change. However, recent evidence indicates it may have been due to the rapid spread of a pathogen, similar to that which has wiped out most of the *Castanea* population in North America this century (Allison *et al.*, 1984). *Tsuga canadensis* was initially replaced by *Betula*, and subsequently by *Fagus grandifolia, Acer* and *Ulmus*. *Tsuga* populations recovered slightly after about 1500 years, but never reached the dominance they had enjoyed in the early-mid Holocene.

Sites in the modern Deciduous forest show that *Tsuga* was not the sole tree species to increase in importance following the decline of *Pinus strobus*. *Quercus, Ostrya/Carpinus, Ulmus, Acer* and *Carya* also increased at this time (Mott and Farley-Gill, 1978; McAndrews, 1981; Bennett, 1987). At 7000 yr BP, there was a dramatic increase in *Fagus grandifolia* at these sites. This probably signifies the development of the *Acer saccharum-Fagus grandifolia* association that was widespread in southern Ontario until disturbance by European settlers 150 to 200 years ago.

Some sites in southern Ontario, such as Hams Lake and Miller Lake, show a decrease in *Fagus grandifolia* and *Acer saccharum* and increases in *Pinus strobus* and *Quercus* at about 1000 yr BP (Bennett, 1987; McAndrews, unpublished data, 1989). This shift in vegetation dominance is similar to that noted by McAndrews (1976) at Crawford Lake, which was attributed to native agriculture. Whether the impact of agriculture was more widespread than was previously thought is unclear. However, these changes also coincide broadly with a documented global cooling trend often referred to as the Little Ice Age (McAndrews, 1988). Further research is needed to distinguish between the effects of climate and the impact of native cultures during this period.

The impact of European settlers is far more apparent in the pollen records of southern Ontario. Every pollen record from this region which includes post-settlement sediments displays a significant increase in

Ambrosia pollen, along with Gramineae and other herbs (Mott and Farley-Gill, 1978; McAndrews, 1976, 1981, 1988, unpublished data, 1989; Bennett, 1987; Ritchie, 1987). Widespread clearance allowed the spread of weedy and ruderal species along the edges of fields, roads and in other disturbed habitats. Also apparent in some diagrams is a decrease in the abundance of some tree species as a result of clearance and logging (McAndrews, 1988). In southern Ontario, for example, *Pinus strobus* has been logged extensively over the last 150 years (Head, 1975).

Upon examination of the pollen records of several sites in the Deciduous and Mixed forest regions of southern Ontario, McAndrews (1981) estimated that temperatures reached modern levels at about 7000 yr BP to 8000 yr BP, and have remained fairly stable since. These estimates were made based on the assumption that both the assemblages seen in the pollen record and modern assemblages were and are in equilibrium with climate. This question of vegetation-climate equilibrium has become more important now that quantitative palaeoclimatic estimates are being made from pollen data using transfer functions (Howe and Webb, 1983; Bartlein *et al.*, 1984, 1986). Some researchers believe that factors such as lags in the postglacial migration of poorly dispersed species and lags in soil development may lead to non-equilibrium between climate and vegetation (Davis, 1978, 1984; Pennington, 1986). Others agree that these lags may occur, but would not be of sufficient magnitude to produce non-equilibrium conditions on the regional scale of investigation (Webb, 1986). The matter is further complicated by the uncertainty in determining when a species is first present at a site. Ritchie (1987) proposes that, despite the slow migration of a few species, "the full complement of forest species found today in southern

Ontario was present early in the Holocene". Some taxa may have been present in very small populations and thus were invisible in the pollen record (Bennett, 1985).

The palaeoclimatic estimates of McAndrews (1981) do not record a mid-Holocene Hypsithermal in Ontario as has been noted in various climatic reconstructions from the midwest (McAndrews, 1966; Grimm, 1983; Bartlein *et al.*, 1984; Winkler *et al.*, 1986) and Quebec/New England (Terasmae and Anderson, 1970; Davis *et al.*, 1980). This may indicate that the climate has indeed remained stable over the past 8000 years or so, but it is more likely due to the uncertainty involved in reconstructing climate from pollen records, and the resistance of mesic temperate forests to successional change following climatic variations.

Recently, Edwards and Fritz (1988) found evidence for a warmer period in southern Ontario between 7500 yr BP and 3000 yr BP, using $\delta^{18}O$ records from lake cores. Photosynthetic humidity measurements on plant cellulose in the cores indicated that this warm period was dry between 7500 yr BP and 6000 yr BP, and moist after 6000 yr BP.

1.6 - Research Objectives

The primary objective of this research is to determine the timing and causal factors relating to the origin of the oak plains in southern Ontario. Through the palaeoecological analysis of a radiocarbon dated core of sediment from a lake within the pre-settlement oak plains, supported by comparisons with the pollen stratigraphies of nearby sites, and the mapping of local soils, Quaternary geologic features, and archaeological sites, the hypothesis that the oak plains were the result of burning by natives will be tested. In testing this hypothesis, several questions will be addressed:

1) Do the oak plains produce a distinctive pollen assemblage?

2) If so, how far back does this assemblage extend in the palynological record?

3) Is the vegetational history of the oak plains unique throughout the postglacial compared to other sites in southern Ontario, or was it similar up to a certain time?

4) If a distinctive oak plains pollen assemblage develops at a certain time, does this coincide temporally or stratigraphically with changes in the microscopic charcoal record?

5) Does oak plains development coincide temporally with significant changes in local or regional native populations or cultures?

Answering these questions will reveal whether the factors that led to oak plains development can be reasonably determined through examination of the climatic and edaphic setting of the historical oak plains and the fossil record.

The postglacial history of the oak plains is best studied using a small lake (<1 ha), which receives most of its pollen deposition from local sources (Jacobson and Bradshaw, 1981). The vast majority of palaeoecological studies in southern Ontario have been carried out on medium-sized basins (1-100 ha), and so do not reflect local, small-scale vegetation dynamics. Consequently, in addition to investigating the origin of the oak plains, this study should provide new insight into the dynamics of postglacial vegetation change in southern Ontario.

CHAPTER 2 - CONTROLS ON THE DISTRIBUTION OF PRE-SETTLEMENT VEGETATION IN HALDIMAND-NORFOLK-DUMFRIES

In order to investigate the postglacial development of the oak plains in southern Ontario, it is necessary first to understand the controls relating to the extent of this vegetation assemblage in immediate pre-settlement times. An area including all or part of Haldimand-Norfolk, Brant, Elgin, and Waterloo counties (Figure 2) was selected for this study. Pre-settlement vegetation records, based on survey notes, indicated that oak plains were fairly widespread in this area (J.D. Wood, 1961; C.J.B. Wood, 1966; Chanasyk, 1972). This chapter will discuss the distribution of vegetation assemblages found in the area in relation to geologic, edaphic, and climatic controls.

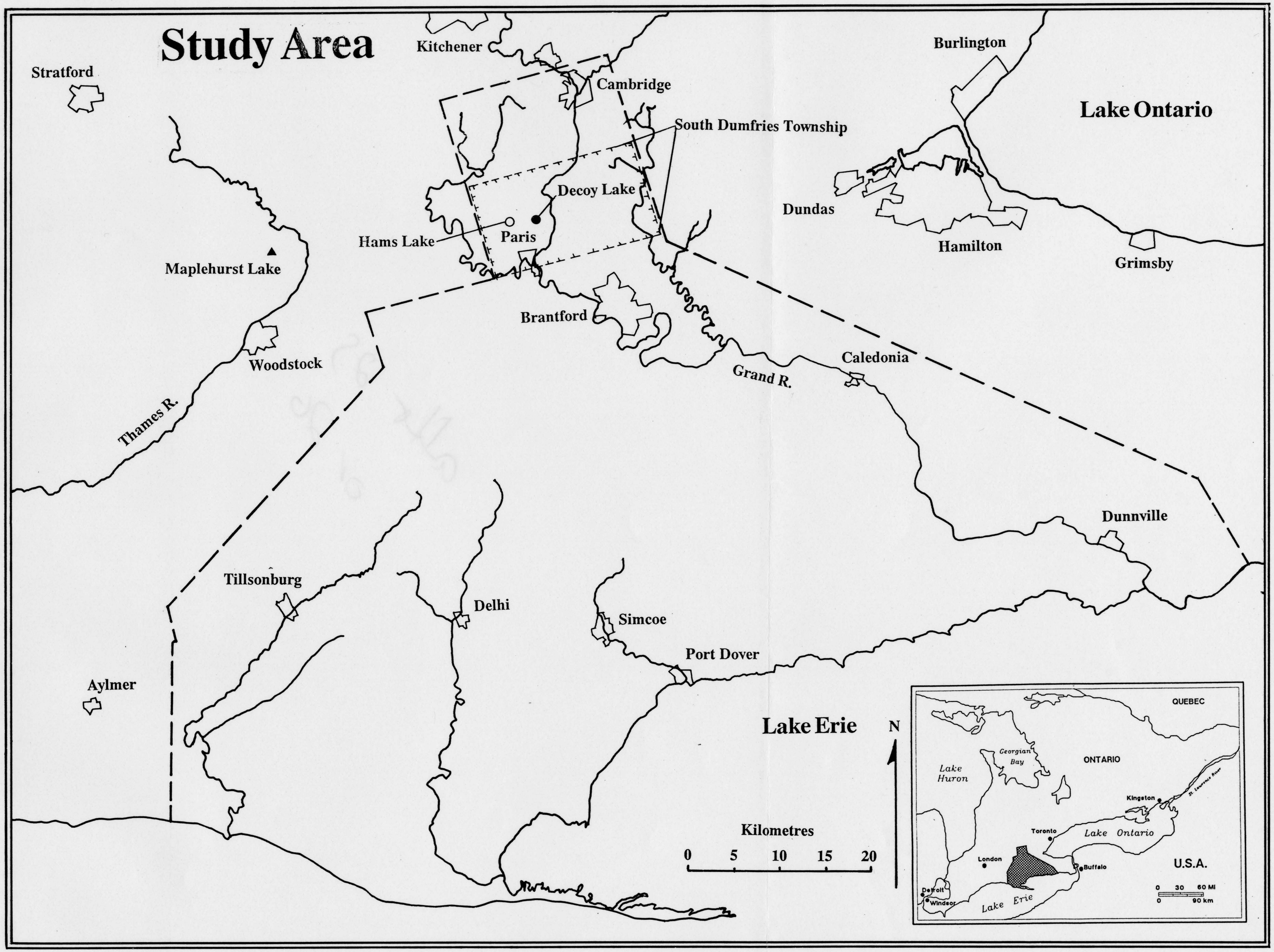
2.1 - Vegetation of Haldimand-Norfolk-Dumfries

All of the study area save the most northern portion falls within the Deciduous forest region, as mapped by Rowe (1972). This forest region is dominated by broadleafed deciduous species, with conifers being "poorly represented" (Rowe, 1972). The most common association in the region, particularly on mesic soils, is *Acer saccharum-Fagus grandifolia*, with *Tilia americana, Acer rubrum, Quercus rubra, Quercus alba* and *Quercus macrocarpa* also being widespread.

The northern portion of North Dumfries township falls within the Huron-Ontario subdivision of the Great Lakes-St. Lawrence or Mixed forest region (Rowe, 1972). The *Acer saccharum-Fagus grandifolia* association is still common, as are *Tilia americana, Quercus rubra, Quercus alba* and

Figure 2: Location of Haldimand-Norfolk-Dumfries study area in southern Ontario

The locations of Decoy Lake, Hams Lake, and Maplehurst Lakes are also indicated
A detailed map of soils in South Dumfries Township is shown in Figure 7


Study Area
Kitchener
Stratford
Cambridge
Burlington
Lake Ontario
South Dumfries Township
Decoy Lake
Dundas
Hamilton
Grimsby
Hams Lake
Paris
Maplehurst Lake
Brantford
Woodstock
Caledonia
Grand R.
Thames R.
Dunnville
Tillsonburg
Delhi
Simcoe
Port Dover
Aylmer
Lake Erie
N
Kilometres
0 5 10 15 20
QUEBEC
Georgian Bay
ONTARIO
Lake Huron
Kingston
St. Lawrence River
Toronto
Lake Ontario
London
Buffalo
Detroit
Windsor
Lake Erie
U.S.A.
0 30 60 MI
0 90 km

Quercus macrocarpa. In addition, several coniferous species, absent or rare to the south, are widespread. These include *Tsuga canadensis, Pinus strobus, Pinus resinosa* and *Thuja occidentalis.*

Far more informative than a simple species list was the study by Maycock (1963) on the phytosociology of the Deciduous forest. The simplified forest regions defined by Rowe (1972) are by no means definitive, and the distinction between the Deciduous and Great Lakes-St. Lawrence forest regions is not absolute. For instance, *Pinus strobus* was found by Maycock (1963) in one quarter of all stands he examined within the Deciduous forest region.

Maycock (1963) studied 131 stands of about 10 acres in size throughout southern Ontario. Stands showing signs of disturbance were not included in the study. The uniform topographic conditions of the area have resulted in what Maycock (1963) considers to be a fairly uniform vegetation cover, with soil moisture conditions being the major factor in determining the associations present at a site.

Dry, well-drained soils were dominated by *Quercus rubra, Quercus velutina* and *Carya ovata. Quercus alba, Ostrya virginiana, Castanea dentata, Populus grandidentata, Fraxinus americana, Juglans nigra, Prunus serotina* and *Pinus strobus* (in the northern portions) are also common in these areas. Maycock (1963) also mentions the presence of oak plains or oak savannas scattered throughout the region. "These are invariably associated with a number of prairie forbs and often prairie inclusions frequently of an extensive nature occur in their vicinity" (Maycock, 1963). The primary species found in these savannas are *Quercus velutina, Quercus rubra, Quercus alba, Quercus macrocarpa,* and *Carya ovata.*

The majority of sites in Maycock's study were in areas of mesic soils, and were dominated by *Acer saccharum* and *Fagus grandifolia*. These two species occurred as co-dominants, singly, or in any given combination of relative importances. Also common but of lesser importance on mesic soils were *Tilia americana, Acer nigrum, Acer rubrum, Ulmus americana, Carya cordiformis, Fraxinus americana, Ulmus rubra, Juglans cinera, Juglans nigra, Liriodendron tulipifera, Prunus serotina,* and *Ostrya virginiana*.

Moist soils tended to be dominated by *Ulmus americana* and *Acer saccharinum*. Also found at these sites were *Quercus palustris, Platanus occidentalis, Tilia americana, Fraxinus nigra* and *Fraxinus pennsylvanica*.

The spatial distribution of forest associations described by Maycock (1963) in the times before extensive European settlement can be reconstructed using the notes of early surveyors. Several authors have compiled data from survey notes for the area of this study. These data (J.D. Wood, 1961; C.J.B. Wood, 1966; Chanasyk, 1972) were combined to produce a map of the pre-settlement vegetation of the study area (Figure 3). Unfortunately, some of the survey records have been lost or are unavailable, leaving large areas with no data. Nonetheless, this map shows a complex mosaic of various vegetational associations throughout the area. It is interesting to note that much of the area is dominated solely by *Pinus strobus*, despite Rowe (1972) regarding conifers as "poorly represented" in this forest region.

2.2 - Physiography and Quaternary Geology

The Laurentide ice sheet, which reached its maximum extent about 18,000 yr BP, covered the entire study area and extended south to southern Ohio (Chapman and Putnam, 1984). Southern Ontario was one of the first

Figure 3: Pre-settlement vegetation of Haldimand-Norfolk-Dumfries

Survey records are unavailable for much of the area between Brantford and Lake Erie. In the extreme northern section of the study area (North Dumfries and part of South Dumfries) data only indicated the location of the oak plains, and not of other associations.

Data are compiled from J.D. Wood (1961), C.J.B. Wood (1966) and Chanasyk (1972)
Terminology follows that of Chanasyk (1972)

Pre-Settlement Vegetation

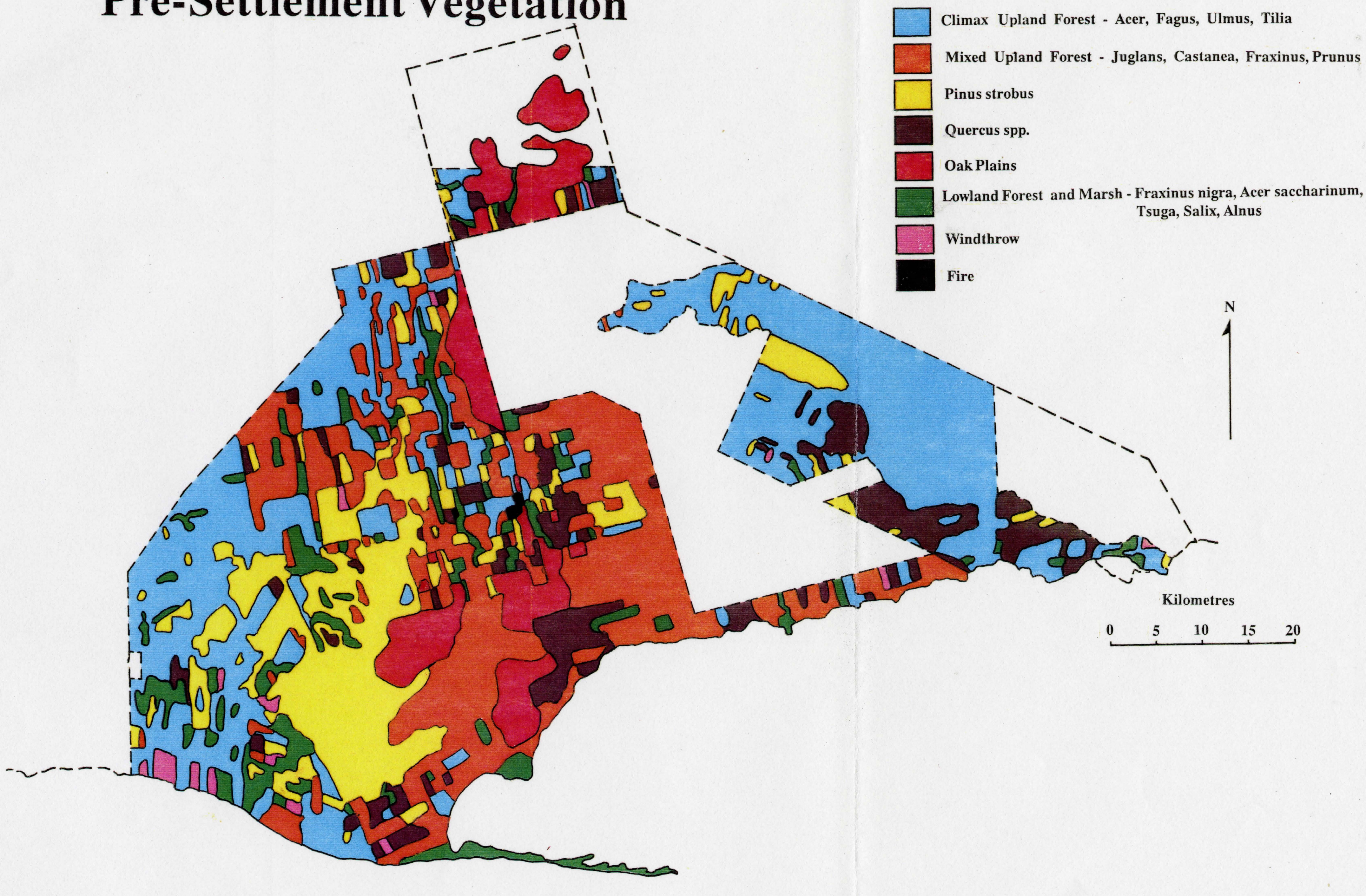


Figure 4: Quaternary Geology of Haldimand-Norfolk-Dumfries study area

The locations of Decoy, Hams and Maplehurst Lakes are indicated

Compiled from Chanasyk (1972), Cowan (1972), Chapman and Putnam (1984), and Karrow (1987)

QUATERNARY GEOLOGY

areas in eastern Canada to become deglaciated. Deglaciation did not occur as a simple northward retreat of the ice sheets, however. A number of local and regional re-advances occurred between about 14,000 yr BP and 13,000 yr BP, and the margin of the ice was controlled strongly by topography.

The major features produced by the Wisconsin glaciation in the study area can be broadly classified into three groups: tills, coarse glaciolacustrine sand plains and glaciofluvial outwash sands and gravels, and fine glaciolacustrine sediments. The north-eastward retreat of the Erie-Ontario ice lobe, punctuated by occasional minor and major re-advances, laid down till in parts of the study area as a series of moraines extending in a southwest-northeast orientation, and as a till plain in the northwest corner of the area (Cowan, 1972; Chapman and Putnam, 1984; Karrow, 1987). The two tills widespread in the area are the Port Stanley Till and the Wentworth Till. The Port Stanley Till is the older of the two, and forms the Tillsonburg Moraine and surrounding till plains along the western edge of the region (Figure 4). In this area it is a clayey silt till (Cowan, 1972), though it becomes more sandy north of the study area (Karrow, 1987).

A strong re-advance of the Erie-Ontario ice lobe between 13,000 yr BP and 14,000 yr BP (the Port Huron advance) led to the formation of the Wentworth Till, which forms the Paris and Galt Moraines in the study area (Cowan, 1972; Chapman and Putnam, 1984; Karrow and Warner, 1988). It is classified as a stony, silty sand till, with an average composition of 50% sand, 35% silt, and 15% clay (Cowan, 1972). The two moraines parallel each other in the northern and central section of the study area, the Paris Moraine being the more westerly and thus slightly older. Both of them are rugged and stony in the north, becoming smoother and fainter south of the Brantford-Paris area (Chapman and Putnam, 1984).

During and soon after the formation of the Paris and Galt Moraines, meltwater carrying large quantities of gravel, sand, silt and clay ran in a channel or spillway between the ice lobe to the east and exposed land to the west (Figure 5). Gravel and sand were deposited on the bed of this spillway, as well as in a delta in Lake Whittlesey (and later Lake Warren) to the south (Cowan, 1972; Chapman and Putnam, 1984). Finer sediments were carried further out into the lake and deposited in deeper water. Fluvial sands and gravels occur from the Brantford area northwards, and deltaic deposits are found to the south of these, down to the Lake Erie shoreline (Figure 4). The sand plains south of Brantford are up to 20 m deep, and have partially buried the southern portions of the Galt and Paris Moraines.

Fine silts and clays settling on the bed of proglacial Lake Warren formed the Haldimand Clay Plains (Cowan, 1972; Chapman and Putnam, 1984), located in the eastern half of the study area (Figure 4). These plains are fairly flat and poorly drained, particularly towards the southeast. Their depth ranges from 45 m to negligible (where bedrock or tills are exposed) (Cowan, 1972).

Several other minor components complete the suite of Quaternary and recent deposits in the study area. These include alluvial sediments (gravels, sands, silts and clays) along modern watercourses and Halton Till, a silty till found primarily in the Dundas Valley to the north. There are also a number of ice-contact features comprising sands and gravels; these were included in the outwash/lacustrine sands classification, as they are found on a relatively small scale.

The land in the study area slopes gradually upward moving north from Lake Erie, elevations ranging from 180 m at the Lake Erie shoreline to just over 340 m in parts of North Dumfries township. The till plains and moraines in the western third contain hummocky and ridged terrain, while the sand and clay plains to the east are much flatter. A number of rivers dissect both the till deposits and flatter plains. Several, particularly the Grand River, have cut sizeable valleys in the soft sediment. Cliffs or bluffs have formed along much of the Lake Erie shoreline (Wood, 1966).

The distribution of pre-settlement vegetation types in the area (Figure 3) correlates broadly to the distribution of Quaternary parent materials. The most common vegetation type on both the eastern clay plains and fine-grained Port Stanley Till to the west was the mesic *Acer-Fagus-Ulmus-Tilia* association. *Juglans, Castanea, Carya, Quercus* and *Pinus strobus* appear to have been common, though not as widespread. The coarser grained tills, outwash and deltaic deposits also supported a variety of associations. *Quercus, Juglans, Castanea* and *Pinus strobus* were widespread in this area, whereas *Acer, Fagus, Tilia* and *Ulmus* were more restricted in distribution. Of particular interest is the distribution of the oak plains; they are restricted almost entirely to growing on coarse Wentworth Till and sandy glaciofluvial and glaciolacustrine deposits.

Large-scale topographic variations do not appear to influence the distribution of vegetation associations within the study area. The flat clay plains in the east and more rolling Port Stanley Till in the west were both dominated by mesic *Acer-Fagus-Ulmus-Tilia* forests. Similarly, the oak plains were found both on flat sandy outwash and hummocky moraines in the Wentworth Till.

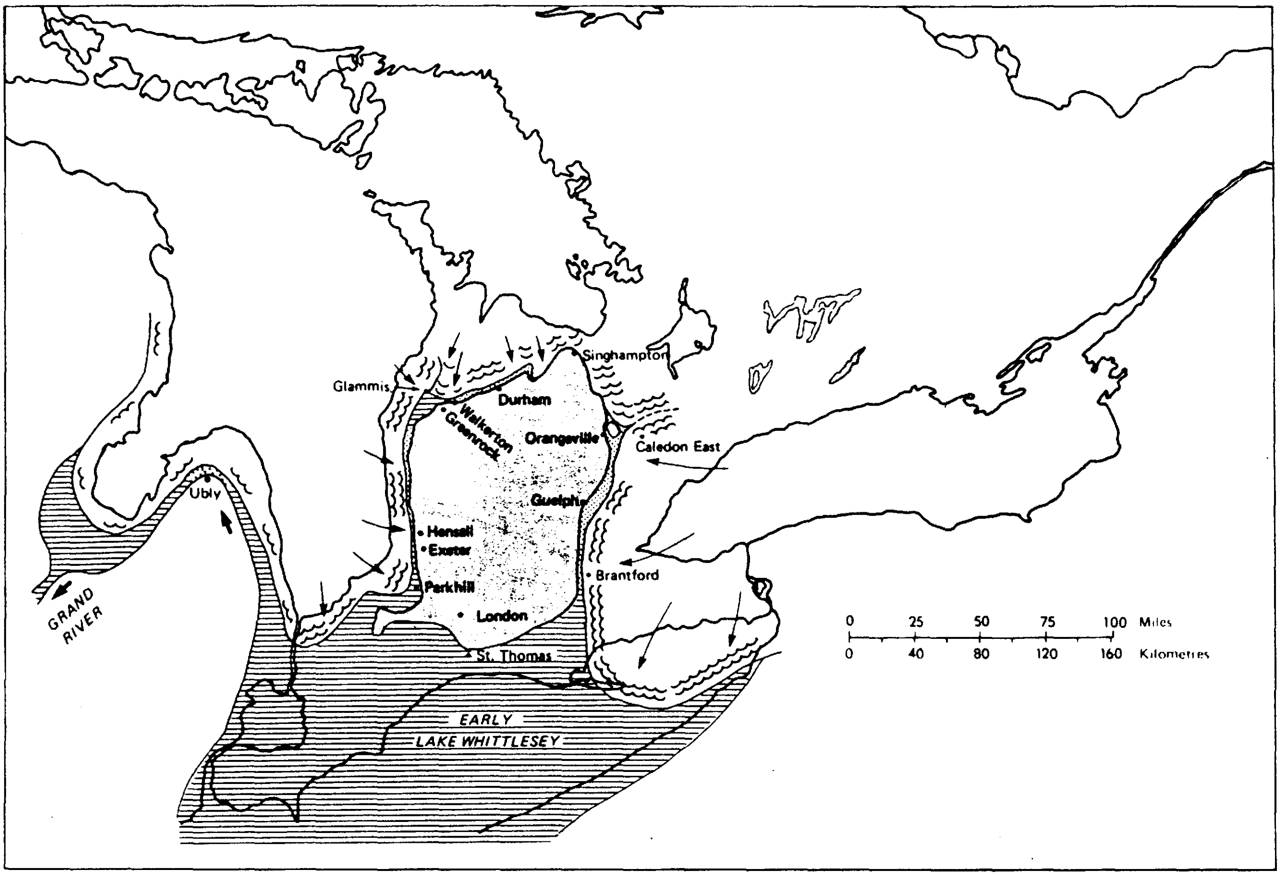


Figure 5: Position of Erie-Ontario ice lobe during formation of glacial spillway, c. 13,000 yr BP

Grey shading indicates exposed land
Horizontal hatching indicates proglacial lakes

From Chapman and Putnam (1984)

2.3 - Soils

The large majority of soils in the study area are Grey-Brown Luvisols (Orthic Luvisols in the FAO system), typical of the Deciduous and southern Mixed Forest vegetation regions in southern Ontario (Bentley, 1978). These soils are characterized by an eluvial Ae horizon and an illuvial Bt horizon (Presant and Wicklund, 1971; Bentley, 1978). Some well and moderately drained areas support Melanic Brunisols and Regosols, while in poorly drained sites Humic Gleysols and Organic deposits are found (Presant and Wicklund, 1971).

The soil types and associated drainage classes in this area are strongly correlated to the Quaternary parent materials present (Presant and Wicklund, 1971; Ontario Institute of Pedology, 1988). Coarse grained soils overlay most of the Wentworth Till and sandy outwash and deltaic deposits, but are far less common on the Haldimand clay plains or Port Stanley Till (Figure 6). It follows that soil texture correlates with the distribution of vegetation associations. The oak plains are restricted primarily to coarse-grained soils within the study area.

On a smaller scale, the relationship between vegetation distribution and soils is still apparent, although they do not correlate precisely. Figure 7 shows the distribution of soil associations in South Dumfries township in relation to the extent of the oak plains as mapped by Wood (1961). Finer grained, moderately well to poorly drained soils, such as those of the Brantford, Colwood and Toledo series, did not generally support oak plains. However, all well drained soils did not support oak plains; for example, they were found on Woolwich loams to the east of the Grand River, but not on those in the northwest corner of the township. The oak plains were most

Figure 6: Coarse and rapidly drained soils in Haldimand-Norfolk-Dumfries

Compiled from Chanasyk (1972) and Ontario Institute of Pedology (1988)

Soils

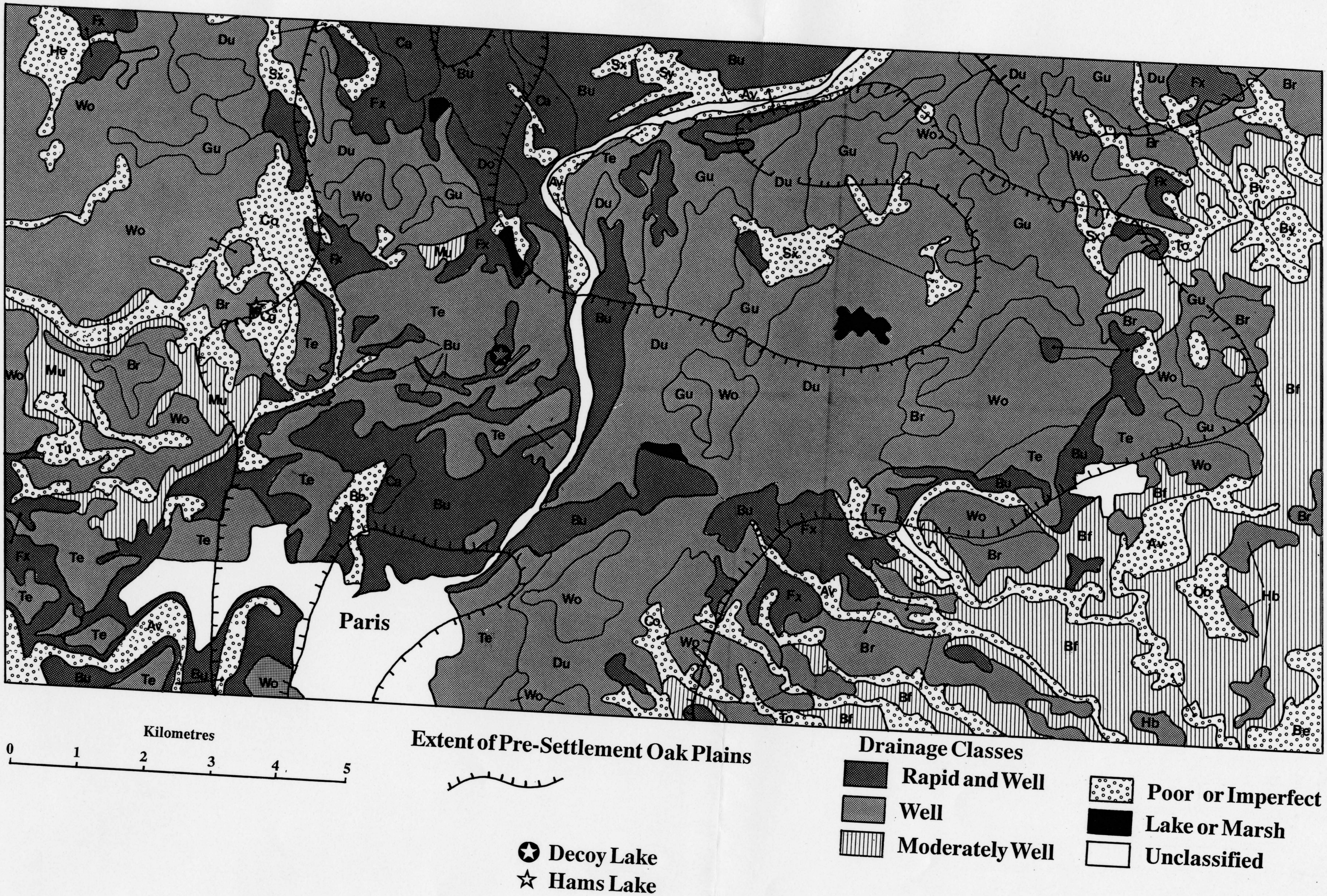

Coarse Soils
Rapid and Well-Drained Coarse Soils
N
Kilometres
0 5 10 15 20

Figure 7: Soils of South Dumfries Township

Drainage	Symb.	Name	Parent material component
Rapid and Well	Bu	Burford	fluvial gravel and cobbles
	Ca	Caledon	sandy testures over fluvial gravelly sand and gravel
	Do	Donnybrook	fluvial esker or kame gravel and cobbles
	Fx	Fox	lacustrine sand and loamy sand
Well	Br	Brant	lacustrine silt loam, very fine sandy loam
	Du	Dumfries	stony loam till
	Gu	Guelph	loam glacial till
	Hb	Harrisburg	silty textures over silty clay loam
	Te	Teeswater	silty and loamy textures over fluvially gravelly sand and gravelly loamy sand
	Wo	Woolwich	silty textures over loam glacial till
Moderately Well	Bf	Brantford	lacustrine silty clay
	Mu	Muriel	clay loam or silty clay glacial till
Poor or Imperfect	Av	Alluvium	silty clay loam recent alluvium
	Bb	Brisbane	fluvial gravelly sand and gravel
	Be	Berrien	sandy texures over silty clay and clay
	Bv	Beverly	lacustrine silty clay loam or silty clay
	By	Brady	lacustrine sand and loamy sand
	Cg	Connestoga	silty textures over loam glacial till
	Co	Colwood	lacustrine silt loam and very fine sandy loam
	He	Heidelburg	lacustrine fine and very fine loamy sand
	Ob	Osbourne	?
	Sx	Styx	decomposed organic matter
	Sy	Sylvan	decomposed organic matter
	To	Toledo	lacustrine silty clay loam or silty clay

Soil data from Ontario Institute of Pedology (1988)
Extent of oak plains from Wood (1961)

Soils of South Dumfries Township



widespread on soils of the rapid and well-drained Burford series and well drained Dumfries, Teeswater, Woolwich and Guelph series.

The eastern border of the oak plains correlates well with the boundary between coarse soils of glaciofluvial and Wentworth Till origin and the less well drained soils of the clay plain. Other borders are less well defined by variations in soil texture and drainage, however. Substrate is important in determining the extent of the oak plains, but is not the sole factor.

2.4 - Climate

On a broad scale, the study area fits into the Great Lakes-St. Lawrence climatic region of Hare and Thomas (1979). The climate is continental, but modified by the proximity of the Great Lakes. The lakes moderate temperatures in winter, but slightly delay the onset of warmer temperatures in spring. Mean daily temperatures in July average about 20^0 C, and in January average -5^0 C. Precipitation varies to a greater extent than temperature from station to station, but averages 800 to 1000 mm through much of the region. This is distributed fairly evenly throughout the year, about 1/5 of it falling as snow.

To obtain a more accurate indication of climatic trends on a smaller scale, climatic data for 16 stations within or close to the study area were compiled (Table 1, Figure 8). From these data, simple maps of mean winter temperature (Dec.-Feb.), mean summer temperature (June-Aug.), mean annual precipitation, mean frost-free period, and mean number of degree-days above 5^0 C were produced (Figures 9-13).

Winter temperatures are highest in the southeastern portions of the area (Figure 9), while summer temperatures show negligible spatial variation within the confines of this study (Figure 10). Annual precipitation is greatest near the shores of Lake Erie, and lowest in the north-central part of the region (Figure 11). Both the mean frost-free period (Figure 12) and mean number of degree-days >5^0C (Figure 13) are greatest in the southern half of the area. The number of degree-days decreases substantially to the west and north of the region, but gradients are far less within the confines of the study.

The northward decreases in precipitation, winter temperatures, growing season and frost-free period had no apparent influence on the pre-settlement distribution of vegetation types. Despite Rowe's (1972) placement of the Deciduous-Mixed forest boundary in the northern section of the study area, the only significant conifer in the area, *Pinus strobus*, shows no apparent north-south trends in its distribution. Increased precipitation towards the south may be offset by slightly warmer temperatures, making moisture availability roughly similar throughout the region.

2.5 - Conclusions

Maycock (1963) suggested that within southern Ontario, soil moisture is the most important factor determining the vegetation present at a site. Although precipitation, seasonal temperatures, and growing season show variations within the study area, it is suggested that available moisture was fairly consistent. Independently of climate, variations in soil moisture at a given site depend primarily upon topography and the texture of soil and underlying parent materials. On the scale at which vegetation associations

TABLE 1: CLIMATE DATA FOR SELECTED STATIONS

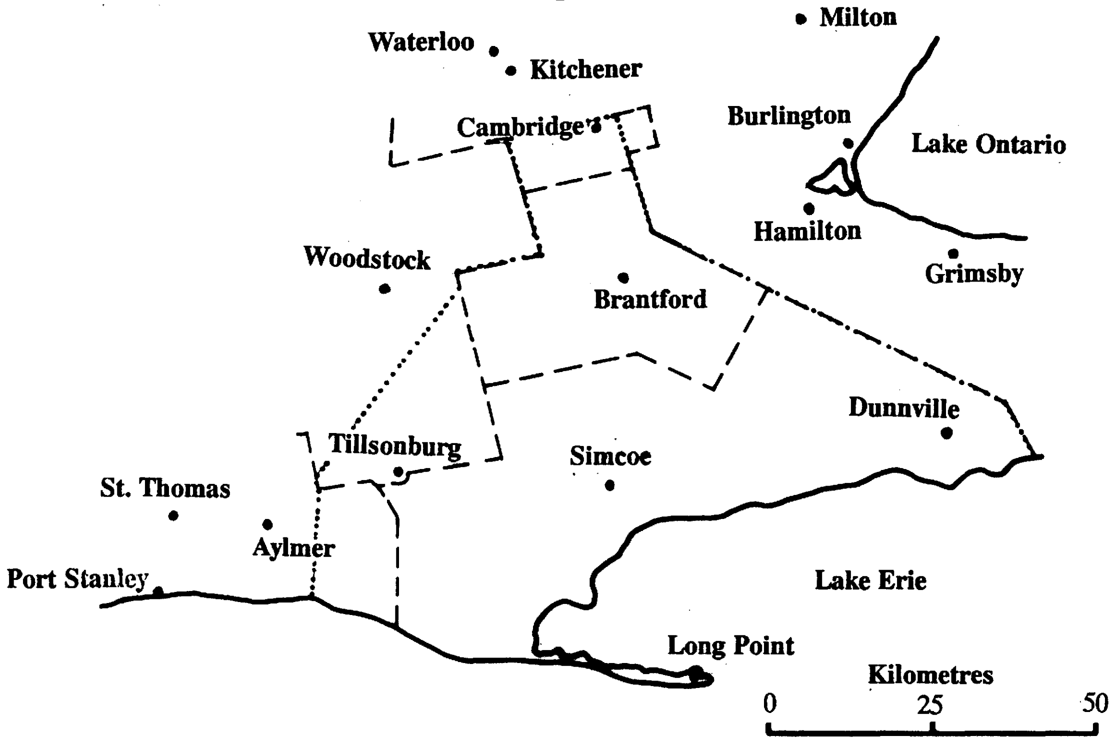
Station	Lat., Long.	Elev. (m)	Mean Daily Summer Temp. (°C)	Mean Daily Winter Temp. (°C)	Mean Annual Ppt. (mm)	Mean Degre Days >5°C	Mean Frost-Free Period (days)
Aylmer	42 46'N, 80 59'W	229	19.7	-4.3	967	2270	141
Brantford	43 8'N, 80 14'W	198	19.8	-5	819	2255	156
Burlington	43 20'N, 79 50'W	99	20.5	-4	822	2357	158
Cambridge	43 20'N, 80 19'W	268	19.3	-5	899	2169	143
Dunnville	42 50'N, 79 37'W	175	19.2	-3.5	905	2152	164
Hamilton	43 14'N, 70 54'W	198	20.3	-4.8	854	2353	176
Kitchener	43 26'N, 80 30'W	343	19.5	-5.5	897	2169	151
Long Point	42 33'N, 80 3'W	175	20	n/a	n/a	2294	198
Milton	43 30'N, 79 57'W	244	19.4	-5.5	875	2153	145
Port Stanley	42 40N, 81 13'W	183	18.4	-4.9	902	2023	144
St. Thomas	42 47'N, 81 10'W	236	19.3	-4.8	912	2187	142
Simcoe	42 51'N, 80 16'W	240	19.5	-4.3	888	2224	155
Tillsonburg	42 51'N, 80 43'W	213	n/a	n/a	914	n/a	n/a
Waterloo	43 27'N, 80 23'W	314	18.7	-6.1	850	1995	139
Woodstock	43 8'N, 80 46'W	282	19.1	-5.3	861	2117	138

Source: Environment Canada (1982a, 1982b, 1982c)

Figures 8 - 13: Winter temperatures, summer temperatures, precipitation, frost-free period and degree-days >5^0C for the study area

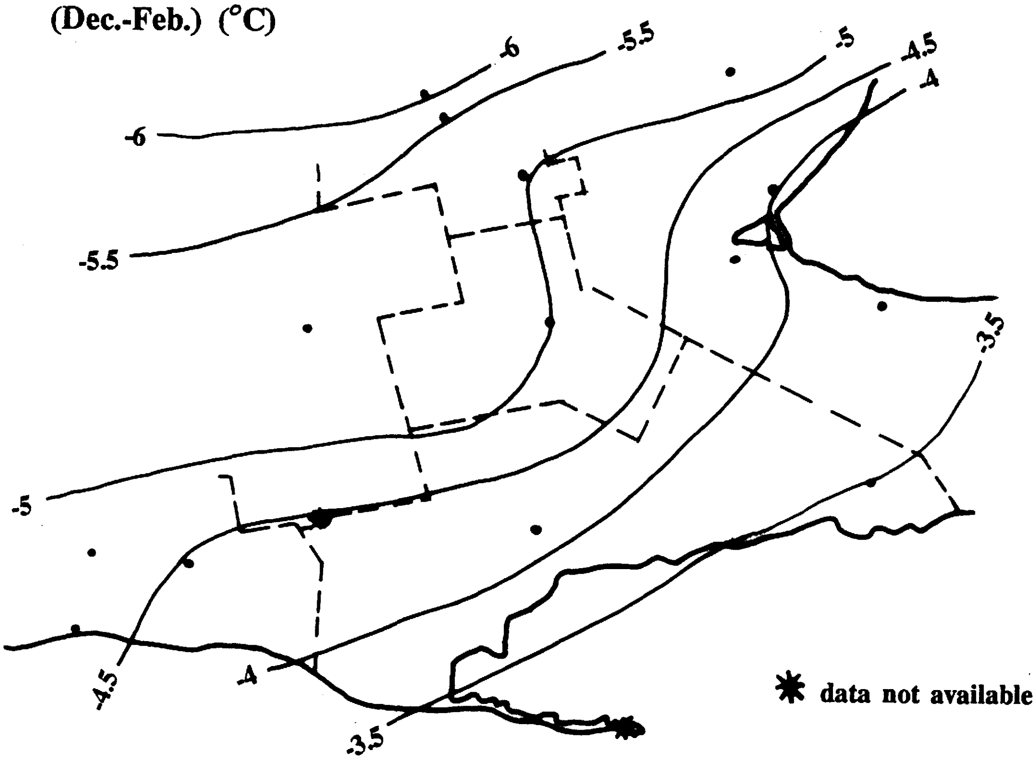
Data compiled from Environment Canada (1982a, 1982b, 1982c)

Location of Climate Recording Stations



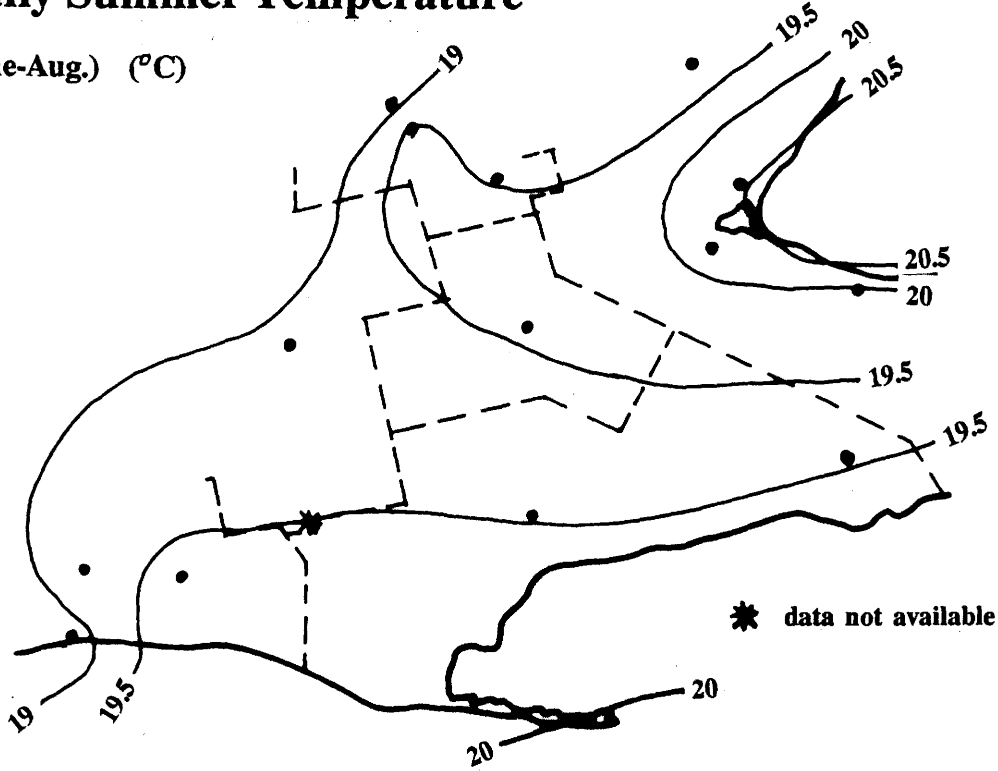
Mean Daily Winter Temperature

(Dec.-Feb.) (°C)



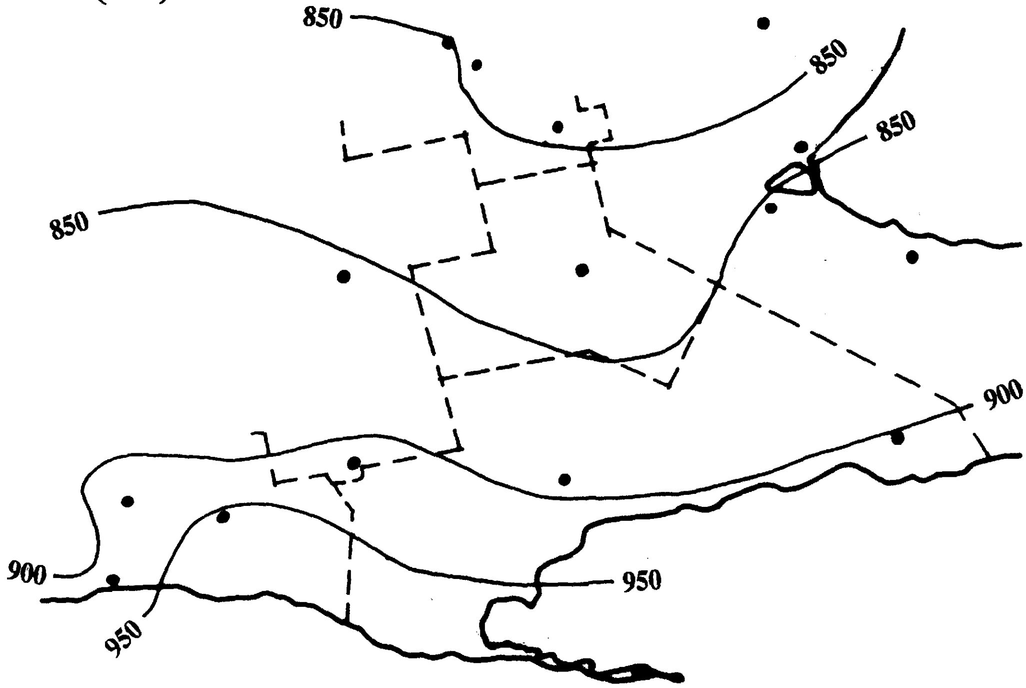
Mean Daily Summer Temperature

(June-Aug.) (°C)



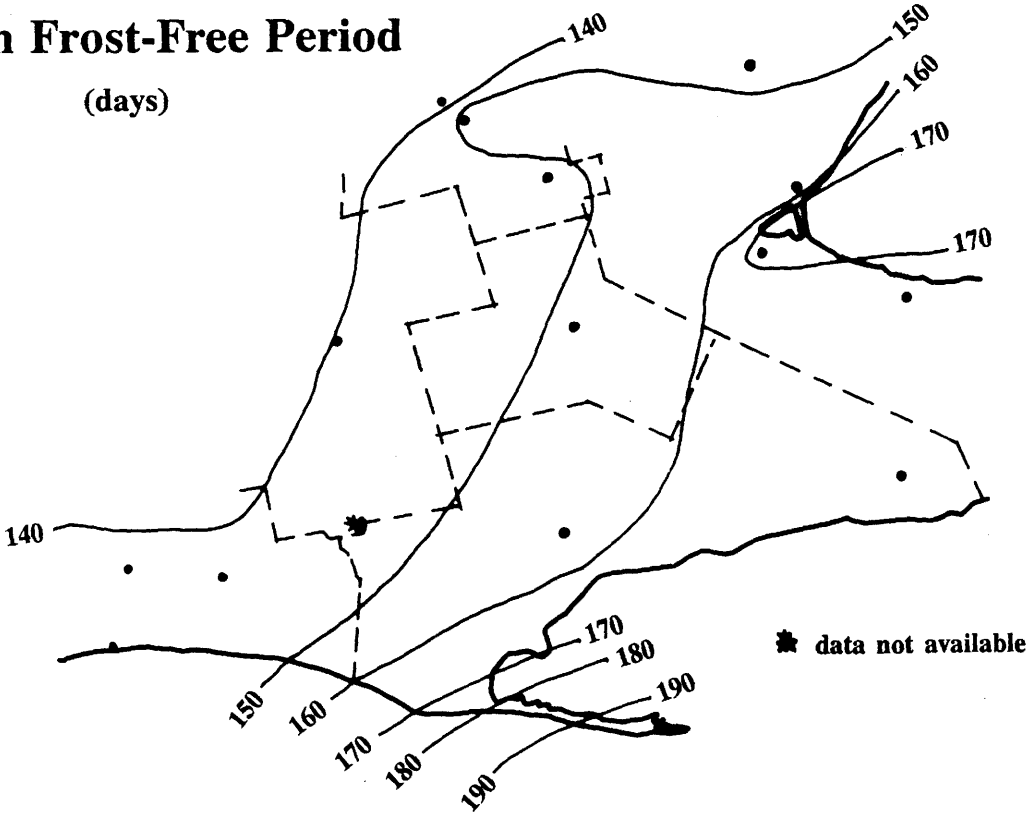
Mean Annual Precipitation

(mm)

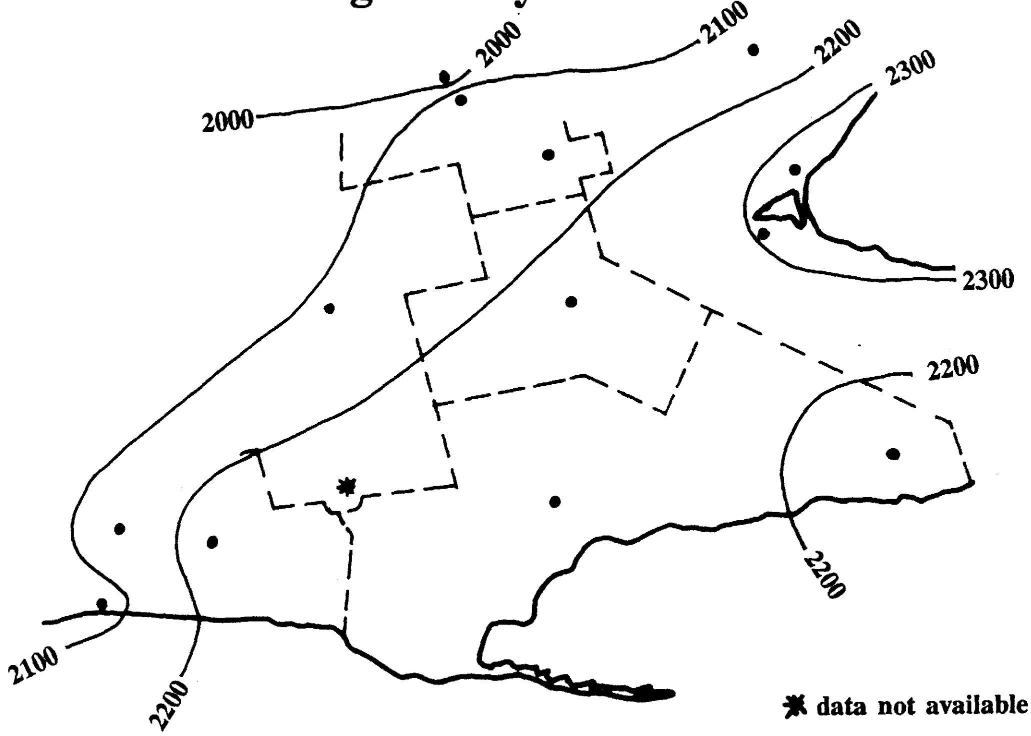


Mean Frost-Free Period

(days)



Mean Number of Degree-Days>5°C



are mapped in Figure 3, topography does not appear to be an important factor. Therefore soil and parent material texture is the most important physical factor in determining the distribution of vegetational associations in the study on the scale of kilometres.

It has also been demonstrated, however, that soils and underlying parent materials do not account for all of the spatial variation in the distribution of vegetation associations. The pre-settlement vegetation at a site is a function not only of relatively stable physical factors such as soils and topography, but also of historical factors. These may include climatic change, competition, disease, anthropogenic disturbance and stochastic or chance factors such as chance dispersal.

The use of fire by natives may have been the trigger necessary to allow oak plains to develop on some areas of well-drained soils. In testing the hypothesis that native burning led to the establishment of the oak plains, it is hoped to unravel the historical factors which have operated in conjunction with the edaphic conditions to allow the development of this association.

CHAPTER 3 - METHODS AND STUDY SITE

3.1 - Site Selection and Field Methods

Several criteria were used in order to select a site within the oak plains likely to produce a pollen record extending back to the late Pleistocene. Since the extent of the presettlement oak plains in the Paris region was on the scale of tens of kilometres (Wood, 1961), a medium or large lake (>1 ha) would not be appropriate since the inputs of pollen from distant areas would be high. A lake with an area of 1 ha or less should receive about 90% of its pollen from local and extra-local sources (those within several hundred metres of the site) (Jacobson and Bradshaw, 1981). Thus, a site of this size would be appropriate in order to study the postglacial history of a meso-scale vegetation assemblage such as the oak plains. Preferably, the site should also have no inflowing streams which may transport pollen collected elsewhere in the watershed. Though most of the original vegetation in the area has been cleared and the land is under fairly intense cultivation, it was hoped to find a site at which some of the native vegetation still remained. This would indicate that disturbance to the watershed immediately surrounding the site may not have been extensive. In addition, the components of the vegetation could be studied in order to compare the flora with that of extant oak savanna-type vegetation in southern Ontario.

Potential lakes were identified using 1:50,000 topographic map sheets overlaid with an outline of the presettlement oak plains in North and South Dumfries townships as defined by Wood (1961). These lakes were visited in the summer of 1987, and several were selected as potential coring sites. Test cores at the first two of these sites showed the sediments to be unsuitable for analysis, but the third site, unofficially named Decoy Lake, produced suitable cores.

Coring of Decoy Lake was carried out in November 1987 using a modified Livingstone piston corer (Wright *et al.*, 1984). The cores were extruded in 1 metre segments and wrapped in plastic film and aluminium foil for safe transport to the lab. A clear plastic tube was used to sample the upper 20-25 cm of unconsolidated sediment.

In the late summer of 1988, a partial species list for the vegetation immediately surrounding the site was completed, with the help of W. Bakowsky. The presence of prairie or oak savanna indicator species would help provide further evidence for the pre-settlement vegetation found in the area of Decoy Lake.

3.2 - Decoy Lake

Decoy Lake is situated in a kettle depression in an area of outwash sands and gravels at lat. $43^0$14'N, long. $80^0$22'W, about 4 km NNW of Paris, South Dumfries Township, Brant County, Ontario (Figures 2,4,7). The size of the lake itself varies depending on water levels, and was 60 m by 70 m when cored in the fall of 1987. The lake is very shallow, the depth in the centre at time of coring being only 30 cm. The lake does dry up occasionally; when visited in the fall of 1988, after an unusually hot and dry summer, herb vegetation grew across the basin. This is probably an exception, however, as the lake still contained 30 cm of water after a 'normal' summer in 1987, and the recent sedimentological record shows no evidence of periodic hiatuses in sedimentation (the upper sediments are gyttja). The soils around Decoy Lake are of the rapid and well drained Burford Loam series (Presant and Wicklund, 1971; Ontario Institute of Pedology, 1988).

Decoy Lake is well within the limits of the pre-settlement oak plains, as mapped by Wood (1961). Ploughed corn fields surround the lake on all sides; an area within 100-200 m of the lake has remained unploughed, however. A list of the tree, shrub, and herb species identified from the unploughed area around the site is given in Table 2 and summarized below.

The lake is ringed by shrubs and many large *Quercus alba* and *Quercus macrocarpa* trees. Two *Quercus alba* individuals were aged using a tree corer, though the corer was too short to reach the pith of either tree. One tree was 86.3 cm in diameter and greater than 99 years old, while the other tree had a diameter of 90.3 cm and an age a little in excess of 141 years (the end of the core was close to the pith). The size of these two trees is typical of the 20 or so oaks around the lake.

The slopes beyond the ring of trees and shrubs are occupied by a low cover of herbs and scattered small trees 3-5 m in height (*Populus tremuloides, Quercus macrocarpa* and *Ulmus americana*). Most of the herb species found are typical invaders of disturbed open sites; however, at least two of those identified are good indicator species of prairie and oak plains/savanna sites in southern Ontario and the mid-western United States (W. Bakowsky, pers. comm.). These species are *Solidago nemoralis* and *Luspideza capitata*. Additionally, *Andropogon gerardii*, a typical prairie grass, was found growing along a road near the site.

Although many weedy species have invaded the area around the site, it appears to be a modified remnant of the oak plains that occupied the area

TABLE 2: VEGETATION SURVEY OF THE DECOY LAKE SITE

Grassy slopes around pond

Trees and shrubs:
Cornus stolonifera (red osier dogwood)
Populus tremuloides (trembling aspen)
Quercus macrocarpa (bur oak)
Ulmus americana (American elm)

Herbs:
Ambrosia artemesiifolia (ragweed)
Arctium minus (burdock)
Asclepias syriaca (milkweed)
Aster ericodes (many-flowered aster)
Dipsachus sylvestris (teasel)
Lespideza capitata (round-headed bush clover) **
Monarda fistulosa (wild bergamot)
Oenothera biennis (evening primrose)
Poa praetensis (Kentucky blue grass)
Potentilla canadensis (dwarf cinquefoil)
Rosa blanda (smooth rose)
Solidago canadensis (goldenrod)
Solidago nemoralis (showy goldenrod) **
Trifolium dubium (least hop clover)
Verbascum thapsus (common mullein)
Verbena hastata (blue vervain)

Ring of trees/shrubs around pond

Canopy trees:
Quercus alba (white oak)
Quercus macrocarpa (bur oak)

Understory of:
Cornus stolonifera (red osier dogwood)
Cornus racemosa (dogwood)
Prunus serotina (wild cherry)
Prunus virginiana (chokecherry)
Prunus americana (wild plum)
Rhamnus sp. (buckthorn)
Salix sp. (willow)
Vitis riparia (frost grape)

TABLE 2 (CONT'D)

At edges of pond

Carex muellenburghii (sedge)
Epilobium sp. (fireweed)
Leersia oryzoides (rye grass)
Lycopus europeus (water-horehound)
Panicum sp. (millet)
Poa palustris (fowl blue grass)
Polaris sp. (canary reed grass)
Polygonum lapathifolium (pale smartweed)
Polygonum pennsylvanicum (Pennsylvania smartweed)
Scirpus atroverens (green bullrush)

Notes:
- ** denotes prairie/oak plains indicators
- survey was compiled in August and October of 1988 with the assistance of W. Bakowsky, University of Toronto

over 150 years ago. Two of the five tree species listed by Maycock (1963) and Bakowsky (1988) as typical of oak plains in southern Ontario are found at this small site, in addition to the presence of at least two prairie/savanna indicator species. The ages on the two oaks indicate establishment at or soon after the time of initial settlement in the area. It thus appears that even the scattered trees on the oak plains may have been cleared soon after arrival of Europeans. Chanasyk (1972), however, notes several >300 year old *Quercus* individuals on remnant oak plains sites in Haldimand-Norfolk, to the south of Decoy Lake.

Additional evidence that this area supported oak plains comes from local placenames. The Paris Plains Church is located about 1 km west of Decoy Lake. The towns of Oakland and Fairfield Plain and the township of Oakland are all located in Brant County, about 10-15 km south of Paris.

Within a 7 km radius of Decoy Lake, there are 19 catalogued archaeological sites (Kathy Dandy, personal communication, 1988). Of these, 10 are Archaic, two are Middle Woodland, one has both Archaic and early Woodland affinities, one has Archaic and middle Woodland affinities, two have Archaic and late Woodland affinities, and three are of unknown cultural origin. All of the 19 sites represent temporary camps, with stone tools and weapons being the primary components of the collections. Although nearly all of the sites are found along watercourses, only one is within a kilometre of the Grand River, the major river in this area. There is a cluster of seven Archaic sites about 2.5-3 km west of Decoy Lake, these being the closest sites to the Lake.

The predominance of Archaic sites in this area is a result of the transient nature of these peoples. Being hunter-gatherers, they would have left behind many temporary hunting camps. More sedentary cultures, in particular the late Woodland agriculturalists, lived in more permanent villages. There is no evidence for any villages or agricultural activities within the boundaries of this survey.

3.3 - Laboratory Methods

Dating

Five radiocarbon dates were obtained from the Decoy Lake core in order to provide chronological control. Bulk dating of sediment can lead to errors due to old carbon contamination (MacDonald *et al.*, 1987), and there is the added complication that the large sample size necessary to obtain an accurate date may represent up to several hundred years of deposition, particularly if sedimentation rates are slow. To avoid these problems, all dates were made on terrestrial macrofossils using Atomic Mass Spectrometry (AMS). Dating was carried out by the Isotrace Laboratory at the University of Toronto. The five macrofossils to be dated were selected from levels at or near points at which there appeared to be a significant change in the pollen stratigraphy. The levels dated were 497 cm (basal date), 418 cm, 250 cm, 135 cm and 94 cm.

Pollen Analysis

Sub-sampling of the sediments for pollen analysis was carried out at 5 cm intervals along the core. To enable calculation of pollen concentrations and pollen accumulation rates, a calibrated tablet of pre-treated *Lycopodium* spores was added to each sediment sub-sample (Stockmarr, 1971). These samples, each of 1 mL volume, were prepared following the standard procedures of Faegri and Iversen (1975). This procedure involves treatment with HCl to remove carbonate, KOH to remove humic acid and HF to remove silicates. Samples still having a large amount of fine-grained sediment following the HF treatment were sieved using the procedure outlined by Cwynar *et al.* (1979). Cellulose was removed by acetolysis (9 parts $(CH_3CO)_2O$ to 1 part H_2SO_4). Samples with a high content of coarse organic matter were also sieved with a 0.6 mm screen to simplify slide preparation and counting. Finally, samples were dyed with safranin and mounted on slides in 2000 cs silicon oil.

Between 290 and 480 grains of terrestrial pollen were counted at each level down to 495 cm, below which the sediments were essentially sterile. Identifications of pollen grains were based upon a modern reference collection and the works of McAndrews *et al.* (1973) and Kapp (1969). *Picea* grains were differentiated into *Picea* cf.*glauca* and *Picea* cf.*mariana* using the morphological characteristics outlined by Hansen and Engstrom (1985). Morphological characteristics were also used to distinguish between grains of haploxylon pine and diploxylon pine (McAndrews *et al.*, 1973). In northeastern North America, *Pinus strobus* is the only Haploxylon pine, whereas the Diploxylon subgenus is represented by both *Pinus banksiana* and *Pinus resinosa*; pollen grains of the latter two species are indistinguishable. At least 25 grains of *Pinus* were differentiated at 20 cm intervals throughout the whole core and at 10 cm intervals during the time of high *Pinus* percentages. Counting was carried out on a Zeiss compound microscope at 400x, with some detailed examinations of grains being made at 1000x.

Diagrams of relative pollen frequencies (percentages) and pollen accumulation rates (PAR) were produced from the raw pollen counts. In calculating pollen percentages for terrestrial taxa, the pollen sum included terrestrial pollen plus Cyperaceae, since this family includes both terrestrial and aquatic species. The pollen sum for calculating percentages of aquatic taxa included terrestrial plus aquatic components. PAR values were calculated using the following formula:

$$\text{PAR (grains/cm}^2\text{/yr)} = \frac{\text{grains of sp. A} \times 12{,}077 \times \text{sedimentation rate}}{\#\ \textit{Lycopodium}}$$

where 12,077 is the number of *Lycopodium* spores in each tablet. The sedimentation rate (in cm/yr) is calculated by taking the slope of the line between individual radiocarbon dates.

Charcoal

The total area of charcoal on one or more slides was calculated for 47 samples along the length of the core using digital image analysis (Moser, 1988; MacDonald *et al.*, 1989). Image analysis involves digitizing each of at least 150 views on the slide(s) for a given level from the core, and measuring the area within those views which exceeds a pre-determined threshold optical density. Microscopic charcoal fragments appear black on prepared slides, and so this technique should provide a reasonable estimate of the total charcoal present on a slide. *Lycopodium* spores are also counted in the views, allowing calculation of charcoal concentrations. These concentrations are then multiplied by the sediment accumulation rate in order to calculate the charcoal accumulation rate (CHAR).

Plant Macrofossils

Fifty mL samples of the core, taken at 20 cm intervals, were passed through a 0.6 mm screen in order to isolate any plant macrofossils such as needle fragments, twigs, seeds and macroscopic charcoal. The macrofossils were stored in glycerol and, at a later date, identified with the help of a reference collection and Montgomery (1977).

Loss on Ignition

The organic content of each sample was determined by loss on ignition (LOI) as outlined by Dean (1974). 1 mL of sediment from each sampling level was dried overnight at 60^0C, weighed, fired in a furnace at 550^0C, and then reweighed. Since organic Carbon is oxidized by firing at this temperature, the difference between the dried and fired weights is proportional to the organic content of the sample. Percent LOI is calculated by dividing this difference by the original dry weight, and multiplying by 100%.

3.4 - Difference Diagrams

A numerical analysis was carried out on the pollen data from Decoy Lake and two nearby lakes (Hams Lake and Maplehurst Lake) in order to compare the changes that have occurred in the pollen stratigraphies of these sites since deglaciation.

The differences between the pollen stratigraphic history of Decoy Lake and that of nearby sites in southern Ontario can be made on a qualitative level by visually comparing the pollen diagrams from the sites. To compare the stratigraphies in a quantitative manner, difference diagrams were prepared. Jacobson (1979) used difference diagrams from several pairs of small basins to reconstruct the postglacial history of *Pinus strobus* in Minnesota. Each paired site consisted of two small basins of similar size and catchment area located in close proximity to one another but on different substrates (i.e. sand plain vs. till moraine). The regional pollen record for each of the basins in a given pair should be similar, since this pollen would have a source area of many hundreds, even thousands, of square kilometres. The local pollen records, however, might be very different due to the contrasting local edaphic and topographic conditions. Comparison of the pollen records at the basins within each paired site, using difference diagrams, would filter out most of the regional record, and emphasize the differences in local vegetation histories. Jacobson (1979) compared PAR records by simple subtraction, while percentage records were compared by taking the log of the ratio of the two values.

The two sites selected for comparison to Decoy Lake were Hams Lake (Bennett, 1987), a medium-small (2.5 ha) kettle lake about 5 km. west of Decoy Lake, and Maplehurst Lake (Mott and Farley-Gill, 1978), a slightly larger lake (6 ha) located about 25 km WNW of Decoy Lake. Both lakes are larger than Decoy Lake and are located on moderately drained till, though Hams Lake is just west of the oak plains as mapped by Woods (1961). The pollen records of these sites should to a large degree reflect the regional, mesic-type vegetation found throughout the majority of southern Ontario, due to their substrate and basin characteristics. On the other hand, the Decoy Lake pollen record should reflect more local vegetational trends as a result of its small catchment size. Comparing the record of Decoy Lake to those of Hams and Maplehurst Lakes using some form of difference diagrams should show how vegetation development at Decoy Lake differed from that at more mesic sites in the area, and possibly most of southern Ontario.

Difference diagrams were constructed in this study using the pollen percentage records from the three lakes. When comparing percentages, Jacobson (1979) used log ratios; however, this will tend to greatly overemphasize small differences, and underemphasize larger differences. For this study, diagrams will be constructed by taking the difference between the raw percentages at two sites. This method will tend to overemphasize differences in taxa which are copious pollen producers. Thus, the difference diagram should be examined in conjunction with the pollen percentage diagram from one of the sites.

For reasonably accurate comparisons to be made between sites, the difference diagrams must be calculated at levels corresponding to the same ages. It is unreasonable to assume that dating and sampling at all of the three sites is accurate enough to warrant calculations to be made at close intervals. The calculations were therefore made at 500 year intervals, and all samples falling within a 150 year period on either side of the given date were averaged to give the value for that date. For example, percentages of a given taxon at all samples between 850 yr BP and 1150 yr BP were averaged to give the 1000 yr BP comparison percentage. The only exception is that there is no 0 yr BP comparison percentage; the uppermost sample used for the difference diagrams was taken to be the most recent sample before the rise in *Ambrosia* pollen indicating European disturbance. This correlates to a date of about 150 yr BP. The number of samples averaged for each interval varied from 1 to 7, depending on the original sampling interval and the sedimentation rate. Dates for each original sample were obtained by extrapolating between individual radiocarbon dates for Decoy and Maplehurst Lakes, and using the regression equation provided by Bennett (1987) for Hams Lake.

Difference diagrams were produced for Decoy and Hams Lakes, Decoy and Maplehurst Lakes, and Hams and Maplehurst Lakes. The following taxa were plotted in each of the comparisons: *Picea, Pinus, Tsuga, Betula, Ostrya/Carp, Quercus, Ulmus, Fraxinus, Fagus, Acer, Carya,* Gramineae, Cyperaceae, Tubuliflorae, and total herbs.

CHAPTER 4 - RESULTS

4.1 - Sediment Stratigraphy

Two sediment cores were retrieved from Decoy Lake using the Livingstone corer, one 530 cm long (20 cm to 550 cm depth) and one 500 cm long (20 cm to 520 cm depth). In addition, the top 23 cm of sediment were sampled using a plastic tube. The shorter of the two Livingstone cores was used in all analyses, and the second was retained as a backup.

From the base of the core up to 497 cm, the sediments are grey clays and sands (Figure 14), indicative of glacial conditions. Organic sedimentation began at this point, and fine green gyttja was deposited up to about 445 cm. The sediments then grade into peaty gyttja. The peat (vascular, not bryophytic) is coarsest and most abundant between about 330 cm and 170 cm. Within this peaty phase numerous wood fragments were found, and in a test core (unrecovered), a complete *Pinus banksiana* cone was found at a depth of about 250 cm. In addition, a lens of sand and clay, 2 to 3 cm thick, was located at 286 cm depth in the primary core; a very large number of wood fragments, primarily twigs, were found both above and below this lens. This feature does not appear to have been continuous throughout the entire lake, since only a little sand was found at this level in the backup core, taken within a metre of the primary core. From 170 cm to 30 cm, the peat is finer and less abundant. The very top of the Livingstone core is composed of fine grained gyttja and mineral sediments.

The sediments recovered from the plastic tube core are gyttja with a relatively high mineral content, particularly towards the top. The sediments have a high water content, and the top 5-10 cm were poorly consolidated.

Loss on ignition results for the main core (Figure 14) correlate generally with the observed sediment stratigraphy, though not exactly. LOI is very low (<10%) from 495 cm to 445 cm. Between 435 cm and 275 cm, LOI remains between 30 and 60%, except for a very low value of 12% at 286 cm, corresponding with the clay and sand lens. From about 270 to 70 cm, LOI retains values of 80 to 95%, with the highest values being found from 220 to 160 cm, and from 60 to 80 cm. LOI fluctuates near the top of the core, but drops to less than 50% in the upper 10 cm. LOI results from the plastic tube core (Figure 15) show a strong decrease from 67% at 20 cm to 30% at 5 cm, followed by a moderate increase in the surface sample.

The results of the five radiocarbon dates are shown in Table 3 and plotted on the age vs. depth profile in Figure 14. Since it appears there were major changes in the sedimentation rate at the site, a single regression line was not plotted through the five dates. Instead, the sedimentation rate was calculated between each adjacent pair of dates. Comparison of the pollen stratigraphies of the plastic tube core and the top of the Livingstone core showed there to be overlap between the two. This overlap would be due to the unconsolidated nature of the uppermost sediments, slight compaction of the Livingstone core, and inaccuracies in determining the exact location of the sediment-water interface. Fortunately, the rise in *Ambrosia* pollen indicating the commencement of European disturbance provided a marker horizon in the pollen records of both cores. In this area, widespread clearance and agriculture first occurred at about 1850 A.D.

SEDIMENT CHARACTERISTICS
Decoy Lake, Ontario

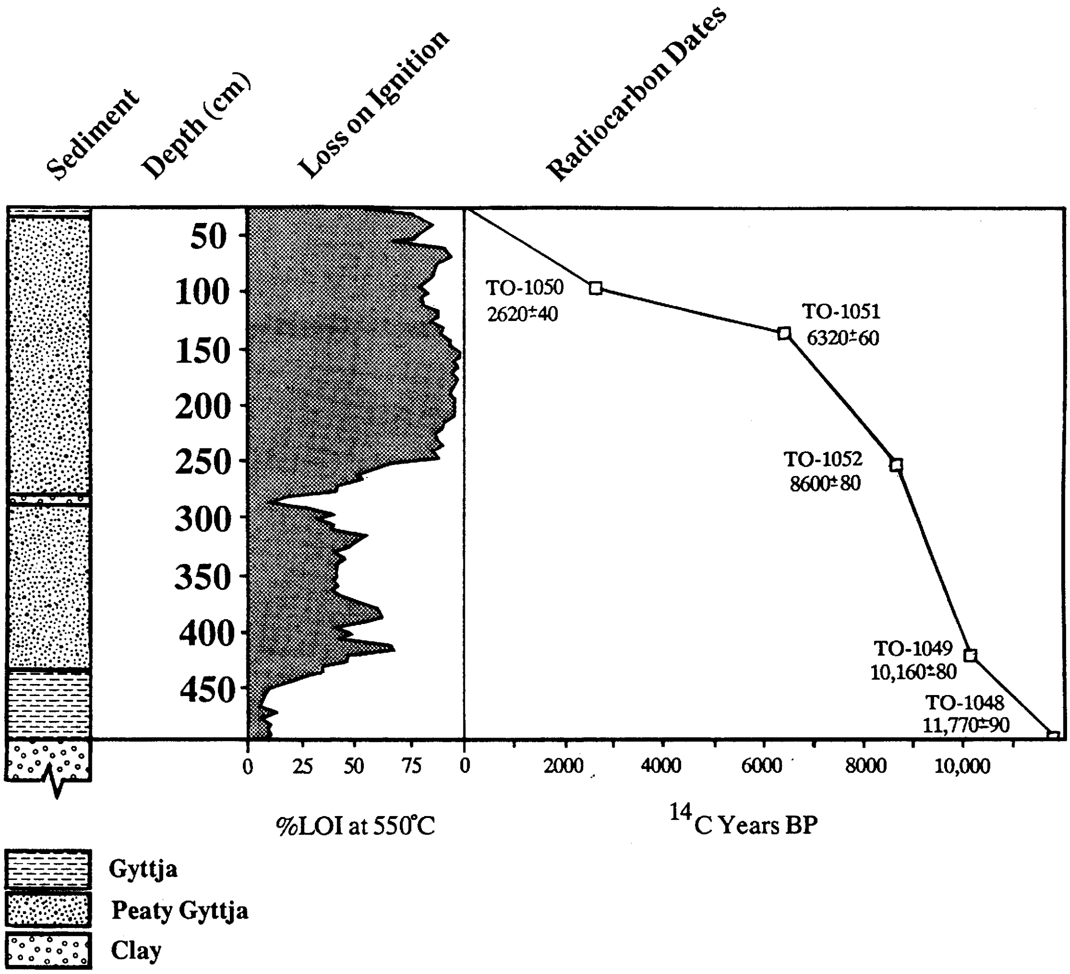


Figure 14: Sediment characteristics, Decoy Lake main core

TABLE 3: RADIOCARBON DATES FOR DECOY LAKE CORE

Depth (cm)	Material	weight (mg)	Lab #	Age (years BP)
94	twig frag.	42	TO-1050	2620 ± 40
135	bark frag.	152	TO-1051	6320 ± 60
250	twig frag.	139	TO-1052	8600 ± 80
418	bark frag.	90	TO-1048	10,160 ± 80
497	twig	449	TO-1049	11,770 ± 90

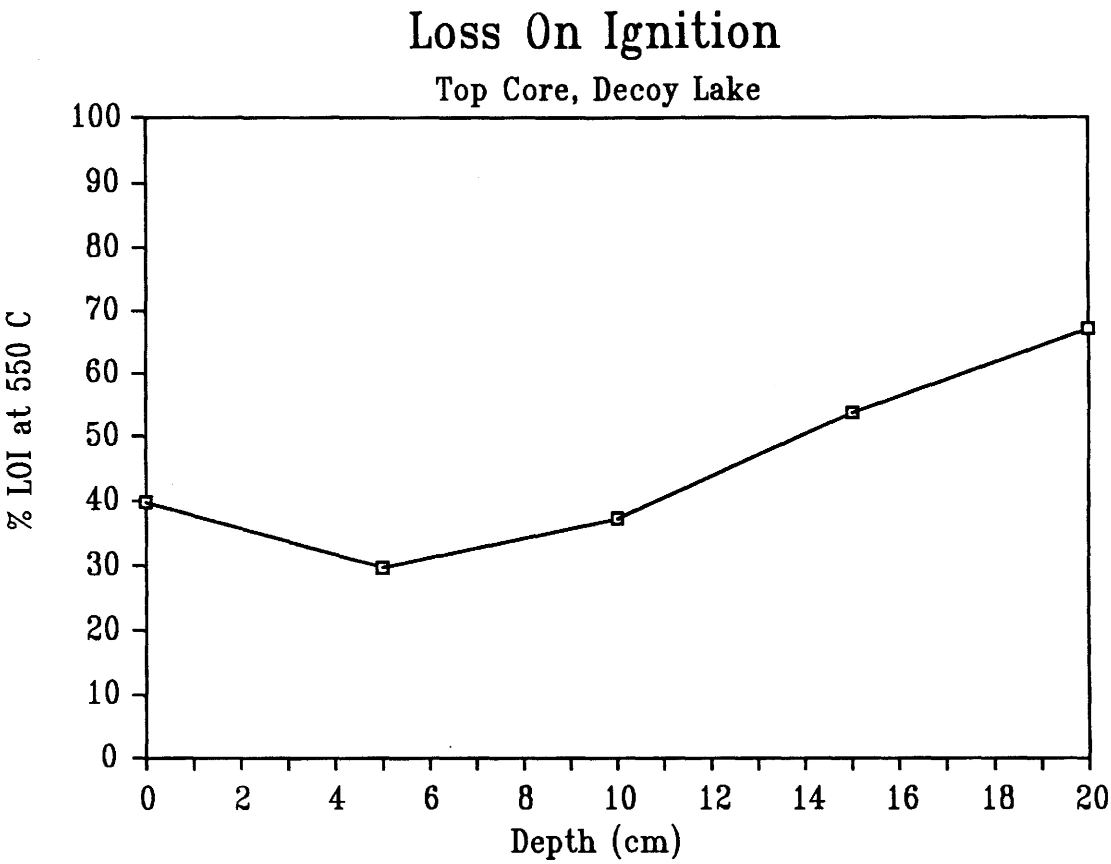


Figure 15: Loss on Ignition, Decoy Lake top core

(McAndrews, 1988), so this date was applied to the base of the *Ambrosia* rise in both cores. Thus, although the long core did not extend to the sediment-water interface, a date of 100 yr BP ('present' being 1950 A.D.) could be applied to 33 cm depth (Figure 14).

The graph of pollen accumulation rate (PAR) for Decoy Lake shows intense sediment focusing occurred during the early to mid Holocene (Figure 16). Sediment focusing is the differential deposition of sediments (and pollen contained therein) in a lake basin over time, resulting from the changing lake bathymetry (Davis *et al.*, 1984). A basin that has a conical shape with steep sides will result in an increase in sedimentation towards the centre of the lake, at the deepest point. As the lake gradually fills in and the basin assumes a flatter shape, sediments will be distributed more evenly throughout the basin. In the early period of the lake's history, then, most of the pollen landing on the surface of the lake will be deposited at the deepest part of the lake. The shape of the PAR diagram in Figure 16 shows a classic case of sediment focusing. As a result of this focusing, accumulation rates for pollen of individual taxa will be meaningless, particularly during the period 10,000 yr BP to 6000 yr BP.

4.2 - Pollen and Macrofossil Stratigraphy: Main Core

The pollen percentage diagram for the main core from Decoy Lake is shown in Figure 17. The sequence has been divided visually into five zones, based upon changes in the frequencies of a number of taxa. The characteristics of each of these five zones will be discussed below.

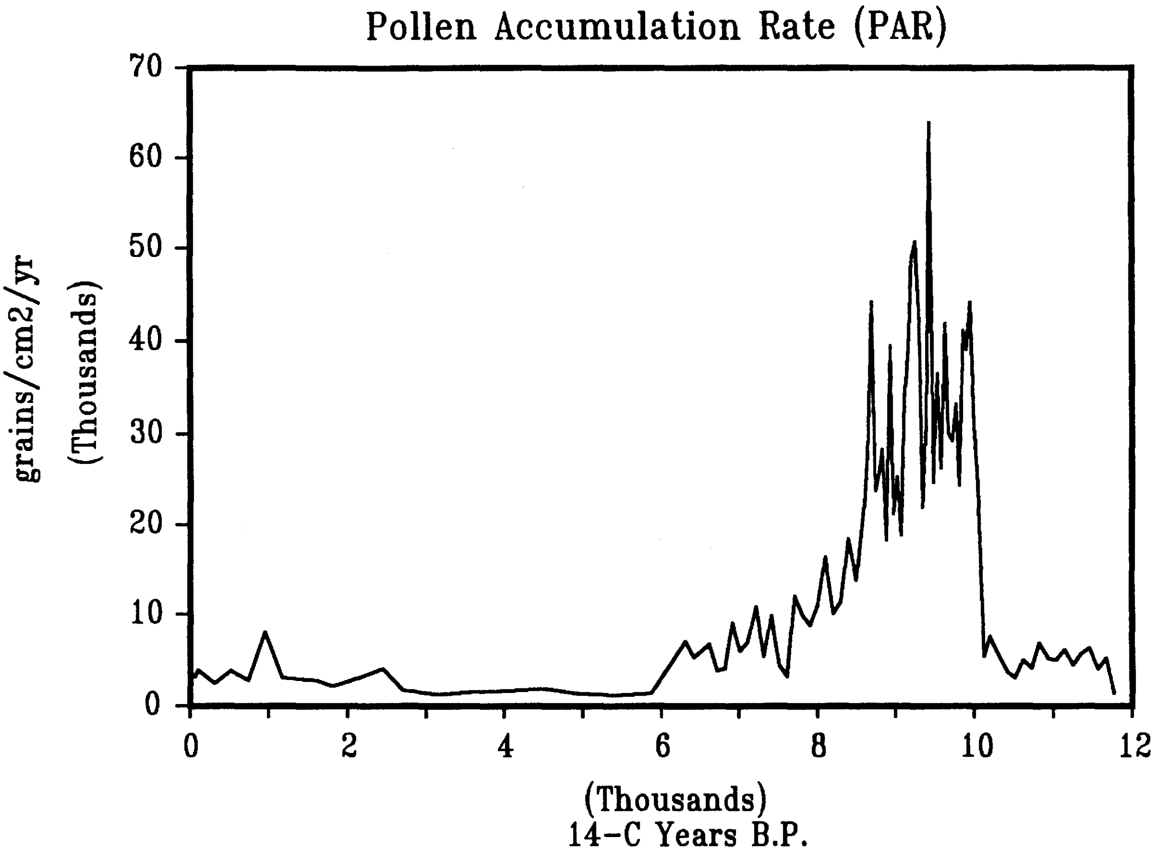


Figure 16: Pollen accumulation rate, Decoy Lake main core

Zone 1 (*Picea* zone): 11,800 yr BP to 10,100 yr BP (495 cm to 415 cm)

This zone is characterized by high percentages of *Picea* pollen. At the very bottom of the zone, there is a higher proportion of herb pollen, with *Picea* reaching frequencies of 40-50% and herbs averaging about 20%. Several other tree taxa also have minor peaks at the bottom of this zone: *Ostrya/Carpinus, Quercus,* and *Fraxinus.* *Betula* is found at low frequencies for the beginning of zone 1, but rises to its maximum value for the entire record, 13%, at 10,400 yr BP; at this point it is the second most abundant tree (in terms of pollen representation). From 11,500 yr BP to the top of this zone, *Picea* increases to 60-80%, while herbs drop to 10-12%. Herb taxa frequent through this zone, particularly towards the bottom, are Gramineae (3-6%), Tubuliflorae (2-7%), *Ambrosia* (1-3%) and *Artemisia* (2-6%). Other herbs found at moderately high frequencies at one or more levels in the zone are Ranunculaceae, Cruciferae, and *Epilobium.* Several herb taxa, though infrequent in this zone, are not found in any other zones except for isolated occurrences; some examples are *Stellaria, Thalictrum,* and *Potentilla* (Appendix 2). Cyperaceae, a family having both aquatic and terrestrial taxa, reaches frequencies of 5-10% at the bottom of this zone. Aquatics and shrubs are infrequent in this zone, except for *Salix* in the basal level.

The macrofossil record for zone 1 for the most part agrees with the pollen record (Figure 18). *Picea mariana* needle fragments are extremely abundant in the basal level of the core, and still common in several levels further up. Seeds of *Carex* (a genus within the family Cyperaceae having both terrestrial and aquatic species) and Cruciferae in the basal level verify the presence of these taxa. In addition to seeds and needle fragments, a fair number of wood and charcoal fragments were found in this zone. Twigs

Figure 17: Pollen percentage diagram, Decoy Lake main core

DECOY LAKE, ONTARIO
Pollen Percentage Diagram

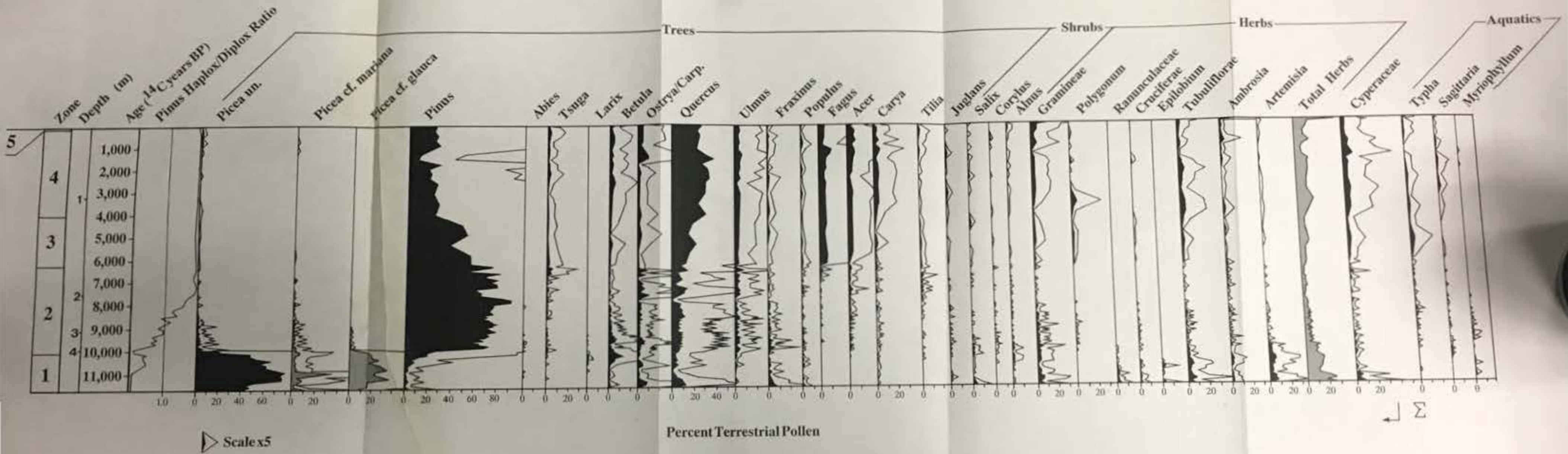
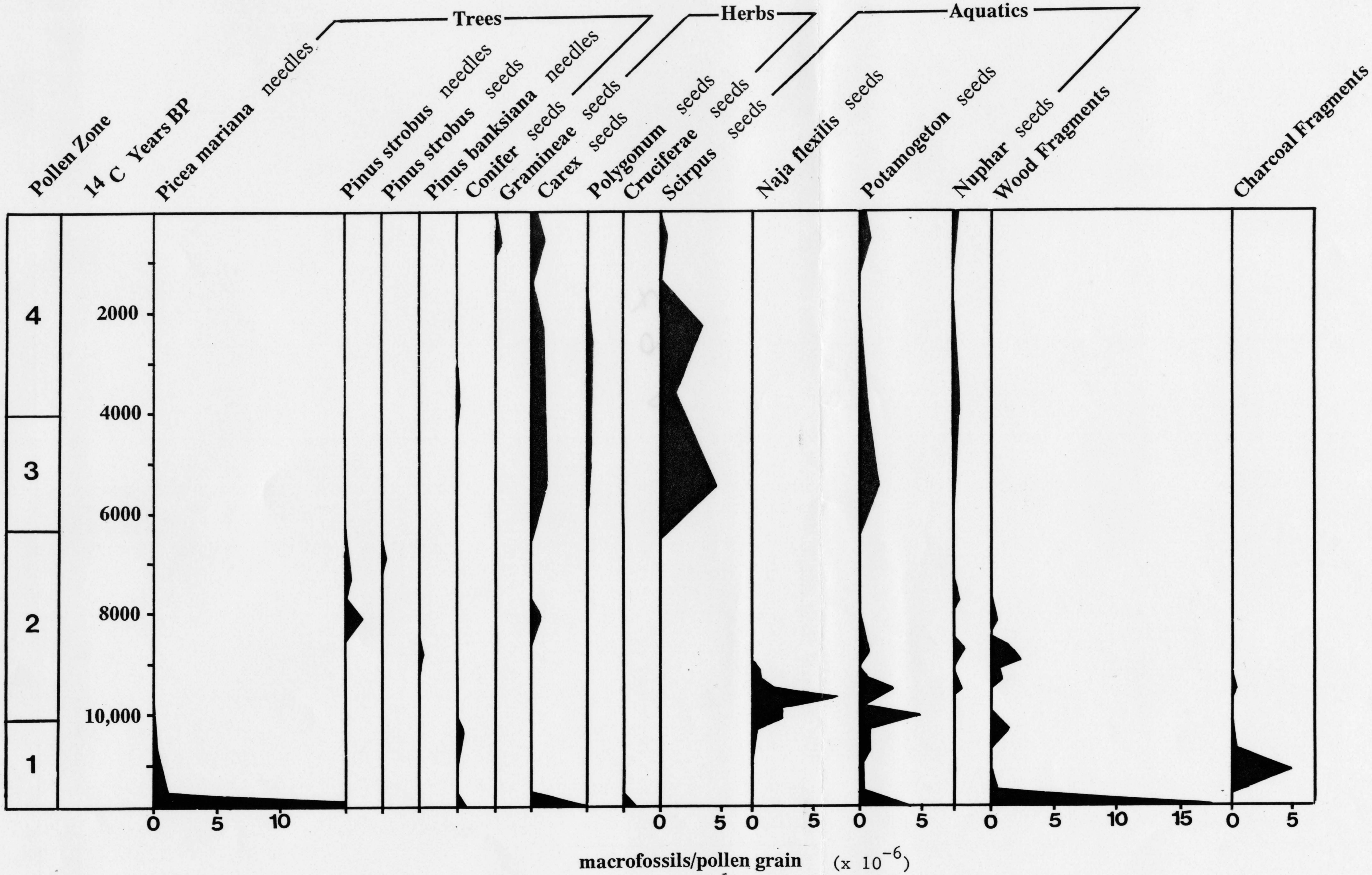


Figure 18: Macrofossil diagram, Decoy Lake main core

The concentration of macrofossils was multiplied by sedimentation rate to obtain macrofossil influx. This value was then divided by PAR to lessen the impact of sedment focusing.

Decoy Lake Macrofossil Diagram



and other wood fragments were particularly abundant in the basal sample, while macroscopic charcoal fragments were found in large amounts in the sample from 11,000 yr BP.

Zone 2 (*Pinus* zone): 10,100 yr BP to 6,300 yr BP (410 cm to 135 cm)

Very high frequencies of *Pinus* pollen (60-95%) and low percentages of nearly all other taxa characterize this zone. *Pinus banksiana/resinosa* (Diploxylon *Pinus*) pollen dominates until about 8800 yr BP, followed by the pollen of *Pinus strobus* (Haploxylon *Pinus*), which has nearly completely replaced the former by 7800 yr BP. *Quercus* maintains frequencies of 8-12% for most of this zone, after rising from levels of about 5% at the top of zone 1. *Betula* pollen decreases from a high of 7% near the bottom of the zone to less than 1% at the top. Other taxa present at fairly low but fluctuating frequencies for the zone are *Tsuga, Ostrya/Carpinus, Ulmus, Fraxinus,* and, to a lesser degree, *Carya* and *Tilia*.

The shrub taxa *Corylus* and *Alnus* are found fairly consistently through this zone at very low percentages. Other shrub taxa occur only in this zone, but are very rare; these are *Cephalanthus, Sambucus*, and, except for two isolated occurrences in zone 4, *Celtis*.

Herbs are found at lower frequencies in zone 2 than in any other period of the record. The total herb sum ranges from 7% to less than 1%. Gramineae, Tubuliflorae, and *Ambrosia* maintain frequencies of 1-3% for the period 10,100 yr BP to 8200 yr BP. For the upper part of zone 2, only *Ambrosia* maintains these values. Cyperaceae pollen is found throughout the zone. Although the percentages are low, there is a higher diversity of aquatic taxa in early zone 2 than during the previous zone. These include

Nuphar, Myriophyllum and *Potamogeton.* However, this diversity decreases after about 8000 yr BP.

As with the first zone, the macrofossil record correlates well with the pollen record in zone 2. A *Pinus banksiana* needle fragment was found at 9000 yr BP, and the *P. banksiana* cone found in a non-recovered core at about 250 cm depth would correspond to an age of about 8600 yr BP. Several *Pinus strobus* needles and one seed from this species were found at levels corresponding to ages between 6500 yr and 8000 yr BP. A number of *Carex* seeds were found throughout zone 2. Macrofossils of aquatic taxa (*Naja flexilis, Potamogeton,* and *Nuphar* seeds) were fairly abundant at lower levels in this zone, but absent or rare in the upper half. Many wood fragments and a small amount of macroscopic charcoal were also found in the lower half of the zone, particularly above and below the clay/sand lens at 286 cm (8900 yr BP).

Zone 3 (*Pinus* - *Quercus* zone) - 6300 yr BP to 4000 yr BP (130 cm to 115 cm)

This zone is somewhat of a transition between the preceding *Pinus*-dominated assemblage and the following *Quercus-Pinus*-herb zone, though it has several features making it distinct from both.

Pinus pollen is abundant throughout the entire zone, though it drops from about 60% at 6300 yr BP to less than 30% at 4000 yr BP. The frequency of *Quercus* pollen rises from 10% to 30% over the 2300 years of zone 3. Both *Fagus* and *Acer saccharum* rise in frequency at the beginning of this zone to levels that are maintained for most of the rest of the record, 7% and 4% respectively. The frequencies of other trees do not vary substantially from the previous zone. Most have more continuous records than before, though to some extent this may be a result of the coarser temporal sampling interval.

Pollen of herbaceous taxa is more common in zone 3 than in zone 2. Gramineae, *Polygonum* and Tubuliflorae maintain frequencies of 1-2% for most or all of the interval; the total herb sum ranges from 4-9%. Cyperaceae pollen is found at a frequency of 2-3% over the entire interval. Among the aquatic taxa, *Typha* is by far the most abundant.

Carex and *Polygonum* seeds comprise the terrestrial component of the macrofossil record for zone 3. The aquatic macrofossil record is dominated by large numbers of *Scirpus* seeds, along with smaller amounts of *Potamogeton* and *Nuphar* seeds.

Zone 4 (*Quercus* - *Pinus* - herb zone): 4000 yr BP - 100 yr BP (110 cm to 35 cm)

Quercus pollen is found at an average frequency of about 28 to 30% throughout zone 4 (low of 24% to high of 39%), making it the dominant pollen type at most levels. The frequency of *Pinus* varies from 8% to 28%, averaging about 25% for all but a few levels. Between about 1700 yr BP and 1200 yr BP, *Pinus* levels drop to 8-10%; however, frequencies average 25% both before and after this drop. *Carya* rises to and maintains a level of about 3-4 % at the beginning of zone 4. Other tree taxa, such as *Tsuga, Betula, Ostrya/Carpinus, Ulmus, Fraxinus, Populus, Fagus, Acer saccharum* and *Tilia* remain at frequencies similar to those in zone 3 or even earlier.

Herb pollen frequencies rise fairly substantially at the zone 3/4 boundary, and average about 8-10% (low of 3.5%, high of 13%) for most of zone 4. The only major drop below this average is during the *Pinus* low, when herbs averaged about 5%. The major contributors to herb pollen in zone 4 are Gramineae and Tubuliflorae. Also common and occasionally reaching frequencies of 3-5% are *Polygonum* and *Ambrosia*.

The only arboreal macrofossil found in zone 4 was an unidentified wingless conifer seed at 3800 yr BP. The seeds of *Carex* were fairly abundant throughout the zone. Several *Polygonum* seeds and one Gramineae seed (at 500 yr BP) made up the remainder of the terrestrial macrofossil record. As with the previous zone, seeds of the aquatic genus *Scirpus* were abundant.

Zone 5 (*Ambrosia* zone): 100 yr BP to present (30 to 25 cm)

This zone is marked by a substantial increase in *Ambrosia* pollen. Since only the upper two levels of the main core correspond to zone 5, it is difficult to discern on the main core percentage diagram. The pollen and macrofossil stratigraphy is better seen in the diagram from the upper plastic tube core.

4.3 - Pollen and Macrofossil Stratigraphy: Upper Core

The 20 cm of sediment sampled from the plastic tube core included all of pollen zone 5 and the very top of zone 4 (Figure 19). Percentages for this core were plotted against depth, since no absolute dates were obtained. The rise in *Ambrosia* pollen between 10 and 15 cm, however, acts as a pollen stratigraphic marker horizon, giving this interval a date of 100 yr BP by comparison with the *Ambrosia* rise in the annually laminated sediments of Crawford Lake (McAndrews, 1988).

Figure 19: Pollen percentage diagram, Decoy Lake upper core

Decoy Lake Upper Core Pollen Percentages

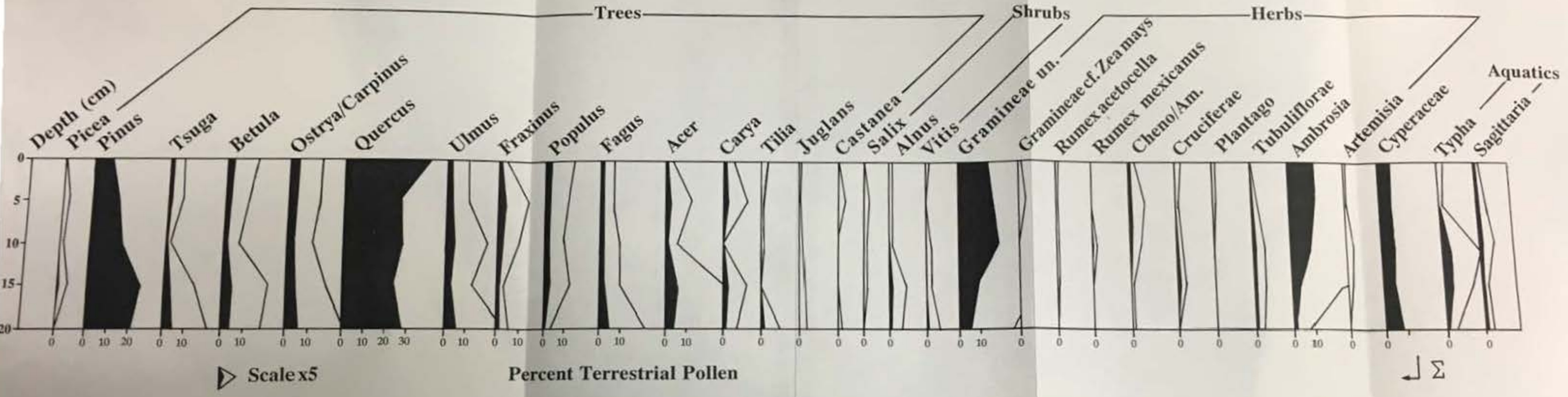


TABLE 4: UPPER CORE MACROFOSSIL RECORD (from 5 cm level)

Macrofossil	Deciduous leaf frags.	Potamogeton	Naja flex.	Scirpus	Carex
Frequency per 50 mL sediment	7	7	10	1	1

Between 10 and 15 cm, *Ambrosia* pollen rises in frequency from 4% to 12%. In addition, Gramineae increases from less than 10% to nearly 20%. The pollen of Cheno/Am also increases in frequency towards the top of the core. Several herb taxa which are rare in the pollen record but good indicators of European settlement and clearance (McAndrews *et al.*, 1973) are found in the upper levels of this core. These are *Zea mays*, *Rumex acetocella*, *R. mexicanus*, and *Plantago lanceolata*.

The pollen of several tree species drop substantially in frequency between the bottom and top of this core. *Pinus* pollen drops from over 20% to less than 10%. Decreases also occur in *Tsuga*, *Ostrya/Carpinus*, *Fagus* and *Acer*.

Only one macrofossil sample was taken from the upper core (Table 4). Aquatic taxa are the most abundant (*Naja flexilis*, *Potamogeton*, *Scirpus*), whereas terrestrial plants are represented by only one *Carex* seed and several deciduous leaf fragments.

4.4 - Microscopic Charcoal Record

The CHAR record for the main core (Figure 20) is very noisy and gives little useful information, due primarily to the intense sediment focusing that occurs between 10,000 yr BP and 6000 yr BP. Thus, the CHAR record was standardized by dividing by the PAR in order to minimize the effects of focusing (Figure 21). The record is still very noisy, but a few trends can be discerned. The basal sample, 11,800 yr BP, has the highest CHAR/pollen value for the entire core. Other times at which peaks occur, albeit much lower than in the basal sample, are at 10,800 yr BP, 5800 yr BP, and 2200 yr BP.

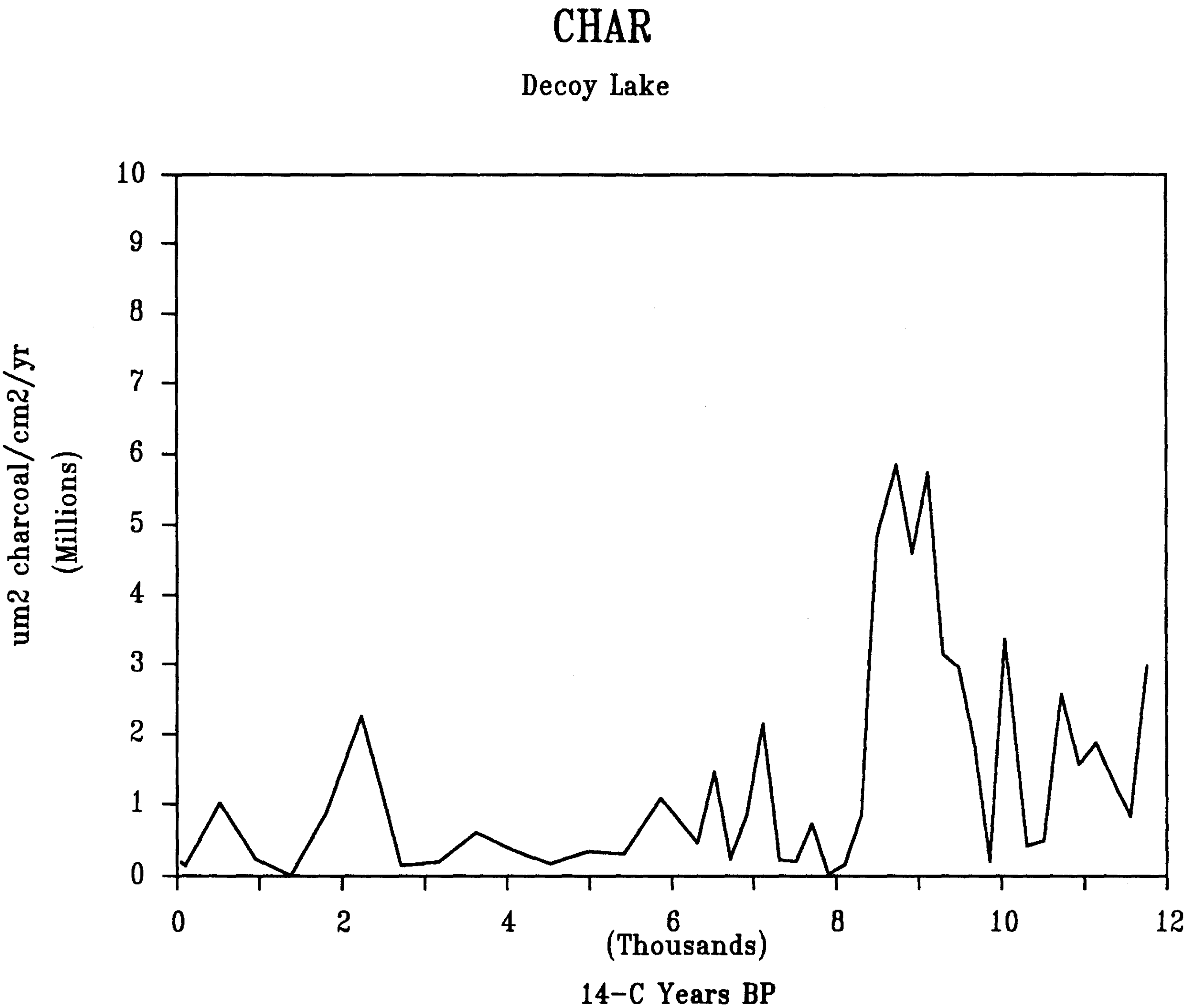


Figure 20: Charcoal accumulation rate (CHAR), Decoy Lake main core

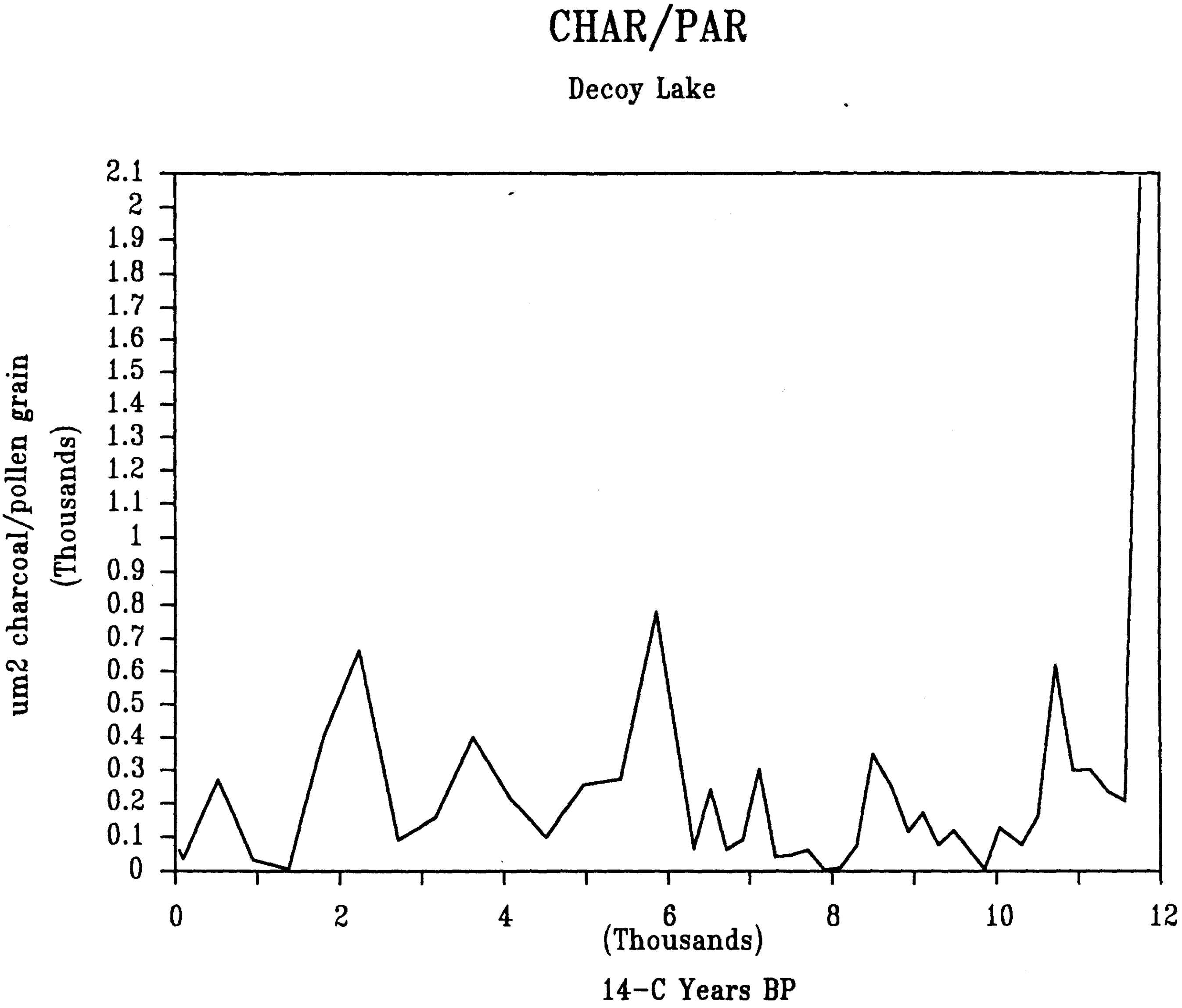


Figure 21: CHAR/PAR, Decoy Lake main core

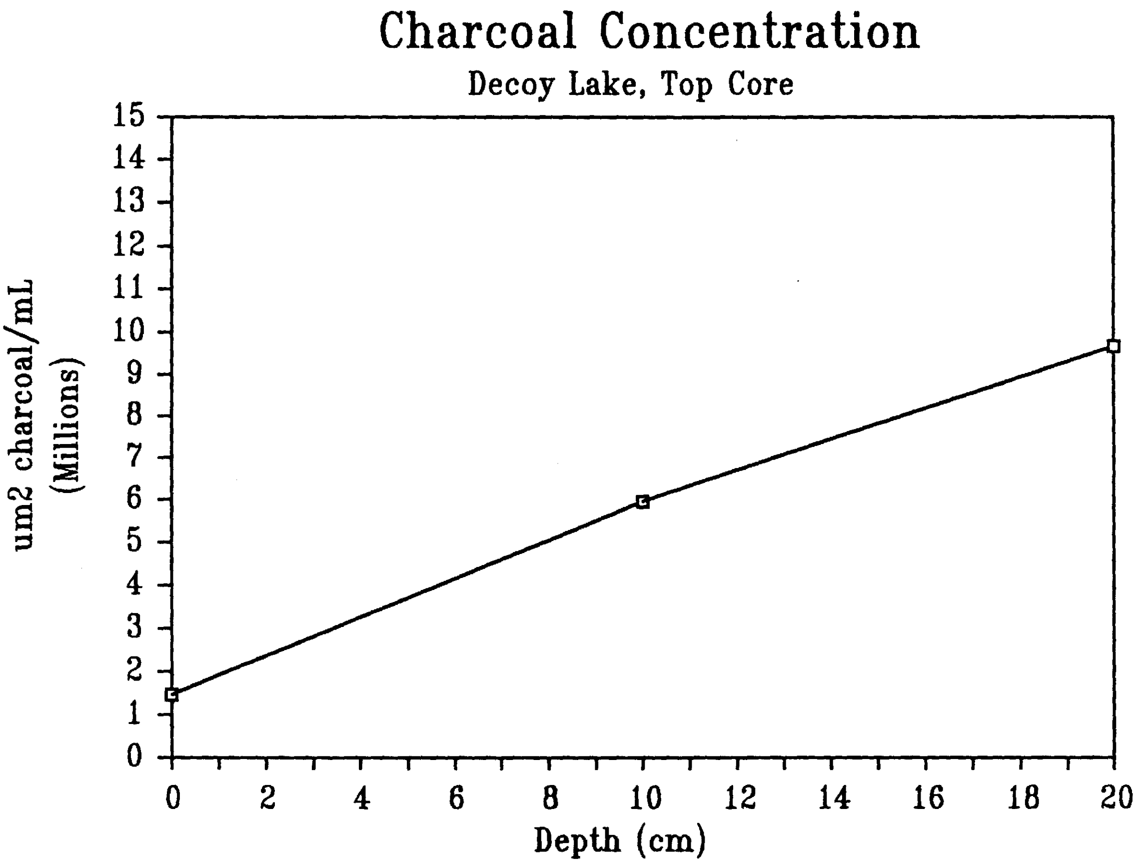


Figure 22: Charcoal concentration, Decoy Lake upper core

The CHAR could not be calculated for the samples from the upper plastic tube core, since accurate sedimentation rates were not available. Accordingly, charcoal concentrations were plotted against depth (Figure 23). The result shows a nearly linear increase in concentration between 0 and 20 cm.

4.5 - Difference Diagrams

Decoy Lake vs. Hams Lake

Between 11,000 yr BP and 10,000 yr BP, most taxa occur at similar frequencies at Hams and Decoy Lakes (Figure 23). Hams Lake has higher percentages of *Pinus* and Cyperaceae, while Decoy Lake has more *Picea* and herbs. At 10,000 yr BP, the difference in *Picea* becomes negligible, whereas *Pinus* percentages at Decoy Lake increase well above those at Hams Lake and remain so for the rest of the record. The difference is greatest between 8000 yr BP and 4000 yr BP. Other tree taxa are lower in frequency at Decoy Lake (*Betula, Ostrya/Carpinus, Quercus, Ulmus* and *Fraxinus*) or approximately equal at both sites (*Tsuga, Fagus, Acer, Tilia* and *Carya*) until about 6000 yr BP. Herb pollen is slightly more frequent at Decoy Lake than at Hams Lake during this period.

Fagus and *Ulmus* percentages at Hams Lake are much greater than at Decoy Lake after about 6000 yr BP. *Acer* and *Fraxinus* are also more frequent at Hams Lake. At 4000 yr BP, the difference between *Pinus* at the two sites decreases, while the *Quercus*, Cyperaceae and herb differences increase. *Tsuga* and *Carya* are found in similar percentages at the two sites. Other taxa maintain difference values similar to those before this time.

Decoy Lake vs. Maplehurst Lake

Differences between the Decoy Lake pollen record and the Maplehurst Lake pollen record are greater than differences between Decoy Lake and Hams Lake before 10,000 yr BP (Figure 24). Since both Decoy and Maplehurst Lakes have longer records than Hams Lake, this diagram also extends back 500 years earlier than Figure 23. The early postglacial is characterized by greater *Pinus, Betula, Quercus, Ulmus* and Cyperaceae at Maplehurst Lake than at Decoy Lake. *Picea* pollen is more frequent at Decoy Lake, while *Fraxinus* and herbs shift from positive to negative values. Other taxa have only minor differences in percentages at the two lakes.

At 10,100 yr BP, *Picea* frequencies shift from greater values at Decoy Lake to greater values at Maplehurst Lake, and *Pinus* percentages shift in the opposite direction. *Ostrya/Carpinus* and *Quercus* maintain higher percentages at Maplehurst Lake until 6000 yr BP. Other taxa are found at similar percentages at the two sites, until about 6500 yr BP. At or soon after this point, *Tsuga, Fagus, Ulmus* and *Acer* rise to much greater percentages at Maplehurst Lake than at Decoy Lake. These changes are contemporaneous with a large increase in the difference between *Pinus* percentages at the two sites.

Pinus remains at much higher percentages at Decoy Lake than at Maplehurst Lake until 4000 yr BP. Also found in greater frequencies at Decoy Lake during this time are herbs and Cyperaceae. *Fagus, Ulmus, Acer, Carya, Ostrya/Carpinus, Tsuga* and *Fraxinus* pollen is found at greater percentages at Maplehurst Lake. *Quercus* and *Betula* fluctuate between positive and negative values.

Figure 23: Pollen percentage difference diagram, Decoy Lake vs. Hams Lake

Decoy Lake-Hams Lake Difference Diagram

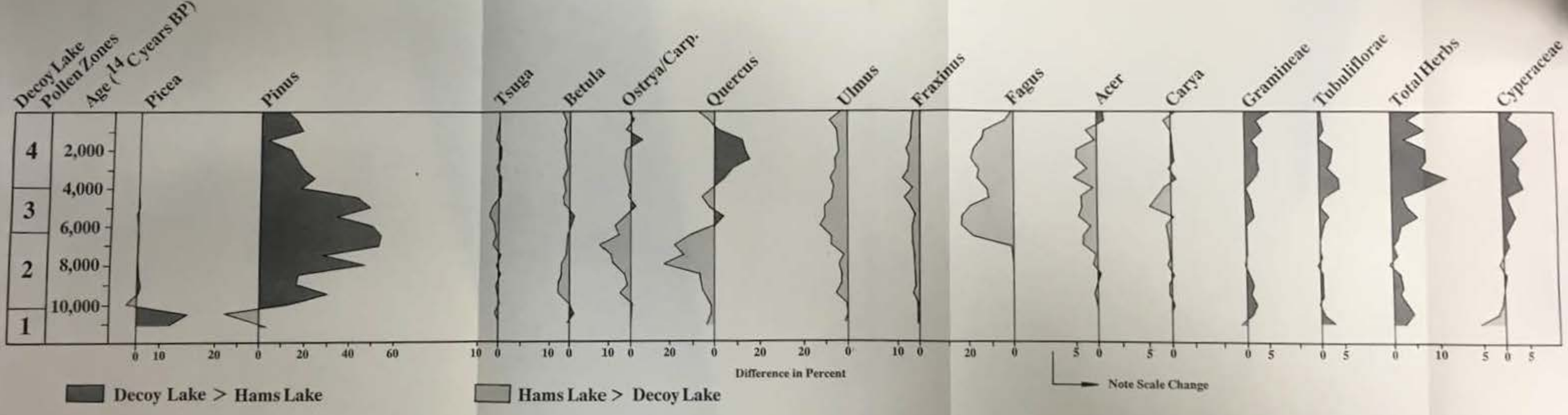


Figure 24: Pollen percentage difference diagram,
Decoy Lake vs. Maplehurst Lake

Decoy Lake - Maplehurst Lake Difference Diagram

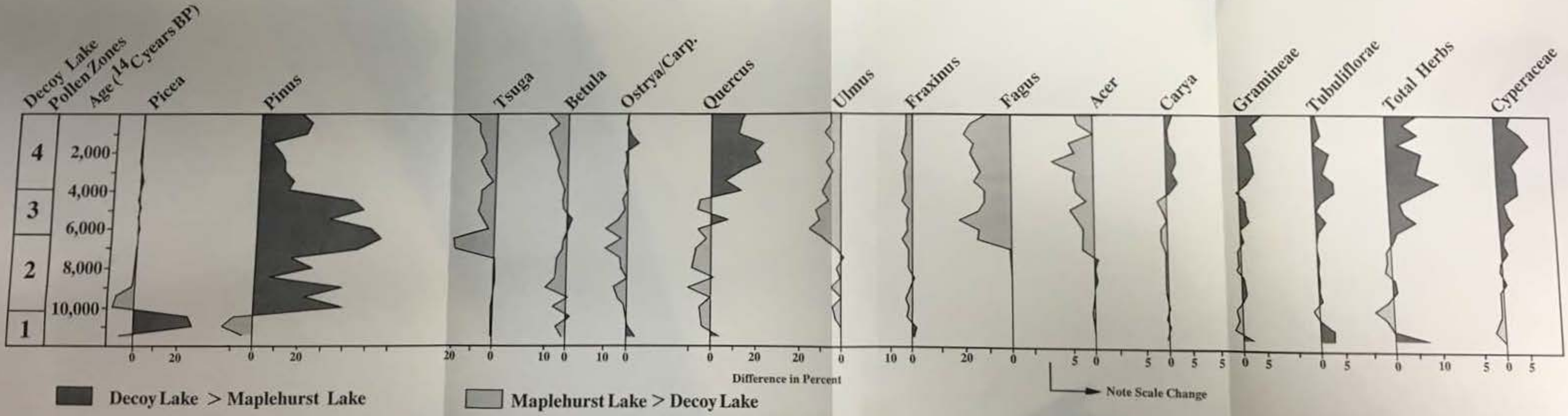
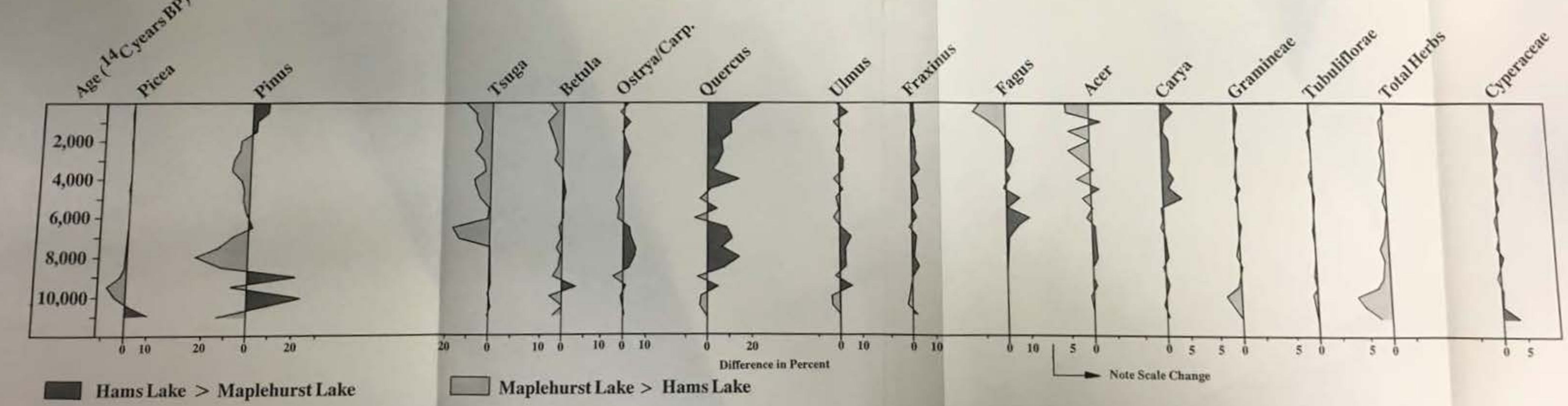


Figure 25: Pollen percentage difference diagram, Hams Lake vs. Maplehurst Lake

Hams Lake - Maplehurst Lake Difference Diagram



After 4000 yr BP, the difference in *Pinus* percentages drops off, while the differences in *Quercus, Carya*, herbs, and Cyperaceae increase to more positive values. *Betula* percentages change from similar values at 4000 yr BP to much greater at Maplehurst Lake by 100 yr BP.

Hams Lake vs. Maplehurst Lake

As a control, a difference diagram was produced for Hams Lake and Maplehurst Lake (Figure 25). In comparison to the previous two diagrams, the differences between these two lakes appear smaller than differences between either of them and Decoy Lake, for the majority of taxa. *Tsuga* is found at much higher frequencies at Maplehurst Lake from 7000 yr BP onwards. *Quercus* is generally more abundant at Hams Lake, particularly in the last 1000 years. *Fagus*, on the other hand, has similar percentages until 1000 yr BP, when its values drop substantially at Hams Lake. *Carya* percentages are higher at Hams Lake from 6000 yr BP to the present, while *Acer* was generally less abundant than at Maplehurst Lake.

CHAPTER 5 - POSTGLACIAL VEGETATION DEVELOPMENT AT DECOY LAKE

Based on the results of the palaeoecological analysis, a chronological reconstruction of the postglacial vegetation in the vicinity of Decoy Lake will be presented. This vegetation history will then be discussed in terms of the differences between it and the records of Hams and Maplehurst Lakes. Finally, the factors affecting vegetation development at Decoy Lake will be examined with respect to the differences between the histories of this and the other two lakes.

5.1 - Vegetation Reconstruction at Decoy Lake

Zone 1 (*Picea* zone): 11,800 yr BP to 10,100 yr BP

The shape, size and location of this basin indicated it to be a kettle depression, produced by the melting of an ice block calved off and left behind by the retreating Laurentide Ice Sheet. Karrow and Warner (1988) note that a number of lakes, ponds and bogs in this area were formed in this way; furthermore, there is evidence that some of these ice blocks actually supported forest or forest-tundra vegetation for up to 1000 years, before melting and collapsing in on themselves. The layer of soil and vegetation would have served to insulate the ice block, enabling its existence to continue well after climatic warming and northward retreat of the ice sheets.

It appears that the ice block which created Decoy Lake supported vegetation in a similar manner. The huge influx of *Picea* needles and wood fragments at the base of the core probably resulted from the collapse of forest or forest-tundra vegetation growing on the ice. Seeds of *Carex* and

Cruciferae, both of which occur in the tundra and northern boreal forest (Ritchie, 1987), further support this hypothesis. The collapse of the ice block and initiation of organic sedimentation in the basin is dated at 11,770 yr BP, using the largest of the wood fragments. This date correlates closely with the two dates (from independent laboratories) of 11,900 yr BP and 12,000 yr BP obtained by Karrow and Warner (1988) on a *Picea* log found in a similar 'trash zone' at the base of a peat and lake sediment sequence from Kitchener, about 20 km to the NW of Decoy Lake.

The pollen analysis of this basal sample indicates the *Picea* forest growing on and around the ice block may have been fairly open. Herbs (Gramineae, Cruciferae, Tubuliflorae, Ranunculaceae, *Ambrosia* and *Artemisia*) and Cyperaceae made up about 35% of the total terrestrial pollen between this time and 11,500 yr BP. The relatively high levels of *Ostrya* and *Quercus* pollen in the lowermost sediments are likely due to long-distance transport from southern populations, since these taxa produce large amounts of well-dispersed pollen (Webb *et al.*, 1981). On the other hand, *Fraxinus* and *Populus* tend to be underrepresented (Mott, 1978; Ritchie, 1987). The presence of the pollen of these two taxa in the basal sample, and higher up in zone 1, probably indicates their local presence in the vegetation. *Picea glauca* presumably dominated the mesic and dry upland sites with some *Populus*, while *Picea mariana* and *Fraxinus nigra* would have been found at wetter lowland sites. Soils above the buried ice block itself may have been fairly moist, supporting the second assemblage. Differentiation of *Picea* pollen indicates that the majority of identified grains in the basal sample were *Picea* cf. *mariana*. All of the *Picea* needle fragments were also tentatively identified as *Picea* cf. *mariana*, based on cross-sectional analysis.

These results support the presence of a *Picea mariana*-dominated woodland living over the buried ice block, with *Fraxinus nigra* possibly being a secondary component.

After 11,770 yr BP, the pollen of *Picea* cf. *glauca* becomes more abundant than *Picea* cf. *mariana*, amongst differentiated *Picea* grains. However, all *Picea* needles recovered in the macrofossil record are identified as *Picea* cf. *mariana*. A possible explanation is that the majority of woodland was dominated by *Picea glauca* stands, growing on the drier slopes surrounding Decoy Lake. A small population of *Picea mariana* living on moister soils immediately surrounding the lake would account for the lower but significant levels of *Picea* cf. *mariana* pollen present until about 8500 yr BP, as well as the influx of *Picea* cf. *mariana* needle fragments. It is unlikely macrofossils were carried more than a few tens of metres from their origin without the presence of any streams flowing into Decoy Lake.

Low LOI values during this time indicate low productivity in the lake, low productivity in the terrestrial system, high erosion of mineral substrate from the drainage basin, or a combination of these factors. Any or all of these can be indicators of a cooler climate and relatively sparse vegetation cover.

At 11,500 yr BP the frequency of *Picea* increases substantially from 50% to 80% and the frequency of herbs decreased, indicating the development of closed boreal forest for most of the region surrounding the site. At all but two levels, *Picea* cf. *glauca* pollen was significantly more abundant than that of *Picea* cf. *mariana*. Also present would have been *Abies balsamea* on mesic sites, *Larix laricina* and *Fraxinus nigra* in moist areas, and *Populus* spp. on a variety of sites. All of these taxa except

Fraxinus are very poorly represented in the pollen record, however, so their relative importances are difficult to determine. It is possible that *Ostrya* and *Quercus* (perhaps *Quercus rubra*) were also present in the latter stages of zone 1 (Bennett, 1987).

For a short period of time, at 11,200 yr BP, *Picea mariana* increases to abundances greater than *Picea glauca*. It is unlikely that this is an indication of the development of very wet or boggy conditions around the site, since there is no concurrent increase in *Sphagnum, Myrica,* or Ericaceae, all of which are indicators of this type of environment (Ritchie, 1984; MacDonald, 1987b). *Picea mariana* is better adapted to reproduce following fire than is *Picea glauca* (Ritchie, 1987), and so it may have temporarily replaced the latter after a single large fire or a period of high fire activity. This dominance would have been short-lived, however, as *Picea glauca* can out-compete *Picea mariana* on well-drained soils due to its greater shade tolerance and longevity (Fowells, 1965; Ritchie, 1987).

Towards the end of zone 1, the dominance of *Picea glauca* on upland sites began to decrease rapidly. First to increase was *Betula*, at about 10,400 yr BP. *Betula papyrifera* often grows in association with *Picea glauca* (Fowells, 1965) and so may for a short period have been the primary sub-dominant in association with that species. However, *Betula papyrifera* is also short-lived and very intolerant of shade, and so rarely persists for more than one generation (Ritchie, 1987). *Betula* very quickly decreased in dominance after 100 to 200 years.

Zone 2 (*Pinus* zone): 10,100 yr BP to 6300 yr BP

Pinus banksiana/resinosa (most likely *banksiana*) very rapidly replaced *Picea glauca* as the dominant at this site between 10,100 yr BP and 10,000 yr BP. Despite its overrepresentation in the pollen record, very high percentages indicate that *Pinus banksiana/resinosa* was the dominant tree here and at other southern Ontario sites for about 1000 years. A number of other taxa first appeared or increased in population at the beginning of zone 2. *Tsuga, Quercus, Ulmus, Ostrya/Carpinus* and probably *Acer saccharum, Fraxinus americana* and *Fraxinus pennsylvanica* arrived at this time, though not all were abundant after arrival. Other taxa, such as *Abies* and *Populus*, have records that are hard to interpret, but probably remained at similar frequencies as before, as did *Fraxinus nigra*.

Pinus banksiana would have dominated on well-drained sites, probably with some *Populus* and perhaps *Quercus* mixed in. Mesic sites were occupied by a number of taxa such as *Abies balsamea, Betula* (*papyrifera* and *alleghaniensis*), *Quercus, Ostrya/Carpinus, Acer* (*saccharum* and perhaps *rubrum*) and *Tsuga*. Given the very high percentages of *Pinus banksiana* pollen at this and other southern sites, it is possible this species lived in a wider range of edaphic conditions than today; it may have been an important component of mesic sites as well as drier areas. Moist soils would have supported *Fraxinus nigra, Ulmus, Abies* and some *Larix* and *Picea mariana*.

The shrub layer during the period of *Pinus banksiana* dominance appears to have been fairly diverse, though no taxa are found at very high frequencies. *Cornus, Cephalanthus, Sambucus, Shepherdia, Celtis, Alnus, Corylus* and *Salix*, all typical of the southern boreal forest and northern mixed forest zones (Soper and Heimburger, 1982), were present. Many of these are insect pollinated plants, and so would tend to be underrepresented in the pollen record. The high diversity of mixed forest shrubs may be an indication of a more temperate affinity to the vegetation than the dominance of *Pinus banksiana* would suggest.

Between 9000 yr BP and 10,000 yr BP *Pinus strobus* first arrived in the area and began to expand, until by 8000 yr BP it had nearly completely replaced *Pinus banksiana*. It was probably a dominant on both dry and mesic soils, though today it is primarily restricted to well-drained soils. During the latter part of zone 2, from about 8000 yr BP to 6300 yr BP, the populations of *Betula* and *Fraxinus nigra* appear to have declined. *Betula* recovers in zone 3, but *Fraxinus nigra* never seems to regain the high values it reached early in zone 2; perhaps it was out-competed by *Ulmus* and *Acer saccharinum* in the wetter areas.

At the same time as these two taxa decreased in numbers, *Tilia* populations increased. Being more shade tolerant and longer lived than *Betula* (Fowells, 1965; Grimm, 1984), it may have replaced that species on some mesic sites; however, both of these taxa are poorly represented in the pollen record, making interpretation of their curves difficult.

Zone 3 (*Pinus* - *Quercus* zone): 6300 yr BP to 4000 yr BP

The beginning of zone 3 is marked by rapid increases in *Fagus* and *Acer saccharum*, the beginning of more gradual increases in *Quercus* and herbs, and the beginning of a gradual decline in *Pinus strobus*. *Quercus* probably expanded on drier sites previously dominated primarily by *Pinus strobus*, though this expansion was slow. A *Fagus* - *Acer saccharum* association dominated mesic areas, with *Ulmus, Tilia, Tsuga, Betula, Fraxinus* *americana/ pennsylvanica, Ostrya/Carpinus* and *Quercus* being secondary components. *Fagus* and *Acer* may have replaced *Pinus strobus* in some areas, despite the fact that in modern forests *Pinus strobus* and *Fagus/Acer* do not generally occupy sites with similar edaphic conditions. In the absence of competition, *Pinus strobus* will grow well on mesic soils (Ritchie, 1987). However, *Acer saccharum* and *Fagus* are more shade tolerant, and so will tend to replace it on favourable soils.

A slight increase in herbs (primarily Gramineae, Tubuliflorae, and *Polygonum*) and Cyperaceae points towards the development of a more open vegetation cover in some areas. Most sites would have supported closed-canopy forest, dominated either by *Pinus strobus, Pinus strobus-Quercus, Quercus,* or *Acer-Fagus* (except in very moist areas, in which *Ulmus* was probably dominant). However, in some areas *Pinus strobus* may have been replaced by either a *Quercus*-herb or a *Pinus-Quercus*-herb association. Cyperaceae may also have been an important terrestrial component of this association; it reaches fairly high frequencies in surface samples from prairie and aspen-parkland sites in central Canada, and *Carex* spp. dominate the understorey vegetation in many savanna sites (Ritchie, 1987; Bakowsky, 1988). Macrofossil evidence shows increases in both *Scirpus*, an aquatic member of the family, and *Carex*, a genus containing both aquatic and terrestrial taxa. This wide range of habitats makes it hard to interpret the palaeoecological record of Cyperaceae. It is likely, however, that at least a fraction of Cyperaceae pollen and macrofossils originated from terrestrial sources.

Zone 4 (*Quercus-Pinus*-herb zone): 4000 yr BP to 100 yr BP

The expansion of *Quercus* and herbs and decrease of *Pinus strobus* accelerated late in zone 3, starting at about 4500 years BP. By 4000 yr BP, *Quercus* must have been the most important tree in the area surrounding Decoy Lake. The concurrent sharp rises in Tubuliflorae, *Ambrosia, Polygonum,* Cyperaceae and (a little later) Gramineae show that the *Quercus*-herb assemblage became more widespread, displacing *Pinus strobus*. Bakowsky (1988) determined that species of Gramineae, Cyperaceae and Tubuliflorae were the dominant understorey components of oak-dominated savanna. It appears that the pollen assemblage which developed by 4000 yr BP, and is nearly identical to that at 100 yr BP, represents the oak plains as encountered by early settlers.

Pinus strobus was not eliminated entirely by the *Quercus*-herb association in the region surrounding Decoy Lake; survey record evidence indicates a number of *Pinus strobus*-dominated stands within 10-20 km of Decoy Lake (Figure 3). It is also possible that *Pinus strobus* was a minor component of the oak plains themselves. Pollen of this species remains at 20-25% for the majority of zone 4; this level is too high to be accounted for solely by long-distance transport in a lake as small as this, although the open nature of the oak plains would allow higher inputs of regional pollen into the lake (Jacobson and Bradshaw, 1981).

It is unfortunate that the species in a genus as widespread and diverse as *Quercus* cannot be separated on the basis of pollen morphology, at least under a light microscope (McAndrews *et al.*, 1973). Maycock (1963) counts 8 species of *Quercus* in southern Ontario, and 6 of these occurred in 15 or more of the 131 stands he surveyed. The soils in which each of these

6 species reached maximum importance varied from wet and wet-mesic to dry and dry-mesic (Maycock, 1963). This diversity of species complicates the interpretation of the *Quercus* curve in this and other pollen records. A survey of the vegetation immediately surrounding Decoy Lake showed all of the large oaks to be *Quercus alba* or *Quercus macrocarpa*. Surveys of other oak plains and oak savanna sites in Ontario and Wisconsin show the Wisconsin savannas to be dominated by *Quercus macrocarpa, Q. velutina* and *Q. alba,* whereas in Ontario savannas, *Q. macrocarpa* is generally not as important as the other two species except in mesic and wet-mesic locations (Curtis, 1959; Bakowsky, 1988). The pollen record does not allow the exact species composition of the oak plains in the vicinity of Decoy Lake to be determined, however.

Based upon evidence from relict oak savanna in Ontario, the *Quercus*-herb association would have been dominated by *Quercus alba* and probably *Quercus velutina*. Subdominants would have included *Populus, Carya* (whose pollen percentages rise substantially at the beginning of zone 4), *Castanea,* and probably *Quercus macrocarpa, Pinus strobus* and *Prunus* (Wood, 1961; Bakowsky, 1988). All these trees would have had an open-grown form, separated by a low cover of herbs and sedges.

The vegetation of mesic sites did not change between zones 3 and 4. These areas supported an *Acer saccharum-Fagus* association, with *Tilia, Ostrya/Carpinus, Betula, Tsuga, Fraxinus americana,* and *Quercus* (probably *Q. rubra*) being subdominants. Similarly, wet areas would still have been dominated by *Ulmus*, as in the previous zone. *Fraxinus nigra* and *Acer saccharinum* may also have been present at wet sites; being an entomophilous species *Acer saccharinum* is poorly represented in the pollen record.

As with *Quercus*, the genus *Populus* is represented in southern Ontario by several species of varied edaphic and moisture tolerances (Maycock, 1963). In addition, there is the added complication that *Populus* pollen is usually very poorly preserved in lake sediments, despite copious production (Mott, 1978). *Populus deltoides, P. grandidentata* and *P. tremuloides* are each found at 25 of the 131 sites surveyed by Maycock (1963). It is likely that, for the duration of zone 4 and probably also zone 3, all of these species were present in the pollen catchment area of Decoy Lake in dry, mesic and wet sites. A number of *Populus tremuloides* individuals are found around the lake today, and they may be clonal relics from the original oak plains (Fowells, 1965).

Further evidence for the existence of oak plains near the site is the continual influx of *Carex* seeds into the lake during zone 4, as well as the presence of a Gramineae seed towards the end of the zone (Figure 18). *Carex pennsylvanica* is the dominant herb in dry-mesic oak savanna, into which classification the Paris oak plains probably fall (Bakowsky, 1988).

Zone 5 (*Ambrosia* zone): 100 yr BP to present

The two uppermost levels of the main core and the upper three levels of the plastic tube core show rapid and dramatic changes in the vegetation around Decoy Lake. Large increases in *Ambrosia* and Gramineae indicate a further opening of the canopy, beyond that which occurred when the oak plains formed between 6300 yr BP and 4000 yr BP. A major decline of *Pinus strobus* occurred, along with smaller decreases in the dominance of *Tsuga,* *Betula, Ulmus* and *Acer.* A drop in LOI indicates an increase in erosion in the Decoy Lake watershed.

5.2 - Vegetation History of Decoy Lake Compared to that of Hams and Maplehurst Lakes

Between 11,800 yr BP and about 8000 yr BP the vegetation around Decoy Lake was compositionally similar to that at other sites in southern Ontario. *Picea*-dominated forests were found between 12,000 yr BP and 10,000 yr BP throughout the region (Mott and Farley-Gill, 1978; Terasmae and Matthews, 1980; Bennett, 1987; Ritchie, 1987). However, an examination of Figures 23 and 24 shows that *Picea* was considerably more abundant at Decoy Lake than in surrounding areas.

The rapid expansion of *Pinus banksiana* at about 10,000 yr BP at Decoy Lake occurs contemporaneously with similar increases at Hams and Maplehurst Lakes. Two differences can be noted, however: 1. the expansion at Decoy Lake appears to have occurred even more rapidly than at other sites, particularly Maplehurst Lake (Figure 24), and 2. as with *Picea, Pinus banksiana* achieves greater dominance at Decoy Lake. Hardwoods such as *Betula, Ostrya, Quercus, Ulmus* and *Fraxinus* were more abundant in the forests around Hams and Maplehurst Lakes.

The replacement of *Pinus banksiana* by *Pinus strobus* between 9500 yr BP and 8500 yr BP at Decoy Lake also occurred at other southern Ontario sites. As with the previous boreal taxa, *Pinus strobus* achieved greater dominance at Decoy Lake than at the other sites. Hardwoods remained a more important component of forests around Hams and Maplehurst Lakes.

Between 8000 yr BP and 7500 yr BP the vegetation histories of Decoy Lake and other southern Ontario sites diverge dramatically. *Pinus strobus* forest remained the dominant association at Decoy Lake for at least another 2000 to 2500 years. Elsewhere, *Pinus strobus* was replaced by a number of other taxa. At Maplehurst Lake, *Tsuga* and *Ostrya* initially replaced *Pinus*; by 6500 yr BP, *Fagus-Acer* forests were the most dominant vegetation association at this site, with *Ulmus* also being an important component. The initial replacement of *Pinus strobus* at Hams Lake appears to have been by *Quercus* and *Ostrya*, with *Tsuga* being only a minor component. *Fagus, Acer* and *Ulmus* then increased to dominate the region around the site, probably in conjunction with *Quercus*. The composition of forests around both Hams and Maplehurst Lakes remained fairly stable between the development of the *Fagus-Acer* association an the development by European settlers about 150-200 years ago.

The replacement of *Pinus strobus* forest at Decoy Lake between 6300 yr BP and 4000 yr BP was not by *Fagus, Acer* and *Ulmus* as was the case at Hams and Maplehurst Lakes several thousand years earlier. Both *Fagus* and *Acer* do initially rise when *Pinus strobus* declines, but their low percentages indicate them to be relatively minor components of the vegetation. The *Quercus-Pine*-herb association, which develops by 4000 yr BP and is maintained until pre-settlement times, was not present at any time at the other two sites.

Once the vegetation histories of Decoy Lake and Hams/Maplehurst Lakes diverged at about 8000 yr BP, they did not converge again until post-settlement times. The clearance of original vegetation for logging and agriculture has had a homogenizing effect on the landscapes of the region; today little remains of the oak plains in the vicinity of Decoy Lake.

5.3 - Factors Affecting Postglacial Vegetation Development at Decoy Lake

The vegetation development over a period of time at any given location is the result of many factors such as climatic change, competition, dispersal, disease, fire, soil development, and anthropogenic disturbance. Determination of the causal factors behind vegetational changes is made difficult by interrelationships between certain factors. Additionally, different factors may result in similar changes in the vegetation, making them hard to distinguish. In this section, the unique vegetation history of Decoy Lake will be examined in the light of both known and inferred climatic changes, biotic factors, and disturbance events.

Zone 1 (*Picea* zone) - 11,800 yr BP to 10,100 yr BP

The vegetation type colonizing newly deglaciated land in northeastern North America depended upon factors such as rate of climatic change, soil development, and availability of seed source. By the time Decoy Lake had formed, *Picea* had already migrated into the area and formed an open woodland. Thus it appears that delays imparted by soil development and geographic barriers (glacial lakes) were not major in this area, at least for *Picea*. The dominance of *Picea* throughout southern Ontario in the early postglacial would have resulted from a cold, dry climate and a lack of competition. Between 12,000 yr BP and 10,000 yr BP the climate was much colder than today, but rapidly ameliorating (Kutzbach and Guetter, 1986; Webb *et al.*, 1987; Edwards and Fritz, 1988). Tree species which survived during the Wisconsin in southern 'refugia' began to migrate northwards as the climate ameliorated (Davis, 1983). Whether this migration occurred in equilibrium with climate or lagging it is debatable (Davis, 1978; Webb, 1986; Prentice, 1986). Before 10,000 yr BP, though, there were few trees to compete with *Picea*, either as a result of the cold climate or delays in migration.

The greater apparent dominance of *Picea* at Decoy Lake than at Hams and Maplehurst Lakes during this period is in part a result of the small size of the basin. The larger Hams and Maplehurst Lakes would receive higher levels of pollen transported long distances, such as *Pinus*, thus reducing the apparent dominance of *Picea*. The well-drained soils surrounding Decoy Lake may also have played a part in increased *Picea* dominance. *Abies balsamea* and *Larix laricina* were probably of moderate importance at this time on mesic and wet soils. The soil conditions at Decoy Lake would have provided less available habitat for these species, allowing *Picea* to attain greater dominance around the site.

Zone 2 (*Pinus* zone) - 10,100 yr BP to 6300 yr BP

Increasing temperatures led to the rapid spread of *Pinus banksiana* throughout southern Ontario between 10,500 yr BP and 10,000 yr BP. The high percentages of pollen of this species reflect the fact that, like *Picea*, it was tolerant of a wide range of climatic and edaphic conditions in the absence of competition (Bennett, 1987). *Pinus banksiana* grows well on light, sandy soils (Fowells, 1965; Brubaker, 1975), and so the area around Decoy Lake would have provided an ideal habitat for this species in the early

Holocene. This explains its greater dominance at Hams Lake during this period.

Fire may have been important in maintaining *Pinus banksiana* at this time, as it is at modern sites (Fowells, 1965; Ritchie, 1987). However, the sandy soils and lack of competition may have been sufficient to prevent its displacement for over 1000 years.

As temperatures continued to increase, more species arrived following dispersal from southern glacial refugia. *Pinus strobus* replaced *Pinus banksiana* throughout the region by about 8000 to 8500 yr BP. It is more shade tolerant than *Pinus banksiana, Betula papyrifera, Populus,* and other common early Holocene taxa (Bennett, 1987), and therefore could out-compete them in most edaphic situations. Once again, the sandy soils at Decoy Lake allowed it to achieve greater dominance at that site by increasing its competitive advantage over more mesic taxa.

The time of arrival of many temperate taxa, such as *Fagus, Tsuga, Acer* and *Carya,* cannot be determined with a high degree of accuracy. Bennett (1985) argues that some species (*Fagus grandifolia* in particular) arrived in southern Ontario early in the Holocene, and were present originally at very low population levels undetectable in the pollen record. Ameliorating climate allowed these populations to expand dramatically at about 7000 yr BP. Alternatively, rapid increases in *Fagus* populations may have occurred soon after the species arrived, the delay in arrival having been caused by slow dispersal of propagules (Davis, 1978, 1983, 1984).

Whatever the mechanisms of spread and exact times of arrival, these temperate taxa began to expand and replace *Pinus strobus* at most sites in southern Ontario between 7500 yr BP and 8000 yr BP. The major expansion of *Tsuga*, *Ostrya/Carpinus*, *Quercus* and later *Fagus* and *Acer* seen at Hams and Maplehurst Lakes did not occur at Decoy Lake, however. Between about 8000 yr BP and 6000 yr BP the climate was drier and summers warmer than at present throughout northeastern North America, as a result of greater summer insolation and thus lower precipitation minus evaporation (P-E) values (Kutzbach and Guetter, 1986; Webb *et al.*, 1987). Though time-transgressive, this period - the so-called Hypsithermal or climatic optimum - has been held responsible for vegetational changes both in the American midwest and New England (McAndrews, 1966; Davis *et al.*, 1980; Grimm, 1983; Bartlein *et al.*, 1984; Winkler *et al.*, 1984). The mesic *Tsuga, Acer, Fagus* and *Quercus* forests of southern Ontario which developed at about 7500 yr BP show little or no response to mid-Holocene climatic change (McAndrews, 1981). At Decoy Lake, the well-drained soils, combined with a dry climate, allowed *Pinus strobus* to resist invasion by *Tsuga* and mesic hardwoods during the mid-Holocene. Fire may have been a secondary factor in the maintenance of *Pinus strobus*. It is a fairly fire-tolerant species (Curtis, 1959; Jacobson, 1979), whereas most of the mesic taxa are very intolerant of fire and would not stand even occasional burning. Fire frequency may have increased during the mid-Holocene, though this is difficult to determine from the Decoy Lake record due to the noisy charcoal signal.

Zone 3 (*Pinus-Quercus* zone) - 6300 yr BP to 4000 yr BP

Before the natural factors that may have led to the replacement of *Pinus strobus* by oak plains are considered, the timing of oak plains development will be examined in the light of archaeological factors such as population size and methods of subsistence.

Most authors suggesting that native burning led to the development of the oak plains list agricultural activity as the primary motivation for clearance (J.D. Wood, 1961; C.J.B. Wood, 1966; Dorney and Dorney, 1989). The pollen record at Decoy Lake has demonstrated that the oak plains became fully developed 4000 years ago, 2500 years before the first record of agriculture in southern Ontario. This leads to the conclusion that the oak plains did not originally become established as a result of burning and clearance for the purposes of agriculture. The possibility remains, however, that they resulted from non-agricultural Indian activity.

Southern Ontario was inhabited by the Laurentian Archaic culture between 6000 yr BP and 4000 yr BP, when the oak plains were developing. These people were hunter-gatherers, and sites discovered so far have been concentrated on sand plains of the Deciduous Forest region (Spence and Fox, 1983). The majority of archaeological sites in the vicinity of Decoy Lake represent temporary Laurentian Archaic campsites, this area being dominated by fluvial and lacustrine sands (Chapman and Putnam, 1984). While this and other areas of sand plains appear to have been the favoured hunting ground for these peoples, there is no evidence for any permanent or semi-permanent settlements. The first structures are not seen in southern Ontario until 2500 yr BP (Dodd, 1984). The location of hunting camps would have varied from year to year, depending on the movements of game. Although the Laurentian Archaic represent the first substantial population in the region when compared to earlier Palaeo-Indian cultures, their numbers would still have been relatively small. A hunting and gathering society such as the Laurentian Archaic was unlikely to have repeatedly burned the same area over a period of several thousand years for the purposes of improving browse and driving game. It is therefore very unlikely that disturbance of the original *Pinus strobus*-dominated forests by the Laurentian Archaic initiated and sustained for thousands of years the oak plains in the region around Decoy Lake. The oak plains must have originated as a result of natural factors, and so the hypothesis that native disturbance led to their development can be rejected.

A number of different reconstructions of Holocene climate in northeastern North America indicate that after about 6000 yr BP available moisture began to increase, due to a combination of gradually decreasing summer temperatures and increasing precipitation (Kutzbach and Guetter, 1986; Webb *et al.*, 1987; Edwards and Fritz, 1988). It is this increase in moisture, perhaps in combination with an increase in winter temperatures (as seasonality decreased), which appears to have led to the replacement of *Pinus strobus* forest by the oak plains. As the dry mid-Holocene gradually gave way to wetter conditions, *Pinus strobus* lost some of its competitive edge over more mesic taxa.

The increases in *Fagus* and *Acer* at 6300 yr BP occur contemporaneously with the increases in *Quercus* and decreases in *Pinus*. *Fagus* expands about 500 years later at Decoy Lake than at Hams Lake. It is possible that dating uncertainties at one or both sites has led to the same event, that of *Fagus* expansion on mesic soils to the west of Decoy Lake, being recorded at different apparent times at the two sites. Alternatively, this difference in expansion times may be real and represent the delay in establishment of *Fagus* around Decoy Lake until increasing moisture levels allowed it to out-compete *Pinus strobus* at favourable sites.

Most areas around Decoy Lake did not become mesic enough to allow *Acer* and *Fagus* to replace *Pinus strobus*, however. Instead, these areas saw an expansion of open-grown *Quercus* populations, eventually leading to the establishment of the oak plains. The population expansion of *Quercus* and presumably the oak plains occurred much more gradually than that of the more mesic hardwoods. The longevity of *Pinus strobus* and slow growth of *Quercus* resulted initially in a slow-paced compositional change (Fowells, 1965; Brubaker, 1986). The acidic needle litter of the pine forest is also likely to have inhibited the initial expansion of *Quercus* (Jacobson, 1979). Between 4500 yr BP and 4000 yr BP the rate of change appears to have increased. The greater the population of *Quercus*, the more suitable the habitat became for further oak establishment. The expansion of the oak plains in the vicinity of Decoy Lake stopped at about 4000 yr BP, and the association was maintained until pre-settlement times by a combination of environmental and biotic factors. If any climatic change occurred during these 4000 years, it is not registered in the local pollen record.

Zone 4 (*Quercus-Pinus*-herb zone) - 4000 yr BP to 100 yr BP

Once the oak plains had become established at 4000 yr BP, apparently as a result of post-Hypsithermal increases in moisture, they appear to have remained compositionally stable until the arrival of European settlers in the early 19th century. Precipitation, summer and winter temperatures have changed little over this time period according to climate models (Kutzbach and Guetter, 1986; Webb *et al.*, 1987). Pollen and oxygen isotope data suggest that the climate may not have been as stable as the models predict (Edwards and Fritz, 1988; Gajewski, 1988), though this is not reflected in the

Decoy Lake pollen record. However, the areal extent and location of boundaries of the oak plains may have fluctuated in response to climatic variations over the past 4000 years without being registered in the local pollen record of Decoy Lake.

Zone 5 (*Ambrosia* zone) - 100 yr BP to present

Between 1800 and 1850 AD the area around Decoy lake was settled by European farmers, who began to clear the land to grow wheat, corn and other crops (Wood, 1961). This clearance resulted in large increases in *Ambrosia*, Gramineae, and other herbs, giving a very distinct signal in the pollen record.

The clearance of vegetation to make way for agriculture would naturally lead to the reduction in populations of those trees occupying sites suitable for agriculture. In addition, trees were cleared to produce timber necessary for an expanding population. *Pinus strobus* was one of the trees most favoured for lumber, and was cut extensively during the late 19th and early 20th centuries (Head, 1975). A significant decrease can be seen in the percentages of *Pinus strobus* pollen immediately following the rise in *Ambrosia* and Gramineae pollen, along with smaller decreases in *Tsuga, Betula, Ulmus* and *Acer*. These decreases are due in part to the clearance of the extant vegetation. However, the rises in herb pollen will also cause the percentages of other taxa to decrease as a result of the non-independence of relative pollen data.

Following initial settlement, the original vegetation of oak plains, *Pinus strobus* stands and mesic hardwood forests was gradually replaced by a mosaic of agricultural fields, pastureland, urban development, and a few relatively undisturbed forested areas, such as along the Grand River to the east. Today, the region is very heavily farmed, and little if any of the original vegetation remains.

CHAPTER 6 - DISCUSSION AND CONCLUSIONS

The results of the palaeoecological and historic studies of the oak plains will be discussed here in three parts. In the opening chapter of this study, several questions were outlined which would help test the hypothesis that the oak plains in southern Ontario resulted from burning by natives. These questions will be addressed in the first part of this discussion in the light of the palaeoecological analysis of Decoy Lake. In the second section, the historic and palaeoecological studies will be combined to provide ecological insights into the presettlement oak plains and their postglacial history. Finally, the results of this study will be discussed in a methodological context.

6.1 - The Oak Plains Palaeoecological Record and Native Impact

Do the oak plains produce a distinctive pollen assemblage, and how far back does it extend in the pollen record?

The oak plains were known to have existed in the area immediately surrounding the site in the early 19th century. Due to the small nature of this basin, the pollen assemblage correlating to that time should represent the oak plains.

The *Quercus-Pinus*-herb assemblage was present in immediate pre-settlement times at Decoy Lake. *Quercus*, Gramineae, Tubuliflorae, and Cyperaceae, all well represented in this pollen assemblage, are the primary components of mesic and dry-mesic savannas in southern Ontario (Bakowsky, 1988). It is thus reasonable to assume that this pollen assemblage represents the oak plains as they were found by early settlers in North and South Dumfries townships.

The pollen assemblage produced by the oak plains is distinct not only from earlier vegetation zones at Decoy Lake, but from any assemblages yet reported from southern Ontario. Contemporaneous pollen assemblages at Hams and Maplehurst Lakes had, for the most part, less herbs, Cyperaceae, *Quercus* and *Pinus*, and more *Fagus, Acer, Fraxinus, Ulmus* and *Betula*.

The southern Ontario oak plains pollen assemblage is also distinct from assemblages representing oak-dominated savanna in the midwestern U.S. All of the American records have lower percentages of *Pinus*, and much higher percentages of herbs, particularly Gramineae and *Artemisia* (McAndrews, 1966; Jacobson, 1979; Grimm, 1983). Several factors could be responsible for these differences. Firstly, the spatial extent of midwestern savannas is generally much greater than that of the southern Ontario oak plains. Thus, a site within the savanna would receive less long-distance transport of pollen from non-savanna vegetation. Despite the fact that Decoy Lake has a small catchment basin, long-distance transport will still contribute a fair amount of pollen to the sediments. Second, the warmer and drier climate of the midwest and the occurrence of frequent fires probably led to a more open nature to the savanna. Not only would this increase the ratio of herbs to trees, but a more open canopy would allow better dispersal of herb pollen, which is produced close to the ground. Lastly, savanna in the midwest is normally bounded on at least one side by open prairie. As a result, much of the pollen transported long distances from non-savanna vegetation will have originated from the prairie, the pollen rain of which is obviously dominated by herbaceous taxa. The prevailing winds are commonly from the west or northwest (McAndrews, 1966), and most areas of savanna lie to the east of open prairie. The oak plains of southern Ontario, on the other hand, were for the most part bounded on all sides by closed-canopy forest.

The oak plains have existed in this area for at least the last 4000 years. The transitional nature of the vegetation during zone 3 indicates that smaller patches of oak plains may have been present near Decoy Lake between about 6300 yr BP and 4000 yr BP.

Is the vegetational history of Decoy Lake unique throughout the postglacial compared to other sites in southern Ontario?

It has been demonstrated that the pollen assemblage produced at Decoy Lake by the oak plains was distinctive and unique to this one site. Comparisons with the pollen records of two other sites, these being representative of the regional record in southern Ontario, show that the record at Decoy Lake has differed from that of surrounding areas for longer than the duration of the oak plains alone.

Picea and *Pinus banksiana* both achieved considerably greater dominance at Decoy Lake than at sites on more mesic soils, though the timing of their respective population expansions and declines coincides with the regional record. *Pinus strobus* also achieves greater dominance, although this time edaphic and climatic factors enabled it to remain dominant at Decoy Lake well after regional population decline and replacement by mesic forests.

The post-Hypsithermal expansion of *Quercus* and replacement of *Pinus strobus* by the oak plains are not synchronous with any major changes occurring at Hams or Maplehurst Lakes. On a scale large enough to be detected by pollen analysis, the changing climate only appears to have had an impact on the vegetation occupying edaphically constrained sites.

Does the development of the oak plains coincide with changes in the charcoal record?

The use of charcoal to interpret prehistoric fires and their effects on vegetation dynamics has not always been successful, due to the great variability inherent in the characteristics of both the fires themselves, and their impact on vegetation (Patterson *et al*, 1987; Larsen, 1989). The production of pollen is relatively constant (on an annual basis), and the source area for a given basin will not change substantially over time. On the other hand, fires producing charcoal are distinct events whose areal extent can vary by several orders of magnitude. Different types and sizes of fires will result in differential production and dispersal of charcoal. For these and other reasons, microscopic charcoal may or may not be a good indicator of local and regional fires on a short time-scale, such as the 1000 year record examined at 5 year intervals by Larsen (1989). It was hoped, however, that sampling of charcoal at 100 to 400 year intervals, each sample representing between 20 and 80 years of deposition, would give a rough idea of regional fire activity during the postglacial. In a record of this type, individual peaks are normally not particularly significant, but periods of increased charcoal deposition could theoretically represent times of increased fire activity.

Unfortunately, the CHAR/PAR record is extremely noisy and difficult to interpret. Even if microscopic charcoal were an accurate indicator of regional fire frequencies, which it may not be, the variability of sedimentation and occurrence of sediment focusing at Decoy Lake would introduce considerable noise into the data. Sedimentation factors play a part in the calculations of both CHAR and PAR, compounding this noise when CHAR/PAR is calculated. It is not acceptable to attach significance to some fluctuations in the charcoal record while ignoring others of similar magnitude. The causal factors relating to the origin of the oak plains will therefore have to be studied without the use of a good proxy record of fire activity.

Does the development of the oak plains coincide with significant events in the archaeological record?

The beginning of *Pinus strobus* replacement by the oak plains at Decoy Lake coincides approximately with the first appearance of Laurentian Archaic sites in southern Ontario, at about 6000 yr BP. In addition, the Laurentian Archaic appear to have favoured sandy outwash and deltaic deposits for their campsites; Decoy Lake is located on a feature of this type. Nonetheless, the hypothesis that native disturbance led to the development of the oak plains has been rejected for two reasons:

1) The Laurentian Archaic were a hunting and gathering society, and so were unlikely to have disturbed vegetation on any more than a local scale (Patterson and Sassaman, 1988). Sedentary agricultural groups were much more likely to have disturbed vegetation on the local or even regional scales. However, the oak plains became fully developed in the Decoy Lake area 2500 years before the first record of agriculture from southern Ontario.

2) The population of Laurentian Archaic was small. Even if they did clear or burn vegetation for the purposes of improving browse or driving

game, it is unlikely that a small population would have disturbed the natural vegetation on the scale of the oak plains, and maintained it in a disturbed state for several thousand years.

6.2 -Ecological Considerations of the Development of the Oak Plains in Southern Ontario

In answering the questions posed at the beginning of this study, an anthropogenic origin to the oak plains has been rejected. Instead, evidence points to an interaction of post-Hypsithermal climatic change and coarse soil texture as the causal factors behind oak plains development. This confirms that the factors leading to oak plains development can be reasonably determined through examination of the climatic and edaphic setting of the historical oak plains and the fossil record. The suggestion of a climatic origin of the oak plains, however, raises some new questions regarding the nature of vegetational changes at Decoy Lake, in particular the replacement of *Pinus strobus* by the oak plains between 6300 and 4000 yr BP.

The post-Hypsithermal replacement of *Pinus strobus* by hardwoods on moderately coarse outwash deposits was noted by Brubaker (1975) at a site in Minnesota. Following 5000 yr BP, increases in soil moisture allowed hardwood forests (*Acer, Quercus*) to invade *Pinus strobus* forests which had been maintained by dry conditions during the Hypsithermal. However, other records from the American midwest suggest that oak savanna is a more xeric association than *Pinus strobus*; Jacobson (1979) recorded the post-Hypsithermal replacement of oak savanna by *Pinus strobus* in parts of Minnesota. Why, then, did oak plains replace *Pinus strobus* at Decoy Lake when moisture was increasing?

All evidence points to fire as being the most important factor allowing the continued existence of oak savanna in the midwestern United States (Ellarson, 1949; McAndrews, 1966; Jacobson, 1979; Grimm, 1983, 1984). On the other hand, studies in Ontario savannas stress the importance of coarse soil texture (Ball, 1981; Bakowsky, 1988). The most dominant tree in midwestern savanna is *Quercus macrocarpa*, the most fire-resistant species of oak (Cottam, 1949; Ellarson, 1949; Fowells, 1965; McAndrews, 1966). Oak savanna in southern Ontario was dominated by *Quercus velutina* and to a lesser degree *Quercus alba*, with *Quercus macrocarpa* being a secondary or minor component (Bakowsky, 1988); both of these dominant species are less tolerant of fire than *Quercus macrocarpa* (Cottam, 1949; Fowells, 1965). This evidence leads to the conclusion that while fires were extremely important, and usually necessary, in the maintenance of midwestern oak savanna, they were less important than edaphic factors in maintaining Ontario's oak plains.

Increasing moisture following the Hypsithermal decreased the extent and frequency of fires which had been maintaining oak savanna in the midwest, allowing some of these areas to be invaded by *Pinus strobus* (Jacobson, 1979) or mesic hardwoods (McAndrews, 1966; Grimm, 1983). In southern Ontario, this climatic shift allowed less xeric oak plains to invade *Pinus strobus* forests in many areas which could not support mesic hardwoods due to edaphic constraints. Natural fires may have played a secondary role in maintaining both the *Pinus strobus* forests and oak plains. On sandy soils, vegetation burns more easily than on more mesic substrates, due to a drier litter layer (Brubaker, 1975).

Increasing winter temperatures, resulting from a decrease in seasonality, may also have been a factor in oak plains expansion. Both

Quercus alba and *Quercus velutina* are at the extreme northern limits of their distribution at Decoy Lake today (Fowells, 1965; Hosie, 1973). An amelioration of winter temperatures since the Hypsithermal and the resultant reduction in occurrence of extremely low temperatures may have reduced the chances of freezing injury and promoted greater seedling survival during the winter, allowing a long-term expansion of populations. Webb (1986) has shown that *Fagus* has advanced northwards in Quebec since 6000 yr BP despite decreasing annual temperatures; he attributes this range expansion to increased winter temperatures.

This study also raises the question of why the oak plains developed only in certain areas of coarse soils. The answer lies at least in part in the stochastic or probabilistic nature of vegetation change over time. Edaphic conditions on the outwash plain and Wentworth Till were not sufficiently severe to allow only extremely xeric vegetation to grow. They did, however, favour the development of more drought-tolerant vegetation types such as the oak plains. Mesic associations had a lower but not negligible probability of developing on the coarse soils, and they are therefore uncommon but not absent in these areas. The stochastic response of vegetation to exogenous and endogenous forcings during the postglacial led to a heterogeneous mosaic of vegetation types in the study area in pre-settlement times.

6.3 - Methodological Considerations

This study is unique in southern Ontario in that it examined the postglacial history of a local scale terrestrial vegetation formation. The vast majority of other Holocene pollen records in this region are from medium to large lakes, and consequently reflect vegetation dynamics on a regional scale. The regional pollen record of southern Ontario is therefore fairly well known and varies only in detail from site to site. Only when vegetation history is studied on a smaller scale, such as the Decoy Lake pollen record, can major variations from the regional record be seen.

Once the *Acer* and *Fagus* dominated forests became established in southern Ontario between 6000 yr BP and 7000 yr BP, they remained relatively stable for at least 5000 years. Climatic changes are best studied using pollen records from ecotonal or otherwise constrained sites (e.g. McAndrews, 1966; Brubaker, 1975; Grimm, 1983). For the most part, regional vegetational gradients in southern Ontario are not steep, as a result of the relatively homogenous topography and climate. Mid- and late Holocene climatic variations have consequently had little impact on large-scale vegetation dynamics, with the possible exception of the last 1000 years (McAndrews, 1981, 1988). However, a meso-scale vegetational association growing in moderately constrained edaphic conditions is more likely to respond to climatic variation; the Decoy Lake pollen record confirms this.

A recent trend in palaeoecology involves an attempt to close the gap between the long term, large scale records of 'traditional' palaeoecological studies and smaller scale, short term neoecological studies. Palynological analysis of soils from forest hollows (Bradshaw and Miller, 1989) provides records with very fine spatial resolution but only moderately fine to coarse temporal resolution. Annually laminated lake sediments provide very fine temporal control for records of local or regional vegetation dynamics (Swain, 1973, 1978; Gajewski, 1988; Larsen, 1989). Although the temporal resolution of this study is no better than that of the traditional radiocarbon dated postglacial record, it is nonetheless a step in the right direction in terms of palaeoecological research in southern Ontario. The local scale of the record has provided new insight into the postglacial history of a unique and interesting vegetation association. Additional palaeoecological studies on small basins should result in further elucidation of mid-Holocene climatic and vegetational changes in southern Ontario.

CHAPTER 7 - SUMMARY

The hypothesis that the oak plains in southern Ontario resulted from burning by natives was tested by pollen analysis of a 5 m sediment core from a small site, Decoy Lake, within an area classified by 19th century surveyors as oak plains. The palaeoecological analysis was supported by comparison of pre-settlement vegetation distribution to Quaternary geology, soils, mesoclimate and topography within a defined study area.

The pollen record at Decoy Lake indicates that *Picea* was dominant from 11,800 yr BP to 10,100 yr BP. *Pinus banksiana*-dominated forest then replaced *Picea*, and this was in turn replaced by *Pinus strobus* between 8000 yr BP and 9000 yr BP. *Pinus strobus* remained the dominant tree in the vicinity of Decoy Lake until well after 6000 yr BP. At this time the oak plains began to expand, and by 4000 yr BP they had become fully developed.

The postglacial vegetation history of Decoy Lake was compared by the use of difference diagrams to the records of two lakes, Hams and Maplehurst Lakes, located in mesic hardwood forests to the west of Decoy Lake. The results of this study have allowed several conclusions to be reached.

1. Substrate texture is the most important physical factor determining the location of the oak plains. This assemblage is restricted to areas of coarse outwash and deltaic sands and coarse tills. Topography and climate are less significant factors in determining the distribution of oak plains and other vegetation associations in the study area.

2. The vegetation of the Decoy Lake area has differed substantially from that of nearby mesic sites for the past 8000 years, since well before the development of the oak plains.

3. The timing of oak plains development suggests that neither anthropogenic disturbance nor mid-Holocene warm, dry conditions were causal factors. *Pinus strobus* forests maintained on well-drained soils during the dry Hypsithermal were replaced by the oak plains as a result of increasing moisture and perhaps increasing winter temperatures between 6000 yr BP and 4000 yr BP.

4. The results indicate that fire is less important than substrate in the maintenance of oak plains in Ontario, contrary to studies in the U.S. midwest which show fire to be the most important factor in maintaining oak savannas. This difference in fire importance is reflected in the fire tolerances of dominant oak species on the two associations. *Quercus macrocarpa*, the most fire-tolerant oak, dominates in midwestern savanna; *Quercus velutina* and *Quercus alba*, less resistant to fire, dominate in the oak plains.

5. Finally, this study has shown that local vegetation dynamics on edaphically constrained sites can reflect changes in climate or other factors that are not recorded at less stressed sites. Very few pollen records from southern Ontario show any response to mid to late Holocene climatic change, whereas the record from Decoy Lake shows clear responses to climatic forcing at this time.

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APPENDIX 1: COMMON NAMES OF TAXA MENTIONED IN TEXT

Nomenclature follows Gleason (1952) and Hosie (1973)

Trees

Abies balsamea - balsam fir
Acer saccharum - sugar maple
Acer saccharinum - silver maple
Acer rubrum - red maple
Betula alleghaniensis - yellow birch (also known as *B. lutea*)
Betula papyrifera - paper birch
Carpinus carolineana - bluebeech
Carya ovata - shagbark hickory
Carya ovalis - pignut hickory
Carya cordiformis - bitternut hickory
Castanea dentata - chestnut
Fagus grandifolia - beech
Fraxinus nigra - black ash
Fraxinus pennsylvanica - red ash
Fraxinus americana - white ash
Juglans cinera - butternut
Juglans nigra - black walnut
Larix laricina - larch
Liriodendron tulipifera - tulip-tree
Ostrya virginiana - ironwood
Picea mariana - black spruce
Picea glauca - white spruce
Pinus strobus - white pine
Pinus resinosa - red pine
Pinus banksiana - jack pine
Platanus occidentalis - sycamore
Populus balsamifera - balsam poplar
Populus grandidentata - large-toothed aspen
Populus deltoides - cottonwood
Populus tremuloides - trembling aspen
Prunus serotina - black cherry
Quercus alba - white oak
Quercus rubra - red oak
Quercus ellipsoidalis - Hill's oak
Quercus palustris - pin oak
Quercus velutina - black oak
Quercus macrocarpa - bur oak
Thuja occidentalis - eastern white cedar
Tilia americana - American basswood
Tsuga canadensis - hemlock
Ulmus americana - white elm
Ulmus rubrum - slippery elm

Shrubs

Alnus - alder
Celtis - hackberry
Cephalanthus - buttonbush
Cornus racemosa - dogwood
Corylus americana - hazel
Empetrum - crowberry
Ericaceae - heath family (includes genus *Vaccinium*)
Myrica - sweet gale
Salix - willow
Sambucus - elder
Shepherdia - buffalo berry
Vaccinium - blueberry
Vitis riparia - frost grape

Herbs

Ambrosia - ragweed
Andropogon gerardii - tall bluestem (grass)
Artemisia - sage
Aster umbellatus, A. cordiformis - asters
Carex pennsylvanica - sedge
Cheno/Am - composed of Chenopodiaceae (goosefoot family) and Amaranthaceae (amaranth family)
Cruciferae - mustard family
Cyperaceae - sedge family (includes genera *Carex* and *Scirpus*)
Dryas - arctic avens
Epilobium - fireweed
Gramineae - grass family (includes genera *Andropogon* and *Poa*)
Helianthus strumosus, H. divaricatus - sunflowers
Lespedeza capitata - bush clover
Plantago lanceolata - English plantain
Poa pratensis - Kentucky bluegrass
Polygonum - smartweed
Potentilla - cinquefoil
Pteridium aquilinum - bracken fern
Ranunculaceae - buttercup family
Rumex acetocella, R. mexicanus - sorrel
Scirpus - bullrush
Smilacena racemosa - false Solomon's seal
Solidago nemoralis - goldenrod
Stellaria - chickweed
Thalictrum - meadow rue
Tubuliflorae - subfamily of Compositae (daisy family) (includes genera *Aster* and *Helianthus*)
Zea mays - domestic corn

Aquatics

Myrophyllum - water milfoil
Naja flexilis - naiad
Nuphar - yellow water lily
Potamogeton - pondweed
Sagittaria - arrowhead
Scirpus - bullrush
Sphagnum - peat moss
Typha - cattail

APPENDIX 2: PERCENT FREQUENCY OF TAXA NOT PLOTTED ON MAIN DIAGRAM

Depth	Age	Castanea	Platanus	Celtis	Vitis	Shepherdia	Cornus stolonifera	Cornus racemosa	Ericaceae	Cephalanthus	Sambucus	Rumex acetocella
25	50				0.63							
30	75				0.48							0.72
35	100				0.27							0.27
40	314											
45	527		0.77		0.26							
50	741				0.27							
55	954		0.97									
60	1168		0.31		0.62							
65	1382		0.34									
70	1595		0.32									
75	1809	0.26										
80	2022		0.25		0.25							
85	2236				0.27							
90	2450		0.77									
95	2710	0.26	0.52		0.52	0.26						
100	3161	0.50			0.25							
105	3613											
110	4064		0.28		0.28							
115	4515		0.55									
120	4966				0.83							
125	5418		0.27		0.27							
130	5869				0.30							
135	6320				0.28							
140	6419				0.32							
145	6518				0.29							
150	6617											
155	6717		0.33									
160	6816		0.34									
165	6915											
170	7014											
175	7113											
180	7212		0.27									
185	7311											
190	7410		0.30									
195	7510											
200	7609											
205	7708		0.28									
210	7807											
215	7906											
220	8005											
225	8104											
230	8203											
235	8303		0.27									
240	8402											
245	8501											
250	8600		0.56									
255	8646			0.29								
260	8693											
265	8739		0.27	0.80		0.27						
270	8786		0.28									
275	8832			0.30								
280	8879		0.29							0.29		
286	8925									0.30		
290	8971					0.29						

Depth	Age	Castanea	Platanus	Celtis	Vitis	Shepherdia	Cornus stolonifera	Cornus racemosa	Ericaceae	Cephalanthus	Sambucus	Rumex acetocella
295	9018		0.25		0.25							
300	9064										0.28	
305	9111		0.55	0.55		0.28						
310	9157											
315	9204			0.63								
320	9250			0.54								0.27
325	9296											
330	9343										0.27	
335	9389						0.28				0.28	
340	9436		0.54	0.27								
345	9482			0.28								
350	9529											
355	9575		0.57	0.28								
360	9621				0.25			0.25				
365	9668											
370	9714											
375	9761											
380	9807											
385	9854											
390	9900				0.28							
395	9946											
400	9993											
405	10039											
410	10086											
415	10132											
420	10202											
425	10306											
430	10411											
435	10515					0.66						
440	10620			0.31		0.31		0.31				
445	10725					0.53						
450	10829					0.85						
455	10934					0.58						
460	11038											
465	11143											
470	11247			0.27		0.27						
475	11352											
480	11456											
485	11561											
490	11665								0.28			
495	11770											

Depth	Age	Cheno/Am	Sarcobatus	Stellaria	Thalictrum	Rosaceae un.	Potentilla	Umbelliferae	Cornus canadensis	Menyanthes	Labiatae	Plantago
25	50	0.83				0.63		0.21				0.21
30	75	0.48				0.96						
35	100	0.55		0.27		0.55						
40	314					0.53						
45	527	0.26										0.26
50	741			0.27		0.27						
55	954			0.24								0.24
60	1168					0.31						
65	1382			0.34		1.02						
70	1595					0.32						
75	1809	0.52										
80	2022		0.25			1.02						
85	2236	0.27	0.54			0.27						
90	2450	1.02				0.26			0.51			
95	2710	0.52							0.26			
100	3161	0.75										
105	3613	0.27										
110	4064	0.28				0.28						
115	4515											
120	4966					0.28						
125	5418	0.54							0.27			
130	5869	0.61										
135	6320											
140	6419	0.64										
145	6518	0.29				0.29					0.29	
150	6617	0.31										
155	6717											
160	6816											
165	6915	0.29										
170	7014	0.29										
175	7113											
180	7212											
185	7311	0.54										
190	7410	0.30							0.30			
195	7510											
200	7609											
205	7708	0.56										
210	7807					0.26						
215	7906	0.31										
220	8005											
225	8104	0.51										
230	8203				0.26				0.26			
235	8303	0.27								0.27		
240	8402					0.27						
245	8501	0.28							0.28			
250	8600											
255	8646											
260	8693								0.27			
265	8739	0.27										
270	8786	0.56										
275	8832											
280	8879											
286	8925											
290	8971	0.86							0.29			

Depth	Age	Cheno/Am	Sarcobatus	Stellaria	Thalictrum	Rosaceae un.	Potentilla	Umbelliferae	Cornus canadensis	Menyanthes	Labiatae	Plantago
295	9018	0.25										
300	9064								0.28			
305	9111	0.55										
310	9157											
315	9204	0.31							0.63			
320	9250	0.27										
325	9296	0.28									0.28	
330	9343											
335	9389											
340	9436										0.27	
345	9482	0.28										
350	9529										0.86	
355	9575										0.28	
360	9621				0.25							
365	9668	0.26										
370	9714											
375	9761	0.28	0.28			0.56						
380	9807											
385	9854											
390	9900											
395	9946			0.27								
400	9993								0.26		0.26	
405	10039	0.27										
410	10086	0.57		0.29								
415	10132						0.67					
420	10202			0.59					0.59			
425	10306				0.28			0.28	0.28			
430	10411			0.32					0.32			
435	10515	0.33			0.33							
440	10620	0.62			0.62				0.62			
445	10725				0.26				0.26			
450	10829				0.85		0.28					
455	10934	0.29							0.29			
460	11038				0.30							
465	11143			0.29								
470	11247				0.27		0.27					
475	11352	0.26										
480	11456						0.31		0.62			
485	11561	0.58			0.58				0.29			
490	11665				0.85				0.28			
495	11770	0.68		0.34	0.34		0.34		1.70			

Depth	Age	Galium	Liguliflorae	Selaginella	Pteridium	Potamogeton	Nuphar	Utricularia	Hippuris	Equisetum	Lycopodium	Sphagnum
25	50		0.21			0.40						
30	75					1.38						
35	100					0.54						
40	314											
45	527							0.50				
50	741					0.27						
55	954					0.72		0.24				
60	1168											
65	1382	0.34										
70	1595											
75	1809		0.26									
80	2022					0.24	0.24	0.24				
85	2236											
90	2450	0.26						0.25				
95	2710											
100	3161	0.25						0.24				
105	3613											
110	4064											
115	4515											
120	4966											
125	5418											
130	5869											
135	6320											
140	6419											
145	6518											
150	6617											
155	6717											
160	6816											
165	6915											
170	7014											
175	7113											
180	7212	1.08										
185	7311											
190	7410											
195	7510					0.30						
200	7609											
205	7708											
210	7807											
215	7906											
220	8005											
225	8104											
230	8203											
235	8303											
240	8402											
245	8501											
250	8600											
255	8646											
260	8693							0.79				
265	8739											
270	8786											
275	8832											
280	8879											
286	8925				0.29		0.88					
290	8971											

Depth	Age	Galium	Liguliflorae	Selaginella	Pteridium	Potamogeton	Nuphar	Utricularia	Hippuris	Equisetum	Lycopodium	Sphagnum
295	9018								0.25			
300	9064						0.27					
305	9111					0.54	0.27					
310	9157						0.29					
315	9204						0.92					
320	9250						0.80					
325	9296					0.28	0.56					
330	9343											
335	9389						1.09					
340	9436						0.54					
345	9482											
350	9529											
355	9575						0.56					
360	9621					0.25	0.25					
365	9668											
370	9714						0.24					
375	9761						0.28					
380	9807											
385	9854											
390	9900						1.09					
395	9946											
400	9993						0.25					
405	10039										0.27	
410	10086							0.28			0.28	
415	10132											
420	10202										0.58	
425	10306											0.28
430	10411											0.32
435	10515										0.33	
440	10620											
445	10725											
450	10829											
455	10934											
460	11038					0.30						
465	11143											
470	11247				0.26							
475	11352										0.26	
480	11456											
485	11561											
490	11665											
495	11770			1.67								

APPENDIX 3: SUMMARY OF POSTGLACIAL VEGETATION CHANGES AT MAPLEHURST LAKE

Maplehurst Lake (Mott and Farley-Gill, 1978) has a pollen stratigraphy that is fairly typical of moderate-size basins in southern Ontario.

12,500 yr BP to 10,000 yr BP - *Picea* zone

High percentages of *Picea* (40% to 60%) and herb (10% to 30%) pollen indicates a *Picea*-dominated forest, open at first (spruce woodland) but becoming more closed with time.

10,000 yr BP to 7600 yr BP - *Pinus* zone

Very high frequencies of *Pinus* pollen (up to 60%), lesser amounts of *Quercus, Ostrya/Carpinus, Betula* and *Ulmus* pollen. Forest dominated first by *Pinus banksiana* and then later *Pinus strobus*; hardwood taxa, such as *Quercus, Betula, Ulmus,* and *Populus* and conifers such as *Abies balsamea* and *Larix laricina* were also present.

7600 yr BP to 200 yr BP - *Fagus-Acer-Quercus-Ulmus* zone

Fagus was the most dominant pollen type (20% to 30%), but pollen of *Acer, Quercus, Ulmus,* and *Tsuga* was also fairly abundant. The forests were initially dominated by *Tsuga*, but after the hemlock crash at about 5000 yr BP it was replaced primarilay by *Acer-Fagus* forests, with *Quercus* and *Ulmus*, among others, being sub-dominants.

200 yr BP to Present - *Ambrosia* zone

The zone of European disturbance, delineated by large increases in the pollen of *Ambrosia* and other herbs.