THE IMPORTANCE OF FIRE IN THE MAINTENANCE OF JACK PINE AT ITS SOUTHEASTERN RANGE LIMIT IN ACADIA NATIONAL PARK, MAINE

A Thesis Presented

by

CHARLES P. LAING

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Approved as to style and content by:

William A. Patterson III, Chair

Brayton F. Wilson, Member

David R. Foster, Member

Donald G. Arganbright, Department Head

Department of Forestry and Wildlife Management

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ABSTRACT

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MAY 1993

CHARLES P. LAING, B.S., UNIVERSITY OF ST. ANDREWS

M.S., UNIVERSITY OF MASSACHUSETTS

Directed by: Professor William A. Patterson III

Pollen and charcoal from small bogs within two isolated jack pine stands - Whalesback and Cadillac Mtn. on Mount Desert Island, Maine - were analyzed to identify the historical relationship between jack pine and fire occurrence in this area. Results of detrended correspondence analysis illustrate changes in vegetation composition over time. The point-centered quarter method (PCQM) was used to characterize the overstory of the two stands, and fixed-radius plots were used to examine regeneration and tree-to-tree competition. Degree of cone serotiny was noted for trees tallied by PCQM.

Both stands are dominated by jack pine with little competition from other tree species that have been able to establish themselves on the shallow soils interspersed with exposed bedrock. Although there is a greater proportion of open than serotinous cones, low levels of regeneration, particularly at Whalesback, indicate substrate availability is limiting.

The pollen records from both sites span ~3000 years and identify several fires which burned over or around the two bogs. Dramatic changes in vegetation composition are associated with these fires. Pre-settlement fires did not, however, result in the persistently high jack pine abundances that follow the most recent,

post-settlement fires. This indicates that human intervention, perhaps through increased fire frequencies, has altered natural fire regimes to favor jack pine over its fire-sensitive competitors.

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CHAPTER I
INTRODUCTION

Jack pine (*Pinus banksiana* Lamb.[1]) is a member of the hard pine group (subgenus *Diploxylon*) and grows farther north than any other North American pine (Fowells 1990). The species' present distribution (Figure 1), stretches from Saskatchewan to Labrador, further south around the Great Lakes and in scattered areas of northern New England and the Maritime Provinces (Yeatman 1967).

Jack pine is labeled a "pioneer" or early-successional species due to adaptations that allow it to rapidly colonize exposed substrates. These adaptations include: good seed crop production - almost every year in some areas (Bergeron & Brisson 1992); tolerance of harsh seedbeds; and rapid shoot and root growth (Thomas & Wein 1985). Such factors contribute to early establishment and dominance of jack pine, particularly on harsh, xeric sites (Fowells 1990). The ability of jack pine to reproduce at an early age [flower production has been seen on three-year-old saplings (Righter 1939)] provides the means for rapid migration onto soil exposed by disturbance.

Jack pine is particularly suited to establishment or regeneration following fire. The species' most distinctive adaptation is its serotinous cones (i.e. cones that only open to release seeds upon heating) (Beaufait 1960). As jack pine cones are generally retained in the tree canopy for many years, a large fire can result in rapid reseeding of the burned area (Cayford 1971). To some extent, jack pine enhances fire recurrence through density-dependent mortality in excessively stocked young stands and a lack of self-pruning, factors that both lead to fuel buildup (Yarranton & Yarranton 1974). This, in conjunction with highly flammable foliage and an ability

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[1] Argus (1971) demonstrates that *Pinus divaricata* (Ait.) Dumont is the correct species name by priority, however, *P. banksiana* will be used in this study due to its present common usage.

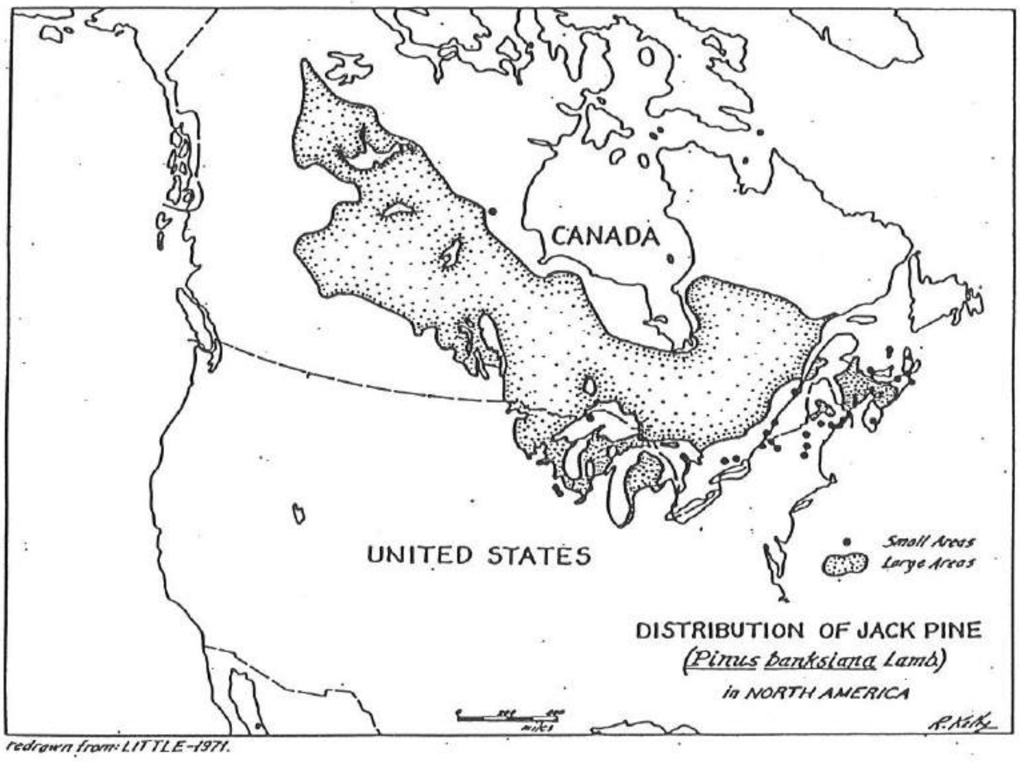

Figure 1. Map of the range of jack pine in North America.
(From Maine State Planning Office, Critical Areas Program, 1983)

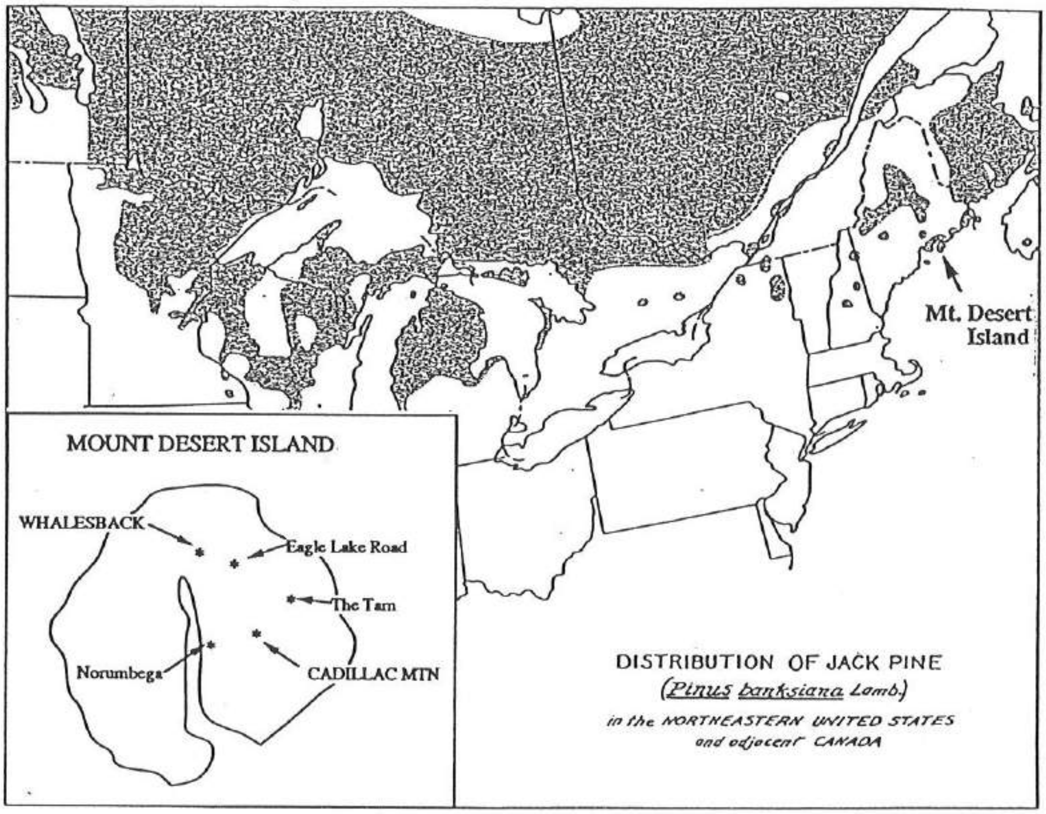

Figure 2. Map of the range of jack pine in northeastern North America and the location of jack pine stands on Mt. Desert Island, Maine. (From Maine State Planning Office, Critical Areas Program, 1983)

to dominate very dry sites, can result in the high fire frequencies that are ideal for the perpetuation of jack pine (Bergeron & Dubuc 1989). Frequent fires also prevent accumulation of organic matter, which, if too thick, would impede seedling establishment (Fowells 1990).

Jack pine stands in Maine have recently been designated as critical areas for conservation due to the species' rarity at this, its southeastern range limit in North America. The Maine Critical Areas Program (MCAP 1983) identified a number of disjunct jack pine stands that should be conserved due to their unusual natural or scientific features. On Mt. Desert Island on the central-Maine coast and five such stands were identified within Acadia National Park (Figure 2). A stand on Cadillac Mtn. was recommended for critical area status. Although information has been gathered on stand dynamics and regeneration in these jack pine communities, little is known of their past history beyond that discerned from dendroecological work for the late 19th and early 20th centuries (Conkey et al. 1991). My study provides data on historic and prehistoric variations in the abundance of jack pine at the two largest of five Mt. Desert Island stands. It also identifies the past occurrence of fire and assesses the relationship between fire and jack pine in these stands. Fine resolution pollen and charcoal analyses provide information on human impacts on fire regimes since the first permanent European settlement on Mt. Desert Island (ca. 1760 A.D.). This information will be useful to the National Park Service and other organizations involved with the management and conservation of these critical areas in Maine.

CHAPTER II

LITERATURE REVIEW

Jack Pine Migration

With the retreat of the Wisconsin ice sheet ca. 12,000 B.P., jack pine migrated northward to its present distribution from refugia in the southeastern United States. Pollen and macrofossil analyses from Georgia (Watts 1970) and North Carolina (Whitehead 1964) have identified jack pine as a major component of a full-glacial spruce-pine forest in the southeast. Jack pine responded rapidly to the post-glacial climatic amelioration, advancing into the deglaciated landscape at a faster rate than any other tree species (Davis 1981). Isopoll maps of northern New England (Davis & Jacobson 1985) indicate that jack pine arrived in coastal Maine ca. 12,000 B.P. while much of northern Maine was still under ice. It is clear from these maps and additional macrofossil data, that jack pine's rapid, northward migration must have been facilitated by its ability to colonize the recently deglaciated landscape.

Jack Pine Species Characteristics

As a 'pioneer' species, jack pine is generally short lived exhibiting dieback at around 70-80 years of age (Fowells 1990), although individuals as old as 225 years have been identified (Heinselman 1973). These older trees were present as scattered emergents among a dense canopy of mixed-hardwoods that had grown up during a prolonged period without disturbance. Jack pine does not have a particularly thick bark compared to other North American conifers such as red (*Pinus resinosa* Ait.), white (*Pinus strobus L.*) and pitch pine (*Pinus rigida* Mill.). Thus under certain conditions (low intensity fires at long intervals) other pine species are favored over jack pine. Where jack pine dominates, however, frequent, stand-replacing fires may kill all seedlings, saplings and mature trees of all species with seed released from serotinous cones favoring jack pine. Young jack pines can also produce cones as early as 3-4 years (Righter 1939, Bergeron & Brisson 1992). This can favor the species on sites supporting fire-return intervals of a decade or less.

Bare mineral soil exposed by fire is the most suitable substrate for jack pine, which is generally unable to seed into areas where organic matter accumulates to more than a few centimeters (Fowells 1990). Fires will also reduce competition from more shade-tolerant species (Fowells 1990).

Although cone serotiny is a noted characteristic of the species, mature jack pines often bear open as well as closed cones. The proportion of each cone type on a tree is genetically determined (Larsen 1980), and the proportion of individuals in a stand bearing many open cones is clearly linked to fire frequency (Bergeron & Brisson 1992). In stands located on sites dominated by thin soils and exposed bedrock, the uneven-aged nature of jack pine populations and high frequencies of open cones indicate regeneration independent of fire (Bergeron & Brisson 1990).

Importance of Fire

In the boreal forest, periodic fires ignited by lightning and/or humans play an important role in the creation and maintenance of a mosaic of vegetation types (Rowe & Scotter 1973). Within this mosaic, stands of jack pine have been shown, through fire-scar analyses and historical records, to often be the result of single-cohort establishment following stand-replacing fires (Cogbill 1984). The reliance of jack pine regeneration on fire has resulted in this species being particularly susceptible to human interference in disturbance regimes. Heinselman (1973) studied the fire regimes of the Boundary Waters Canoe Area in Minnesota through fire-scar analysis and historical records. In this area some jack pine communities burned at intervals of 50 years or less, whereas others hadn't burned since the late 19^{th} century. The jack pines now form a scattered overstory beneath which fir and spruce are establishing. Succession to shade-tolerant species in the absence of fire will, according to Heinselman, ultimately lead to the disappearance of jack pine from the Boundary Waters Canoe Area. Cogbill (1984) demonstrated that in the Laurentian Highlands of Canada the average fire rotation in jack pine forests has been 70 yrs. He suggests that most overstory trees establish in the first 30 years after a fire rather than through continual recruitment. These studies generally led to the conclusion that fire has always played an important role in northern forests, but that recent human interference has significantly altered natural fire regimes in many areas.

Human interference is not the only factor that has or could affect jack pine stands on Mt. Desert Island (MDI). Climate change over the past few millennia has resulted in substantial changes in forest composition and is particularly important in already stressed forests where species are at their range limits (Sirois & Payette 1991). The modern spruce-fir forest type of the Acadian forest region began to develop about 1400-2000 years ago in the Maritime Provinces (Mott 1975, Green 1982, Wein et al. 1986). A similar shift in forest composition towards an increase in the relative importance of spruce and fir occurred in the MDI area of coastal Maine (Rhodes 1991, N. Drake, unpublished data). Throughout the region, the forest's formation may have coincided with a shift to a cooler, moister climate. The change in forest composition subsequently lead to increased fire occurrence as the break-up of the aging spruce-fir stands resulted in increased fuel loads. It has been suggested that increases in disturbance (e.g. fire) associated with climate change might promote the expansion of early successional species such as jack pine (Overpeck et al. 1990). A similar period of increased fire occurrence and climate change may have been an important factor in jack pine's rapid northward migration during the early postglacial period (Green 1982, Tolonen & Tolonen 1984).

Many studies of jack pine ecology have taken place either in the boreal forest region of Canada or in the Lake States, where jack pine is an important timber species. Rowe and Scotter (1973) provide a good review of the integral role that fire plays in the boreal forest ecosystem. Although there has been much debate over the "nutrient lock-up" hypothesis, where fire is assumed to release previously unavailable nutrients (Larsen 1980), it is the removal of organic matter through combustion of organic soil horizons that is most favorable to species such as jack pine (Fowells 1990).

In forests of eastern North America, fires may result from lightning or, more commonly, from human ignitions. A number of studies provide information on the pre-colonial importance of Indian-set fires in the northeastern United States. Patterson and Sassaman (1988) review factors that lead to frequent Indian fires in certain areas of New England but emphasize the difficulty in inferring long-term human-fire relationships from fossil charcoal records. Historical accounts indicate that, at least in the 16th and 17th centuries A.D., Indians used fire to maintain park-like areas of forests and promote the growth of browse and berries in near-coastal environments (Bromley 1939, Day 1953, Russell 1983). Fahey & Reiners (1981) suggest that the potential for lightning and human ignited fires existed in precolonial Maine and New Hampshire. Their analysis reveals that during the 20th century, human activities have resulted in an increase in fire occurrence but that fire suppression has reduced the average size of fires. Unusual climatic conditions such as prolonged drought may still lead to extensive fires like those which occurred in Maine in 1947, however.

Although the above papers provide useful information on the relationship between fire and jack pine and on the historic occurrence of fire in the Northeast, they generally depend on historical records and fire-scar data for evaluating previous fire regimes. Patterson and Backman (1988) present evidence (in the form of fossil pollen and charcoal diagrams) of past fire occurrence for two sites on MDI. Their profiles for The Bowl and Sargent Mountain Pond identify fire histories unique to the occurrence of fire at each site. The Bowl, which lies within the boundaries of a large fire that burned on the island in 1947, shows a dramatic increase in microscopic charcoal coincident with this event. At Sargent Mountain Pond there is no similar increase at this time, which is consistent with this site's location outside the boundary of the 1947 fire. Charcoal peaks at other times in the Sargent Mountain Pond profile indicate fires at other periods during the past 300 years, however.

The first studies of jack pine on MDI and surrounding areas were descriptive in nature (Rand 1889, 1899) and delt primarily with the occurrence of jack pine far south of its typical range. The rare nature of these jack pine stands has, more recently, lead to a study of their distribution and vegetation composition as part of the Maine Critical Areas Program (MCAP 1983). Other recent studies of these stands have focussed on their relationship with fire and the possibility of their continued growth and regeneration in its absence.

The question of jack pine regenerating without fire was originally reviewed by Eyre (1938) whose study of jack pine in the Lake States was prompted by actual and perceived dangers of using prescribed burning to regenerate what had become an important timber species. Although Eyre's study dealt with mechanical means of promoting jack pine regeneration in the absence of fire, it did demonstrate that the species was not necessarily fire dependent. Thompson (1982) studied jack pine stands on Great Wass Island 100 km east of MDI on the Maine coast, and concluded that a very low degree of cone serotiny and the uneven-aged nature of jack pine populations suggested a lack of dependence on fire. A lack of competition from other species on poor and very thin soils coupled with a plentiful jack pine seed fall from non-serotinous cones is apparently allowing jack pine to persist in the absence of fire. A dendroecological study of Acadia jack pine stands by Conkey et al. (1991) on Cadillac Mtn. on MDI and on Schoodic Head (east of MDI) came to a different conclusion, however. Conkey et al. found that regeneration at these sites was apparently not sufficient to off-set age-related losses, and that as a result these stands seem unlikely to perpetuate themselves in the absence of disturbance, particularly fire. Competition from other species together with the accumulation of organic duff will lead to domination by spruce and other late-successional species on these sites.

Factors Affecting Species at their Range Limits

The continued regeneration of species at the limits of their natural range is often linked to particularly favorable site conditions or microclimate. In the case of red pine at its northern range limit in northwest Quebec, the species is restricted to insular stands where the fire regime is similar to that of other parts of its range (Bergeron & Brisson 1990). Elsewhere, on the mainland, larger and more intense fires have eliminated red pine and favored jack pine. At the northern limit of jack pine in western Labrador, King (1986) suggests that infrequent fire resulted in the species' late migration into the area and limits its continued migration north. In Keewatin, Canada, the northern forest border is maintained through the interaction of fire and climate (Larsen 1980). Within this interaction, jack pine distribution is limited on some sites by the presence of permafrost so close to the surface as to thwart the growth of the tree's taproot. Data gained from transects across the tundra-boreal forest border in northern Quebec, were used by Sirois & Payette (1991) to assess post-fire tree regeneration of black spruce. They found that the presence of climatically stressed forests, where trees reach their range limits, is highly dependent on the reproduction of the trees immediately after a fire. On Mount Desert Island jack pine reaches its southeastern range limit and occurs chiefly on rocky, exposed sites. A high proportion of non-serotinous cones (Conkey et al. 1991) suggests low fire frequencies, but all of the five stands on the island have burned within the past 50-100 yrs (W.A. Patterson, pers. comm.). In the past 40 years, however, fire suppression has all but eliminated wildfire from the island's forests. The impact of prolonged suppression of the natural disturbance regime in these MDI jack pine stands will depend on the extent of the species' reliance on fire at these sites.

CHAPTER III

STUDY AREA

Regional Characterization

Mount Desert Island is located off the eastern coast of Maine, at about 44° 4' N latitude, 68° 3' W longitude. This part of the coastline is characterized by numerous islands and peninsulas which extend into the Gulf of Maine. The proximity to these cool waters provides this coastal zone with a strong maritime climate where precipitation is higher and temperatures lower than further inland (Davis 1966). A function of this narrow 'perhumid' belt along the Maine coast is the extension of the northern spruce-fir forest which reaches its southern limit in this area. The soils associated with this coastal spruce-fir forest are generally shallow, coarse-textured podsols (Davis 1966).

European settlement expanded from southwestern Maine into much of this coastal area during the 1700's (Fobes 1944). The first permanent settlement on Mount Desert Island was at Somesville around 1761 (Patterson et al. 1983). Selective harvesting of the largest white pines and spruces of the coastal forests gave way to clearcutting by the late 19th century. The associated build-up of slash lead to many severe fires during this period (Moore & Taylor 1927). In 1947, following the driest October on record (Patterson et al. 1983), fires burned throughout the state and across about 20 percent of Acadia National Park.

Jack Pine on Mount Desert Island

Five jack pine stands 0.25 ha or larger have been identified on Mt. Desert Island (Figure 2). These are referred to as the Cadillac Mtn., Norumbega Mtn., Whalesback, Eagle Lake Road and The Tarn (or Huguenot Head in MCAP, 1983) stands. The density of jack pine populations and the size of stands vary. The largest is ~3.0 ha on Cadillac Mtn.. At an elevation of 300m, this stand is also the highest coastal stand of jack pine in eastern North America. Except for small stands at The Tarn and Eagle Lake Rd., the MDI sites are all located on exposed rock outcrops. The extreme exposure of the summits of Norumbega and Cadillac Mtns. has severely stunted many of the jack pines that grow there. Whalesback is the second largest jack pine stand (~1.5 ha) but is at an elevation of only ~30m. The stands at Cadillac Mtn. and Whalesback were selected for evaluation in this study because they contain small, peat-filled basins that have accumulated sediments suitable for fossil pollen analysis. One important difference between the Whalesback and Cadillac Mtn. stands is that the former lies within the bounds of the 1947 fire, whereas the latter does not.

Cadillac Mtn.

The Cadillac Mtn. jack pine are located on the eastern and southern side of the mountain's south ridge. The site is very exposed and the soils are thin and interspersed with areas of exposed bedrock (MCAP 1983, Patterson 1988). The jack pine are generally open-grown and stunted. Competitors include red spruce and pitch pine, the latter becoming dominant to the east and north of the stand. Jack pine were first identified at this site in 1898 (Rand 1899). Old aerial photographs (ca. 1940's) show a sparser cover of jack pine than at present (Patterson 1988). A recent dendroecological study (Conkey et al. 1991) provided ages ranging from >70 years to <20 years for the Cadillac jack pine, providing evidence of continuous recruitment at this site. The pollen deposition basin cored in this study is a small wetland - 18.7m x 21m - which lies near the western edge of the jack pine stand (Figure 3).

Whalesback

The Whalesback jack pine stand occupies a knoll northwest of Mount Desert Island High School (MCAP 1983). On this area of thin soils and exposed bedrock,

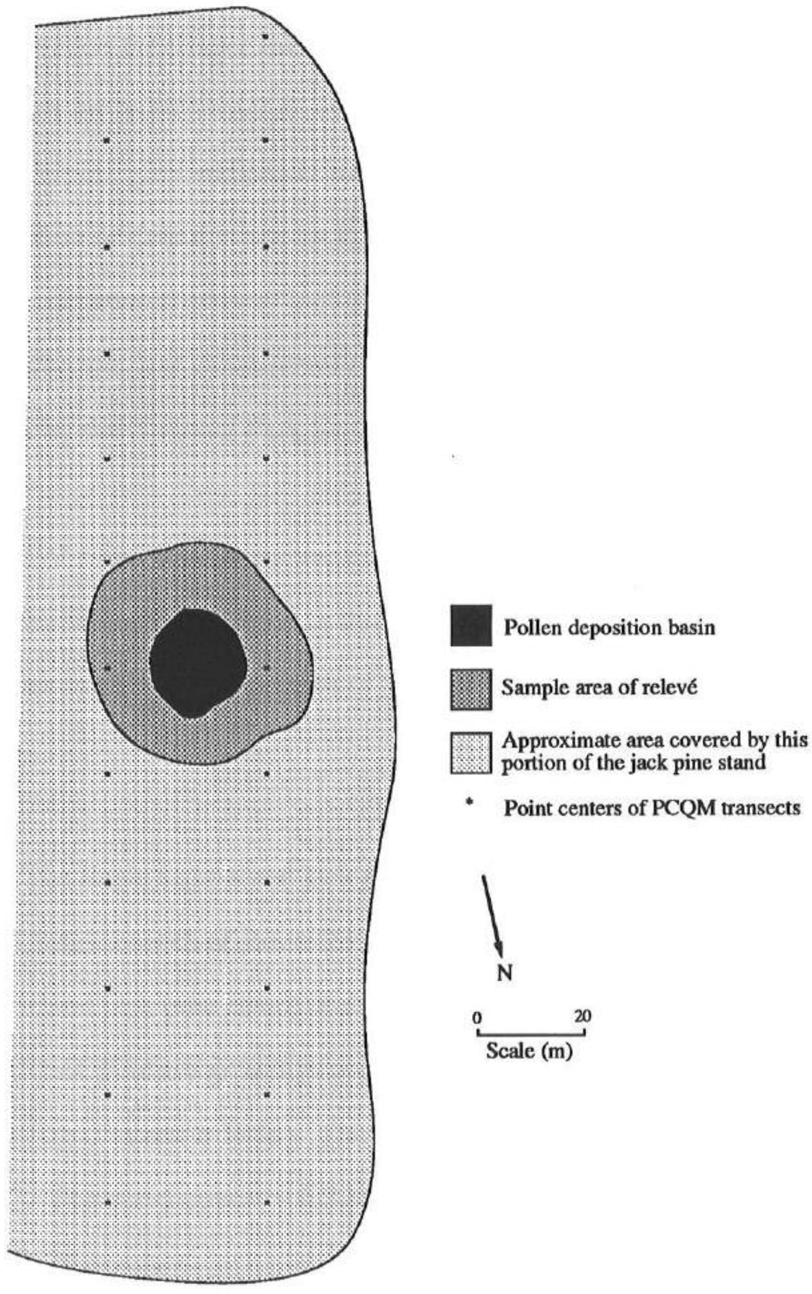

Figure 3. Location of pollen deposition basin and PCQM transects within the western section of Cadillac Mtn. jack pine stand (the stand extends further to the east and southeast).

jack pines are very dense and there are few other tree species present. Jack pine are also present on the deeper mineral soils surrounding the knoll but only as scattered individuals amongst a mixture of hardwood species including red oak, red maple, bigtooth aspen, grey and paper birch (Patterson 1988). A single jack pine was identified on or near this site by Rand (1899). Aerial photographs, tree stumps and evidence of sawmill activity indicate the area was cut over in the 1940's (Patterson 1988). The site was subsequently burned in the 1947 Bar Harbor fire and was acquired by the National Park Service from the estate of John D. Rockefeller, Jr. in 1960. The present dense jack pine stand regenerated soon after the 1947 fire but the presence of some smaller saplings indicates limited continuing recruitment. The pollen deposition basin cored in this study is a small wetland - 10.1m x 6.1m - which lies in the western portion of the jack pine stand (Figure 4).

Other MDI sites

The Eagle Lake Road jack pine stand lies on the east side of Eagle Lake Road about 0.5 miles south of Route 235 (MCAP 1983). It is the smallest of the Mt. Desert Island jack pine stands and consists of about 15 jack pine scattered over <0.1 ha. The jack pine are growing on mineral soil in an area burned by the 1947 Bar Harbor Fire (Patterson 1988). The Tarn jack pine stand lies on the east side of Route 3. The stand covers ~ 0.3 ha of mineral soil that was burned during the 1947 fire. The Norumbega jack pine stand occupies an area of ~0.5 ha on the summit of Norumbega Mountain. The jack pine are stunted and are growing on bedrock or in thin soils.

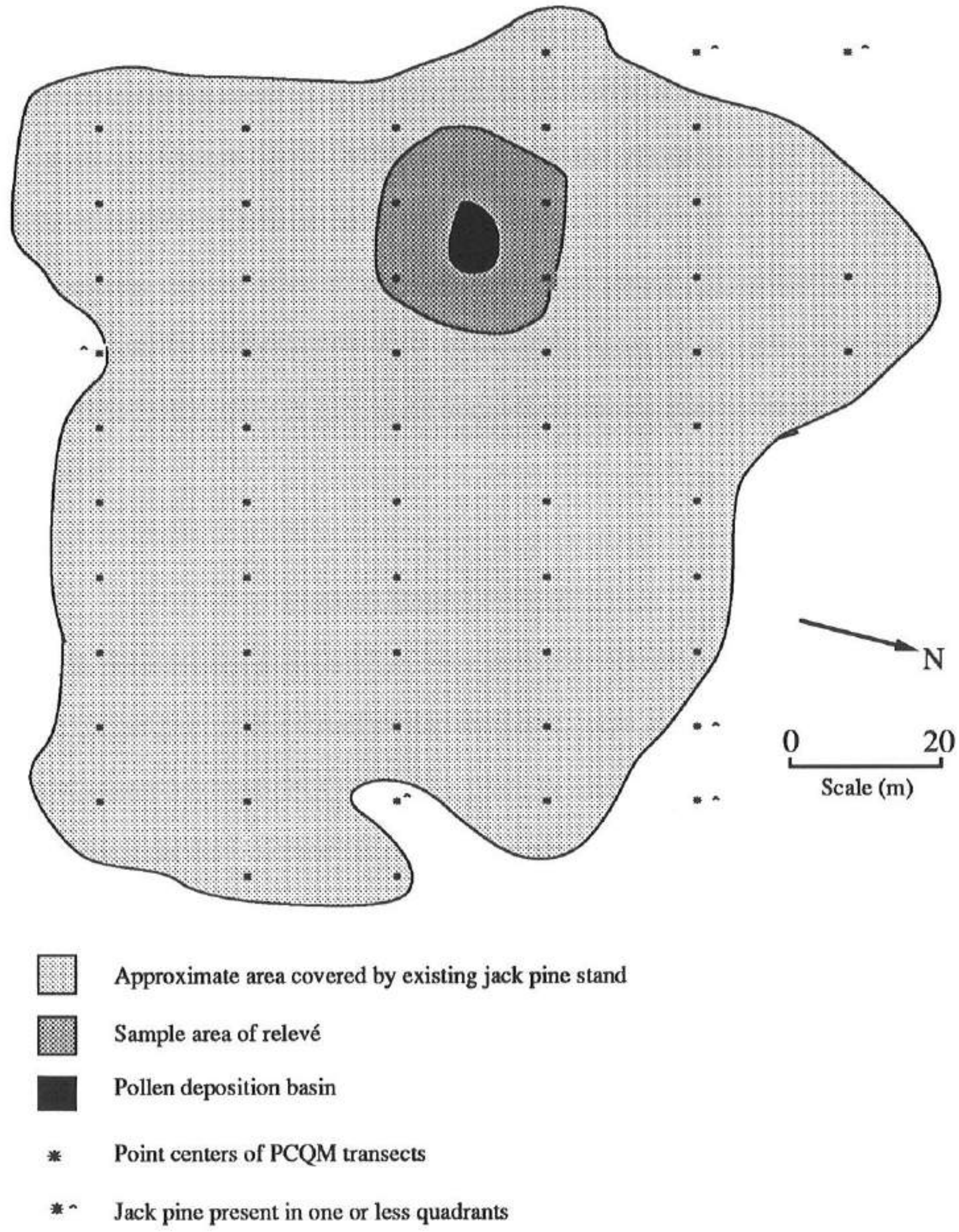

Figure 4. Location of pollen deposition basin and PCQM transects within Whalesback jack pine stand.

CHAPTER IV

METHODS

The following methods were used to characterize the existing jack pine stands on Mount Desert Island (MDI) and identify the vegetation and fire history of two of these stands at Cadillac Mtn. and Whalesback. The aim of these analyses was to assess the regenerative abilities of the present stands at Cadillac and Whalesback, and by analyzing the past relationship between jack pine abundance and fire at these sites, answer questions about their future management and conservation.

Modern Stand Characterization

The Whalesback and Cadillac Mtn. jack pine stands on Mount Desert Island, which are the subject of the fossil pollen analyses, were sampled using the Point-Centered Quarter Method (PCQM). As a plotless sampling technique, PCQM is a relatively quick method of obtaining a number of perameters including species composition, density, basal area and frequency (Meuller-Dombois & Ellenberg 1974). Plots were sampled at 10 or 20m intervals along transects set 20 or 30m apart at Whalesback and Cadillac Mtn., respectively. A total of 57 points were sampled at Whalesback and 21 points at Cadillac (Figures 3 & 4). Data for Cadillac are augmented in part by information provided by a previous analysis of the stand (Conkey et al. 1991).

In addition to basic vegetation perameters, a number of other site/plant characteristics were noted. Soil depth (organic horizon plus total depth to bedrock) and canopy cover were recorded at each point. The height (if <1.4m tall) or diameter breast height (dbh) of jack pine seedlings was recorded within a 5m radius of each point. I also counted the number of serotinous and non-serotinous cones on each jack pine tallied in the PCQM sampling.

Actual species percentage cover was estimated for relevés of vegetation on and within 10m of the two basins cored for microfossil analyses reconstructions at Cadillac Mtn. and Whalesback. The locations of these relevés with respect to the basins and surrounding jack pine stands are shown in Figures 3 and 4.

Stem maps were produced for one plot of 150-300m^2 in three of the Mount Desert Island (MDI) jack pine stands: Norumbega, The Tarn and Whalesback. Two plots were sampled at Whalesback, which is divided into 'bare rock' and 'mineral soil' sections. Basal area by species was calculated from stems sampled on these plots. Competition indices (Martin & Ek 1984, Daniels et al. 1986) were calculated for each jack pine on the four plots. A modified distance-dependent index, based on a ratio of competitor tree diameters and subject tree diameter weighted by the distance from the subject tree (Ganzlin & Lorimer 1983), was used. Competitors were trees other than jack pine within a fixed radius of competition (or 'search radius') of 2.5m and having a crown class equal to or greater than the crown class of the subject jack pine. Adjacent jack pine were not included in the calculations because the aim was to identify competition from other species which may replace jack pine in the future. These indices were used to compare jack pine stands not included in the PCQM characterizations (Norumega Mtn. and The Tarn) with Cadillac and Whalesback.

Sediment Analyses

Core Recovery and Sampling

Two cores were recovered, one each from small peat-filled depressions located within the Cadillac Mtn. and Whalesback jack pine stands (Figures 3 & 4). Cores were taken from the deepest deposits in the respective pollen deposition basins using a piston corer 9 cm in diameter. At both sites, 34cm of organic material were recovered before encountering bedrock.

Prior to sub-sampling for fossil analyses, the location and width of visible charcoal layers within the cores were noted for comparison with the results of microscopic charcoal analyses. An initial sample of the top 2cm of less-consolidated sediment at the surface of each core was followed by samples taken every cm (for a total of 34 samples from each core).

Pollen and Charcoal Analyses

Sub-samples of 0.5 cm^3 were processed chemically according to procedures described by Faegri and Iversen (1975). A known quantity (100,333 grains/cc) of *Eucalyptus* pollen grains was added to each sample prior to preparation, which included treatment with hot 10% KOH to dissolve humic substances, 10% HCL to remove colloidal SiO_2, silicoflourides and $CaCO_3$, 48% HF to remove siliceous matter and acetolysis[1] to remove organic remains. Samples were acetolysed for 1 minute in a water bath kept just below boiling point. Longer acetylation times have been shown to significantly corrode*Sphagnum* spores and possibly *Pinus* pollen (Charman 1992). Samples were stained with one drop of 1.0% safranin, dehydrated with TBA, and suspended in silicone oil (2000 cs). Slides of the resulting material were analyzed under a compound microscope using 400x magnification for pollen grain identification. A minimum of 300 grains were counted for each sample, and an accompanying tally of *Eucalyptus* grains was used in the calculation of microscopic charcoal abundances.

The slides used in the fossil pollen analysis were also analyzed for microscopic charcoal. The point-count method (Clark 1982) was used for estimating the projected area of charcoal for each sample. The pollen/*Eucalyptus*

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[1] A commonly used term for a treatment that is more correctly described as acetylation
(Charman 1992).

ratio was used in the calculation of microscopic charcoal abundances expressed as the ratio of charcoal area (measured in square microns) to fossil pollen (C:P).

Fossil pollen percentages and microscopic charcoal data were summerized in diagramatic form using the graphics program MacDraw II on an Apple Macintosh computer. Additional analysis of the fossil pollen percentages for the major upland taxa was undertaken using a FORTRAN program for detrended correspondence analysis (DECORANA, program CEP-40 written by Mark O. Hill for the Cornell Ecology Program series).

Three members of the hard pine group (subgenus *diploxylon*) occur on Mount Desert Island: jack pine, pitch pine and red pine. Because of the morphological similarity of these pollen grains, and the particular interest of this research in jack pine stand histories, a detailed study was undertaken to differentiate among these pollen types. A number of palynologists have attempted to identify and separate assemblages of diploxylon pollen grains. Their efforts range from using simple size criteria (Winkler 1982, Whitehead 1964) to multiple morphological character analyses (Hansen & Cushing 1973, Ammaan 1977). Watts (1970) concluded that an associated macrofossil analysis was necessary to determine species type. However, in many studies the presence of more than one type of diploxylon pollen in the fossil record with overlapping size frequencies makes species identification impossible (Jackson & Whitehead 1993). A preliminary study of modern diploxylon pollen collected on Mt. Desert Island identified significant differences in sizes for the three pine species.

Jack pine pollen was collected from each of the five jack pine stands identified in the Maine Critical Areas Program (Whalesback, Cadillac Mtn., The Tarn, Norumbega & Eagle Lake Road) as well as from a stand on Schoodic Head, 10 km to the east of MDI, and from a group of planted jack pines located at the Acadia National Park Headquarters. In addition to the jack pine samples, samples were collected from red and pitch pine located on MDI. At each site samples of pollen from five separate trees were collected producing a total of 35 jack pine samples, 5 red pine and 5 pitch pine.

These diploxylon pollen samples were prepared for microscopic analysis following the procedure for fossil pollen material (excepting HF treatment). This was done to reduce the likelyhood of noncomparable alterations in pollen-grain size that can result from some of the chemical treatments (Reitsma 1969). Measurements were taken of the total length (including bladders) of 100 grains per sample, with each pollen grain assigned to one of the three diploxylon pine species using probabilities generated by discriminant analysis. From this reference pollen data the discriminant analysis calculated the likelyhood of a grain of a particular size belonging to each species. Since the size ranges for the three diploxylon pine species on MDI show little overlap, the fossil pollen was generally categorized with a high probability of representing a particular species.

Core Chronology

Stratigraphic control for both cores was provided by a combination of radiocarbon dates and fossil analyses of sediments. Two ^{14}C dates were obtained for each core from Beta Analyticals, Coral Gables, Florida. The samples chosen from the core were from levels that showed the least evidence of root penetration and contamination from carbon sources such as mineral soil and charcoal layers. Other levels in the cores were dated by stratigraphic markers - abrupt changes in the pollen percentages of certain species that could be assigned a known age. Increases in ragweed (*Ambrosia*), sorrel (*Rumex* spp.), plantain (*Plantago* spp.) and grass (*Gramineae*) pollen reflect the land-clearing activities associated with European settlement (Davis et al. 1971). Peaks in microscopic charcoal abundance were correlated with historic fires of known date and location. Changes in arboreal pollen percentages were compared with fossil pollen diagrams of dated lake-sediment cores from The Bowl and Lake Wood (N. Drake, unpublished data). These analyses provided a regional context within which the more localized Cadillac Mtn. and Whalesback vegetation histories could be placed.

CHAPTER V

RESULTS

Characterization of Modern Stands

Species characteristics calculated from the PCQM transects of Cadillac Mtn. and Whalesback (Tables 1A and 1B, respectively), show that the overstory of both stands is dominated by jack pine, which has a frequency of occurrence >90%. The basal area and density of jack pine ($4.35 m^2$ /ha and 491 stems/ha respectively) at Cadillac Mtn. are considerably lower than at Whalesback ($15.91 m^2$ /ha and 1806 stems/ha). These values are consistent with the open nature of the Cadillac stand as previously described by Conkey et al. (1991) and Patterson (1988). At Cadillac other tree species have considerably lower densities and basal areas including grey birch (80 stems/ha & $0.11 m^2$/ha) and red spruce (32 stems/ha & $0.22\ m^2$/ha). The remaining species - northern white cedar, mountain holly, white pine, balsam fir and black spruce - all have importance values of 10 or less and are minor components of the stand. At Whalesback the basal area and density of jack pine are a degree of magnitude greater than for competing species of which red spruce and red oak are the most prominent, with importance values of 23 and 19 respectively.

Crown closure measurements taken at point centers during PCQM stand characterization (Table 2) provide further evidence of the differences between the Whalesback and Cadillac Mtn. stands. The mean crown closure at Whalesback (63%) is considerably higher than at Cadillac Mtn. (39.7%). These readings are consistent with the PCQM data, which identify Whalesback as a denser stand (Table 1). These figures are also consistent with Conkey et al.'s (1991) tree age estimates, which identify Cadillac Mtn. as an older stand that has undergone age-dependent thinning. However, they are mainly correlated with the greater proportion of exposed bedrock that is found at Cadillac Mtn.

Table 1. Characteristics of Cadillac Mtn. and Whalesback jack pine stands from point-centered quarter method data.

A. Cadillac Mtn.

Species	Density (#stems/ha)	Dominance (m^2 / ha)	% Frequency of Occurrence	Importance Value
Pinus banksiana	491	4.35	90.48	212.16
Betula populifolia	80	0.11	33.33	32.95
Picea rubens	32	0.22	14.29	17.47
Thuja occidentalis	16	0.13	9.52	10.41
Ilex montana	24	0.02	9.52	9.31
Pinus strobus	16	0.08	9.52	9.38
Abies balsamea	8	0.02	4.76	4.38
Picea mariana	8	0.01	4.76	4.02

B. Whalesback

Species	Density (#stems/ha)	Dominance (m^2 / ha)	% Frequency of Occurrence	Importance Value
Pinus banksiana	1806	15.91	94.74	219.34
Picea rubens	151	1.09	17.54	23.06
Quercus rubra	101	0.92	15.79	18.89
Acer rubrum	80	0.35	14.04	14.00
Pinus resinosa	60	0.98	8.77	13.11
Betula populifolia	80	0.09	8.77	9.38
Picea glauca	9	0.13	1.75	2.11

Table 2. Estimates of mean crown closure within the Cadillac Mtn. and Whalesback jack pine stands.

	Site	
	Cadillac Mtn	Whalesback
Number of readings	21	57
Mean crown closure	39.7%	63%

Estimates of species cover on and within 10m of the pollen-deposition basins at Cadillac Mtn. and Whalesback (Table 3) shows that jack pine is a major component of the stand in the immediate vicinity of these basins, with cover values of 60% at Cadillac and 80% at Whalesback. Other tree species represent 10% or less of the cover within 10m of the basins, although at Cadillac Mtn. grey birch has a 15% cover on the basin itself. The shrub layer surrounding both sites is dominated by ericaceous species. *Gaylussacia baccata* dominates at Whalesback (80% cover compared to 40% at Cadillac Mtn) where as at Cadillac *Kalmia angustifolia* (45%) and *Vaccinium myrteloides* (35%) are also abundant (5% and 10% of the cover at Whalesback). The flora around the Cadillac Mtn. wetland is considerably richer in species diversity than Whalesback. The species cover on the basin itself is also more varied at Cadillac where tree species such as jack pine, grey birch and red spruce occupy elevated sites within the bog. Wetland shrubs such as *Nemopanthus mucronata, Myrica gale* and *Ilex verticillata* occupy moist sites around and within the Cadillac wetland. At Whalesback the wetland vegetation is restricted to *Sphagnum, Carex* and *Polytrichum* which form 70%, 17% and 15% of the cover respectively. The proportion of these species is lower at Cadillac where *Sphagnum* has only 40% cover. Open water occupies over 45% of the basin at Cadillac.

The proportion of serotinous vs. non-serotinous cones on jack pines sampled during the PCQM stand characterizations (Table 4) is similar for the two stands - 0.13 for Cadillac Mtn. and 0.285 for Whalesback.

These data indicate that in the absence of fire there is abundant seed available for regeneration in both stands. The mean number of cones per tree identifies Cadillac Mtn. jack pines as bearing a considerably greater number of cones. This difference between the stands is consistent with the observations that Cadillac Mtn.

Table 3. Species percent cover on and within 10m of Cadillac Mtn. and Whalesback pollen deposition basins.

Species	(CAD) % cover within 10m	(WHB) % cover within 10m	(CAD) % cover on basin	(WHB) % cover on basin
Pinus banksiana	60	60	15	3
Kalmia angustifolia	45	5	20	7
Gaylussacia baccata	40	80	10	2
Vaccinium myrteloides	35	10	25	--
Bare rock	15	15	2	--
Picea rubens	10	<1	5	--
Betula populifolia	10	5	15	--
Rhododendron viscosum	10	--	15	--
Danthonia sp.	10	--	--	--
Picea mariana	7	--	--	--
Nemopanthus mucronata	5	--	20	--
Viburnum cassinoides	4	--	5	--
Pteridium aquilinum	4	--	--	--
Thuja occidentalis	3	--	3	--
Amelanchier sp.	3	<1	2	--
Juniperus communis	3	--	--	--
Aronia arbutifolia	3	--	--	--
Sorbus americana	2	--	--	--
Acer pennsylvanicum	2	--	--	--
Spirea latifolia	1	--	--	--
Lycopodium sp.	1	--	--	--
Maianthemum canadens	1	--	--	--
Trientalis borealis	1	--	--	--
Cladonia sp.	--	20	--	--
Corema conradii	--	<1	--	--
Gramineae sp.	--	<1	--	--
Lotus corniculatus	--	<1	--	--
Open water	--	--	45	--
Sphagnum spp.	--	--	40	70
Juncus sp.	--	--	35	--
Myrica gale	--	--	35	--
Carex sp.	--	--	15	17
Polytrichum sp.	--	--	15	15
Chamaedaphne calyculata	--	--	7	--
Ilex verticillata	--	--	5	--

Table 4. Serotinous versus non-serotinous cones on jack pines sampled during PCQM stand characterizations.

	Site	
	Cadillac Mtn.	Whalesback
Number of jack pine trees sampled	61	180
Mean number of serotinous cones per tree	11	6
Mean number of non-serotinous cones per tree	75	14
Serotinous cones as a percent of all cones	13%	28.5%

is an older, more open-grown stand containing larger jack pines with more cones. The older trees will tend to bear more cones as each year's production remains in the canopy although competition from adjacent trees limits cone production on supressed individuals.

Soil depth measurements taken at point centers during PCQM stand characterizations (Table 5) identify a marked dissimilarity between the two stands. Although the frequency of bare rock encountered in each stand is comparable, 9.5% for Cadillac and 7% for Whalesback, the percentage of sites characterized by shallow (<3") as opposed to deep (>3") organic soil at Cadillac is less than half of that at Whalesback (28.5% vs. 66.7%). The low percentage of shallow soil sites at Cadillac does not necessarily represent the stand as a whole. Conkey et al. (1991) found a much higher frequency of 'poor sites' [characterized by a shallow or absent organic layer] in three transects spread through a greater proportion of the Cadillac stand. Therefore, the low proportion found in this study is probably not representative due to a small sample size (21) and the fact that some points occurred within another wetland near the pollen-deposition basin. The proportion of sites characterized by shallow organic soil at Whalesback (66.7%) is closer to Conkey et al.'s estimates for Cadillac.

Jack pine seedling density at Cadillac (Table 6) is seven times that of Whalesback.

Paleoecological Studies

Identification of Diploxylon Pollen

The results of the pine reference pollen grain width measurements are shown in Figure 5 in the form of box plots. These plots describe the mean, standard deviation, percentiles and range of the combined measurements from the five samples taken from each jack pine site as well as the five red pine and five pitch pine

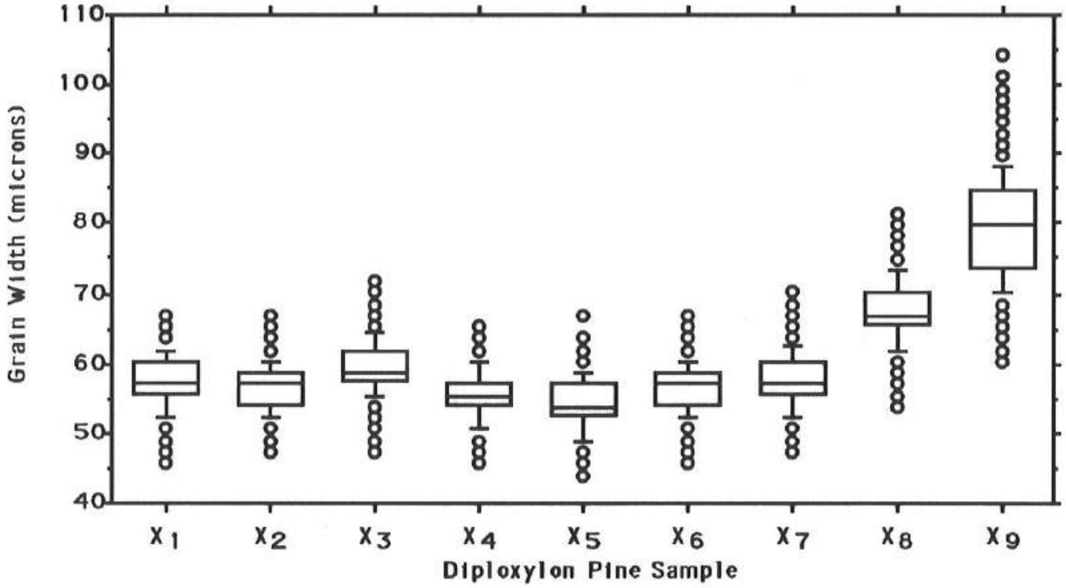
Table 5. Soil depth characterizations at point centers during the PCQM stand characterizations.

	Site	
	Cadillac Mtn.	Whalesback
Percentage of sites characterized by bare rock	9.5%	7.0%
Percentage of sites characterized by shallow organic soil (<3")	28.6%	66.7%
Percentage of sites characterized by deeper organic soil (≥3")	61.9%	26.3%

Table 6. Jack pine seedling density on fixed-radius plots sampled around point centers during PCQM stand characterizations.

	Site	
	Cadillac Mtn	Whalesback
Number of plots	21	57
Total number of seedlings	115	44
Mean seedling density (/100m^2)	6.97	0.98

Circles represent width range , not individual grains.



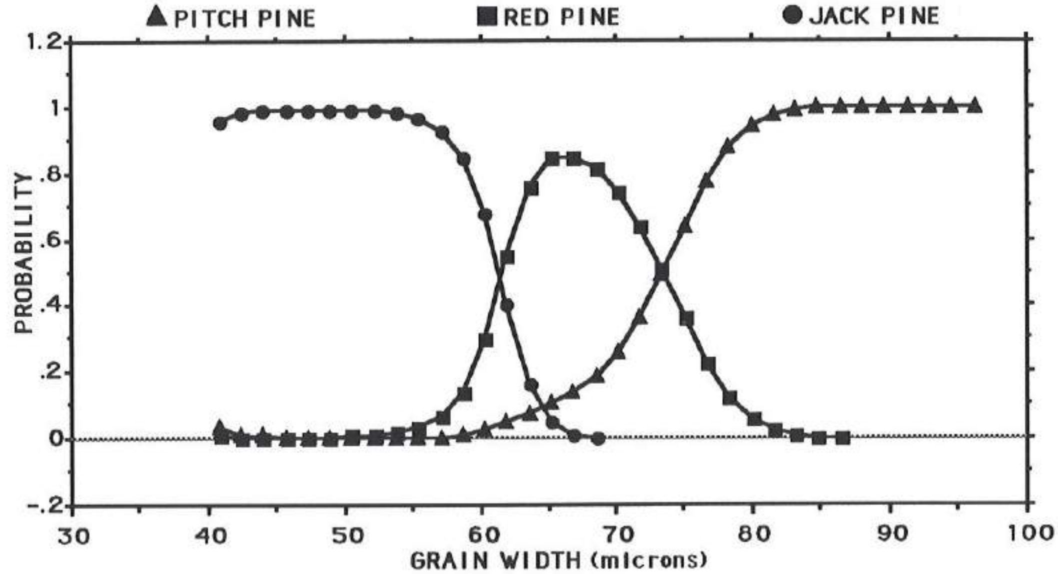
Jack Pine :	Eagle Lake Road	X1	Red Pine	X8
	Whalesback	X2	Pitch Pine	X9
	Schoodic Head	X3		
	Norumbega	X4		
	The Tarn	X5		
	N.P.S. Headquarters	X6		
	Cadillac Mtn.	X7		

Figure 5. Pine reference pollen measurements from seven jack pine sites, red pine and pitch pine on Mt. Desert Island.

samples. The distributions of grain widths for each species overlap by varying amounts, but jack pine grains are generally significantly smaller than the other two pine types. A data base of the Cadillac Mtn. jack pine pollen and the red pine and pitch pine pollen grain measurements was then used in a discriminant analysis to produce classification criteria for the fossil diploxylon pine pollen grains in the core. Another data base with the Whalesback jack pine measurements replacing those from Cadillac was analyzed using the same procedure. The criteria were graphed in the form of probability curves for each pine species (Figure 6). The points where these probability curves intersect indicate the grain widths at which the likelyhood of the grain's provenance changes from one species to another. However, the greatest prospect of accurate identification is to be found some widths away from these intersections, where the probability curves of jack pine and pitch pine reach one.

The intersections of the probability curves produced by the discriminant analysis correspond closely to grain widths used by Winkler (1984) to differentiate jack pine from pitch pine. The grain widths of 62.5μm and 73μm at which the curves intersect are plotted on Figures 7 & 8 with the distributions of diploxylon pine pollen grain widths from selected levels in the Cadillac Mtn. and Whalesback cores respectively. The results indicate that most of the pine pollen grains from the two sediment cores are likely of jack pine. A few grains fall into the red pine or pitch pine categories, but most suggest jack pine is the diploxylon pine pollen represented throughout these cores.

CADILLAC MTN.



WHALESBACK

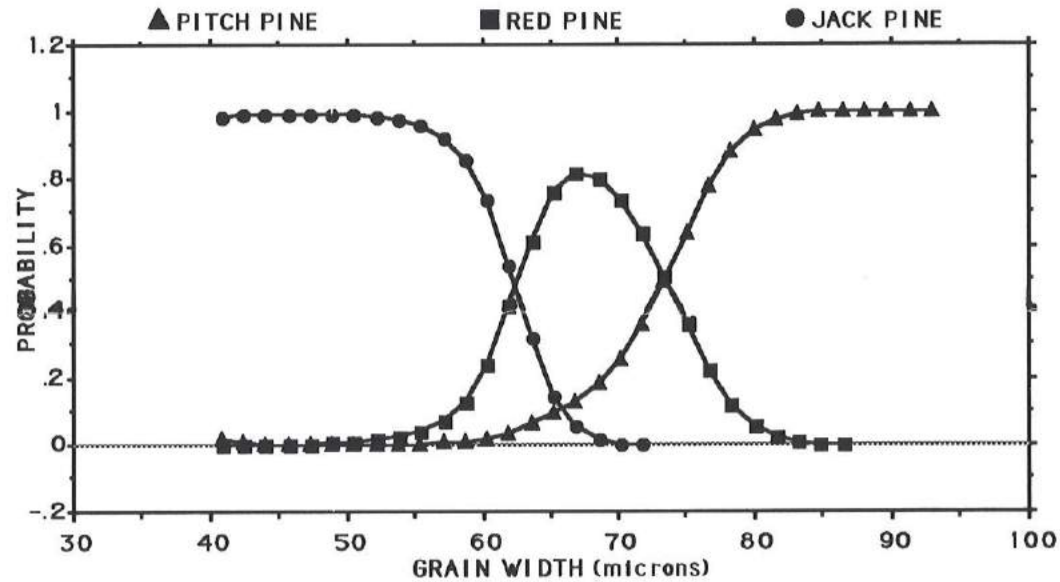


Figure 6. Probability curves, produced by discriminant analyses, used differentiate diploxylon pine pollen types.

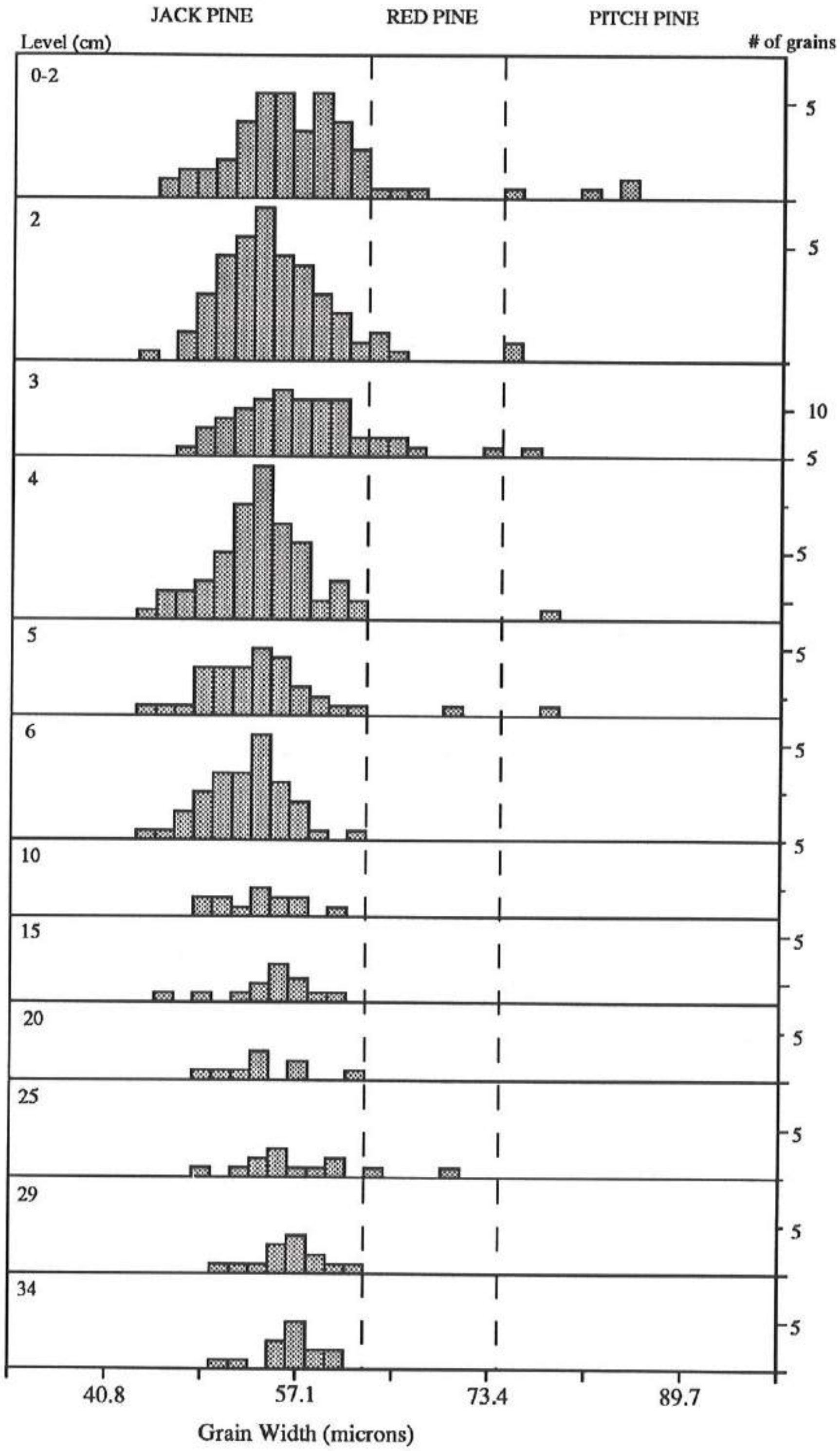


Figure 7. Distribution among species of fossil diploxylon pollen grains from the Cadillac Mtn. sediment samples based on discriminant analysis probabilities.

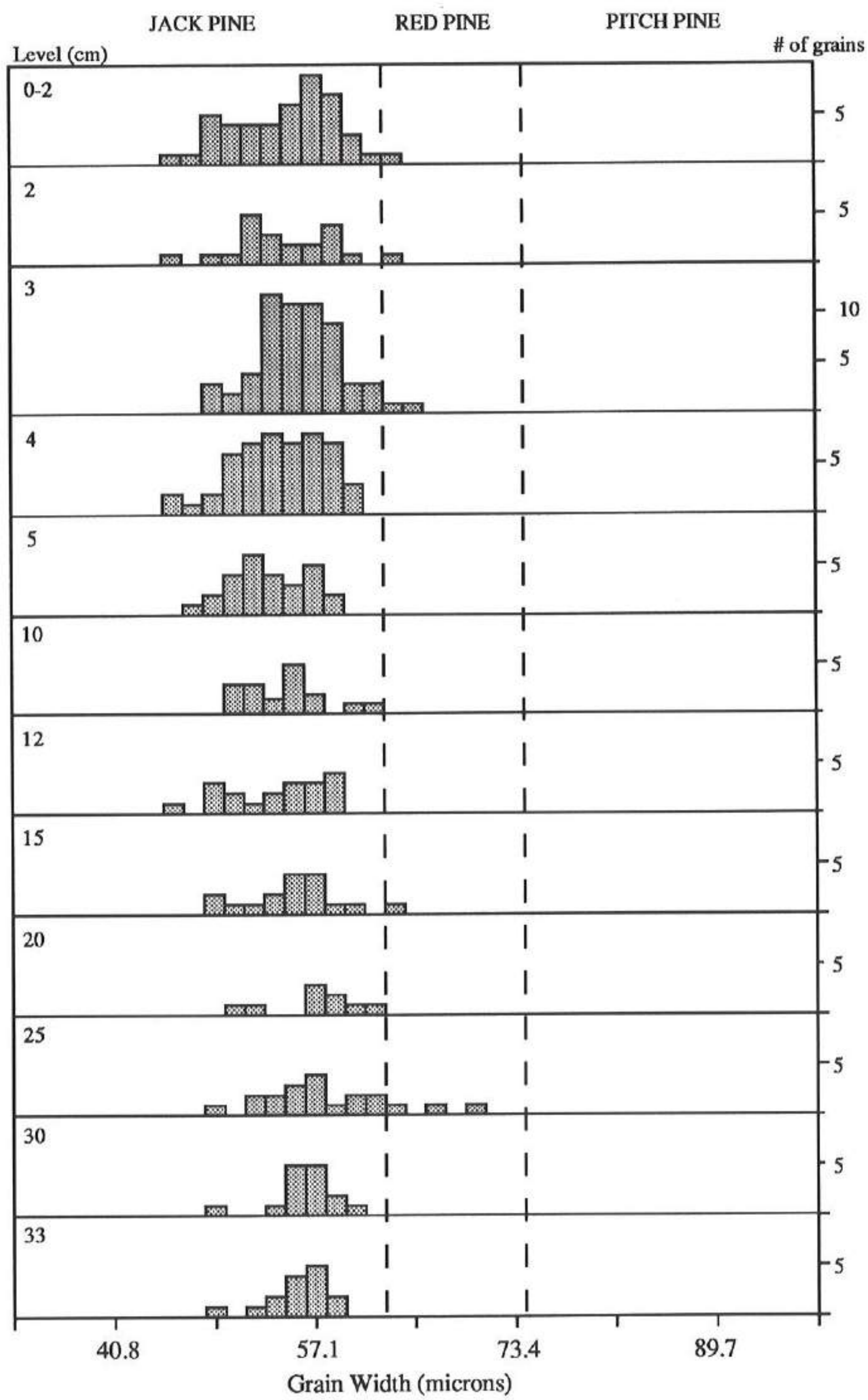


Figure 8. Distribution among species of fossil diploxylon pollen grains from the Whalesback sediment samples based on discriminant analysis probabilities.

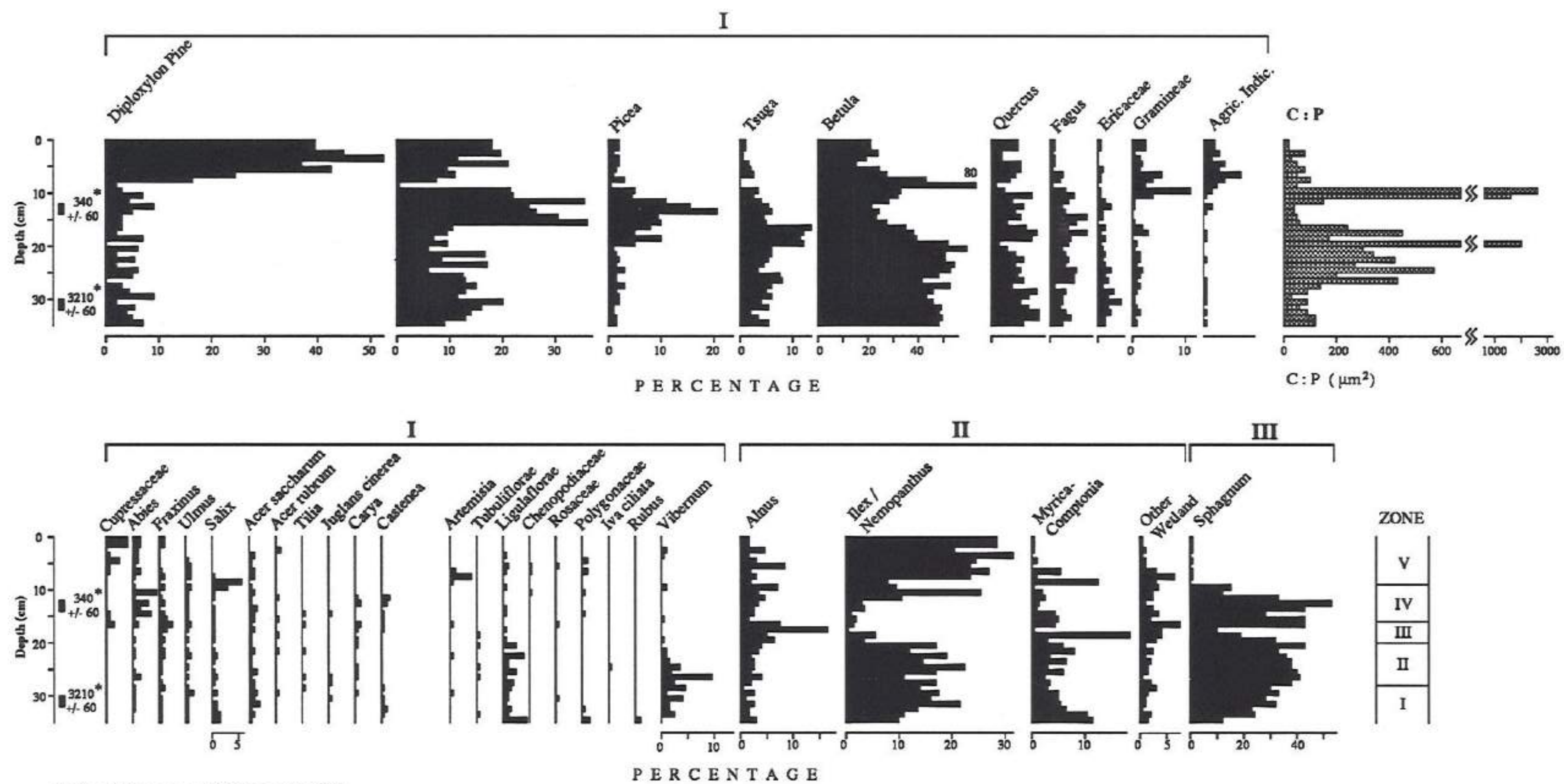
Cadillac Mtn.

Core Chronology

The Cadillac Mtn. core represents approximately the last 3500 years (Figure 9). The level 30-32cm near the base of the core was dated by ^{14}C analysis at 3210 +/- 60 years BP (Beta-51801). The level 12-14cm dates to 340 +/- 60 years BP (Beta-51800). At 19cm there is a visible charcoal layer and a corresponding peak in microscopic charcoal. Such charcoal layers are evidence of fires burning over the peat itself [into the bog] (Tolonen & Tolonen 1984, Wein et al. 1986) during periods of drought. This indicates that the sediment core may be truncated and that the fossil record is not continuous between 3210 and 340 years B.P.

The ^{14}C date for the 12-14cm level does not correspond well with the agricultural indicator pollen percentages which increase at the same time. These indicators, *Ambrosia, Rumex* and *Plantago*, show a slight increase in levels 12 & 13cm. This may represent settlement in southern New England during the 17^{th} century - well before settlement began at Somesville on Mt. Desert Island in 1760 A.D. Another on-bog fire, indicated by a charcoal layer at 9-11cm, occurs during the increases in these indicator pollen percentages. This fire is the most recent in the fossil charcoal record and probably dates to the 1890's when several fires burned portions of Cadillac Mtn. (Moore & Taylor 1927). The proximity of the charcoal layer to the rise in agricultural indicators, which document an event that occurred over 130 years earlier, suggests removal of peat by this fire.

Fossil pollen and microscopic charcoal in the upper 8cm of peat represent changes in vegetation over the past ~100 years.



* Years before present (B.P.) dated by ^{14}C.

I Calculated as a percentage of total upland pollen.

II Calculated as a percentage of total pollen and spores, excluding sphagnum.

III Calculated as a percentage of total pollen and spores.

Figure 9. Pollen diagram from Cadillac Mtn. identifying fossil pollen percentages and microscopic charcoal:pollen ratios.

Vegetation History

The results of the Cadillac Mtn. fossil pollen analysis are presented as a pollen percentage diagram (Figure 9). Separate pollen sums were used for the upland taxa, wetland taxa and *Sphagnum* spp. in order to accentuate changes in relative pollen percentages within each group and reduce the effect of large quantities of wetland pollen and spores on the relative proportion of pollen from other taxa. The pollen diagram has been divided into five pollen assemblage zones based on the major groupings of plots identified using a FORTRAN program for stratigraphically constrained cluster analysis (CONISS, E.C. Grimm, University of Minnesota).

Zone I: This zone includes the basal seven centimeters of the core (from 34-28cm). The absence of a visible charcoal layer and low C:P values at the base of the core may indicate that the bottom-most sediments are considerably older than the ^{14}C date of 3210 +/- 60 B.P. for the 30-32cm segment. Basal sediments of peat bogs often contain abundant charcoal from fires that burned out all organic material from a basin at some point in time, but that does not appear to be the case in this instance. The basal peaks in the herbaceous pollen types - *Liguliflorae, Polygonaceae* and *Rosaceae* - may date to a much older period of more open conditions at the site.

The zone is dominated by *Betula* pollen percentages which remain at or near 50%. Other arboreal taxa include *Pinus strobus* (20%), *Quercus* (9%), *Acer saccharum* (3%), and*Tsuga,* which fluctuates around 5%, plus *Fagus, Picea* and other less-well-represented taxa. *Diploxylon* pine pollen values remain low, fluctuating between 2 and 9%. The presence of a number of *Castanea* grains must be the result of long distance pollen dispersal as the species never reached Mount Desert Island and arrived in southwestern New England only ~2000 BP (Davis 1981). Similar occurrences of *Castenea* pollen have been found at sites even further north (Mott 1975), and long-distance dispersal has been shown to contribute relatively large proportions of pollen especially at exposed sites (Richie & Lichti-Federovich 1966).

Within Zone I there is a large proportion of pollen from shrubs indicative of wetland communities. *Vibernum cassinoides* reaches 5% and *Ilex/Nemopanthus* increases from 10% to 20% before decreasing slightly. *Myrica/Comptonia* pollen is as high as 10% at the base of the core but decreases throughout the zone to less than 5%. Other shrubs indicative of wetland communities increase in representation. These changes coincide with a steady rise within the zone in the percentages of *Sphagnum* spores, indicating growth and development of the bog, and certain associated wetland species.

Zone II: This zone extends from 28-20 cm in the core. In this zone *Betula* percentages consistently exceed 50%, whereas *Pinus strobus* fluctuates between 6-16%. *Tsuga* values peak at 9% then drop before slowly increasing again; *Quercus* decreases throughout the zone; and *Fagus* increases but not above 5%. *Diploxylon* pine percentages remain low, not exceeding 5%.

Ilex/Nemopanthus values remain high at ~20%, whereas *Viburnum* peaks at 10% then falls away to insignificant values throughout the rest of the core. Large numbers of *Sphagnum* spores are present throughout this zone, and there is also a peak in *Liguliflorae* and a subtle rise in *Gramineae,* which may indicate disturbance around the pollen deposition basin associated with the peaks in microscopic charcoal.

Zone III: This zone extends from 20-16 cm in the core and depicts a dramatic change in both the composition of the surrounding woodland and of the vegetation on and around the pollen deposition basin. *Betula* drops from 50%, at the base of section III, to 25% at the top. *Picea* and *Tsuga* pollen percentages increase from 2% and 7% to 10% and 13%, respectively. *Quercus* recovers to Zone-I values and *Fagus* peaks at 7%. *Diploxylon* pine pollen becomes even less important dropping to below 5% and *Pinus strobus* drops to 10%. Dramatic changes are also identified in the shrub pollen with *Alnus* and *Myrica/Comptonia* reaching 15% or more. At the same time, *Ilex/Nemopanthus* values drop to very low levels as do *Sphagnum* spore percentages. All of these changes suggest a dramatic shift in the composition of the wetland community.

Zone IV: This zone extends from 16-10 cm in the core. The most distinctive feature of the zone is a sharp increase in *Pinus strobus* percentages from 10% to 36%. *Picea* values also increase dramatically, reaching 20% by the middle of the zone but then falling to 5% at the top. Both *Tsuga* and *Quercus* fall from peaks in Zone-III to lower levels. *Betula* values continue falling, reaching a low of 20% before recovering gradually. A number of other arboreal taxa are well represented in this zone (e.g. *Cupressaceae, Abies & Fraxinus*) with still others present in trace amounts (e.g.*Tilia, Juglans, Carya, & Castanea*). *Diploxylon* pine pollen occurs at very low percentages throughout much of this zone although there are small peaks towards the top.

Sphagnum percentages recover to Zone-II values at the base of this zone, increasing to 53% - the maximum levels for the core - before declining sharply. *Alnus* and *Ilex/Nemopanthus* increase throughout the zone reaching 7% and 25% respectively. A short period of increased agricultural indicator pollen, indicative of disturbance associated with European settlement, occurs near the top of this zone. These percentages subsequently decrease and another disturbance indicator - *Gramineae* - increases from 1% to 12%.

Zone V: This zone represents the upper 10 cm of the core. It is characterized by a rise to dominance of *Diploxylon* pine pollen, which increases to a maximum of ~50% of the total upland pollen, a considerable shift from all the other zones where it remained below 10%. *Pinus strobus* pollen also increases but does not exceed 20%, whereas *Picea, Tsuga* and *Fagus* all decline to less than 5%. *Betula* also decreases and remains at ~20%, its lowest value in the core . *Cupressaceae* and *Abies* show a slight increase during this period reaching 5% and 2% respectively at the top of the core.

Among the shrub genera *Ilex/Nemopanthus* dominates with values of up to 30%. At the same time *Sphagnum* spores virtually disappear, indicating a dramatic change in the size or water relations of the wetland. Other wetland pollen (mainly *Cyperaceae*) show an increase at the base of the zone, but they, too, drop to low levels near the top. Another significant change that occurs in Zone V is the appearance of large quantities of agricultural indicators - including *Ambrosia, Rumex* and *Plantago* - indicative of the period since European settlement. *Gramineae* values increase perhaps indicating an opening of the surrounding landscape.

Charcoal Analysis

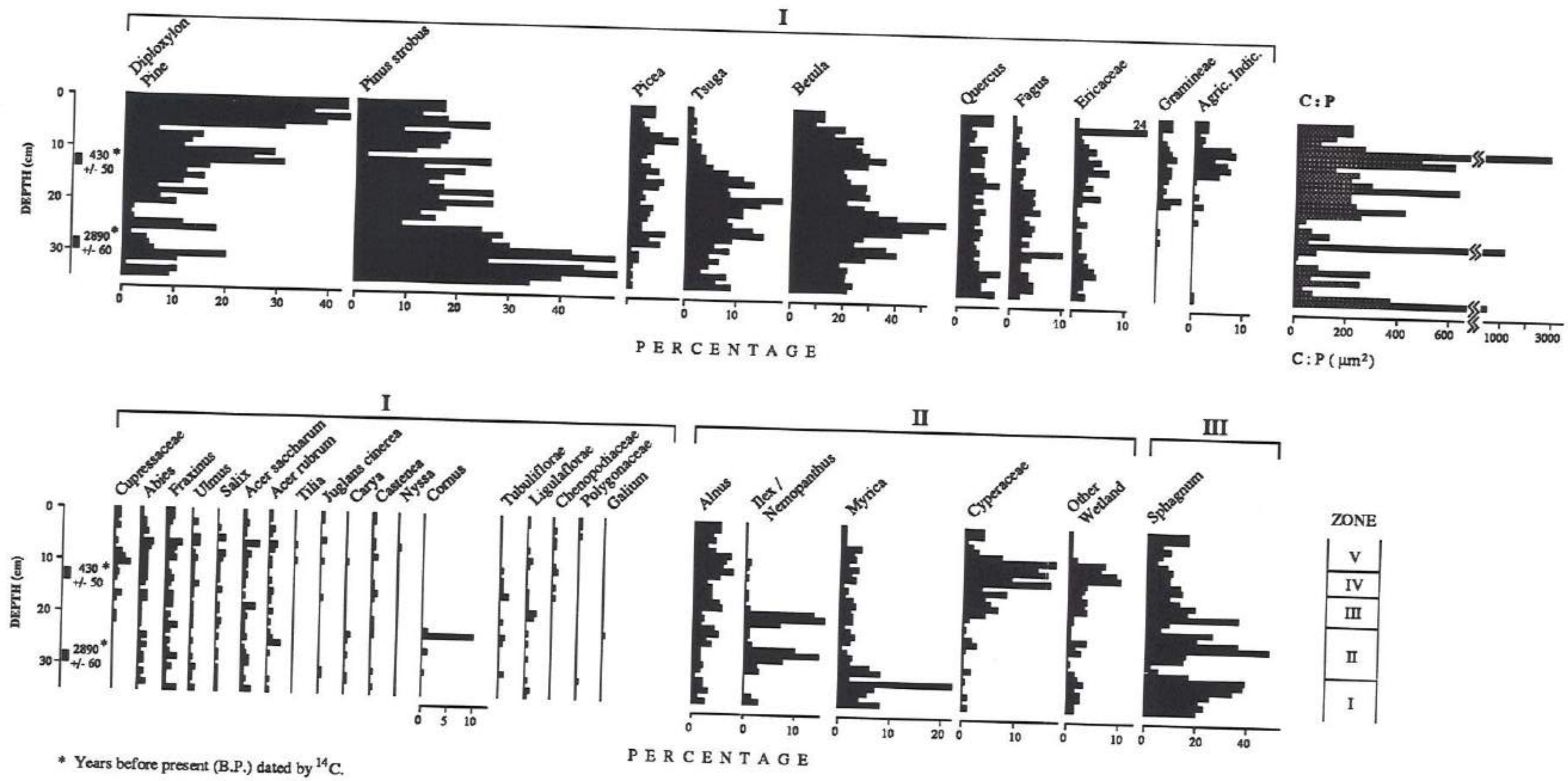
Microscopic charcoal (Figure 9) provides evidence of a period of high presettlement fire activity between 16cm and 27cm which is equivalent to pollen assemblage Zones II and III. There are numerous charcoal peaks interspersed with elevated charcoal concentrations. The peak at 19cm has a particularly high C:P ratio (~2000μm^2/grain) and corresponds with a visible charcoal layer in the core indicating that this fire probably burned over the wetland itself. Another visible charcoal layer between 9 and 11cm and the associated peak in microscopic charcoal identify a postsettlement fire that probably occurred in the 1890's. Above this charcoal horizon microscopic charcoal levels remain low indicating little fire activity around the basin after this event.

In order to discuss the results of the fossil pollen and microscopic charcoal analyses of the Cadillac Mtn. core it is necessary to understand some of the particular factors that affect sediment accumulation in shallow, peat-filled basins. The presence of visible charcoal layers within the core indicate that the site has probably been burnt over more than once. Similar charcoal bands have been noted in a number of other peat profiles (e.g. Tolonen & Tolonen 1984; Wein et al. 1986). These bands provide proof of fire occurrence that may also be identified in the microscopic analyses, but the source of the latter is more difficult to interpret (MacDonald et al. 1991, Clark 1988a, Patterson et al. 1987). Charcoal layers also mean that part of the peat sediment may have been consumed. As the depth of sediment consumed is unknown, these disturbances in the core create gaps in the chronology of vegetation changes identified by the fossil pollen. These fire episodes also alter the sediment accumulation of the site, removing the upper layers of sphagnum peat and with them part of the paleovegetational record. In the years following the fire there also tends to be an increase in sedimentation rates as exposed mineral and organic material is washed into the site particularly with these dry and shallow organic soils of rock outcrops (Clayden & Bouchard 1983).

Whalesback

Core Chronology

The Whalesback core represents approximately the last 3000 years (Figure 10). The level 28-30cm near the base of the core was dated by ^{14}C analysis at 2890 +/- 60 years BP (Beta-51803). The level 12-14cm represents 430 +/- 50 years BP (Beta-51802). A basal charcoal layer suggests that the bottom-most sediments may



* Years before present (B.P.) dated by ^{14}C.

I Calculated as a percentage of total upland pollen.
II Calculated as a percentage of total pollen and spores, excluding sphagnum.
III Calculated as a percentage of total pollen and spores.

Figure 10. Pollen diagram from Whalesback identifying fossil pollen percentages and microscopic charcoal:pollen ratios.

not be much older than the 28-30cm ^{14}C date. The rise in spruce pollen at 26cm and subsequent charcoal peak are comparable to a similar series of events documented at Lake Wood which occur around 2000 BP (N. Drake unpublished data). The analyses from this nearby lake sediment core also identify increased levels of microscopic charcoal and grass pollen above a ^{14}C date of 910 BP. These changes are comparable with the 17cm level in the Whalesback core. Sediment mixing of large quantities of charcoal may be the reason for the younger ^{14}C date of 430 BP. The dated level of 12-14cm is too old given its proximity to the rise in agricultural indicators that occurs at 10cm and presumably represents ca. 1760 A.D. The largest charcoal peak near the top of the sediment core can be attributed to the 1947 fire, which is the most recent to burn over this area.

Vegetation History

The results of the Whalesback fossil pollen analysis are presented as a pollen percentage diagram. A separate pollen sum was used for the upland taxa, wetland taxa and *Sphagnum* spp. in order to accentuate changes in relative pollen percentages within each group and reduce the effect of large quantities of wetland pollen and spores on the relative proportion of pollen from other taxa. The pollen diagram has been divided into five pollen assemblage zones based on the major groupings of plots identified using the CONISS program.

Zone I: This zone includes the basal eight centimeters of the core (from 34-27 cm). The zone is dominated by *Pinus strobus* with up to 50% of the total upland pollen. *Diploxylon* pine is less prevalent with values of 10-20%. *Betula* consistently makes up 20% of the total upland pollen which is a relatively low value due to the presence of other high pollen producers (e.g. *Pinus strobus*). Other arboreal genera such as *Tsuga, Fagus, Quercus* and *Acer saccharum* are 5%, 3%, 4% and 2% respectively, whereas *Abies, Fraxinus* and *Ulmus* are present at lower values.

An increase in *Sphagnum* spores from 20% to 40% together with peaks in *Myrica* (up to 20%) and other wetland pollen types suggests expansion of the bog throughout the zone.

Zone II: This zone extends from 27 cm to 18 cm in the core. At the boundary between Zones I and II *Picea* pollen percentages increase from 1% to 5% and thereafter remain consistently higher than in Zone I. *Tsuga* also increases to a peak of 15% and, after a slight decrease, peaks again at 19% at the top of the zone. There are also peaks in *Betula,* which peaks at 40% and then 60%, and *Diploxylon* pine to 20%, respectively. *Quercus* and *Fagus* remain consistently at 3% except for a single peak of the latter to 10% at the onset of this zone.

A regional shift in forest composition to increased representation of spruce and fir identified in lake sediment pollen analyses (N.Drake, unpublished data) has been associated with a cooler, moister climate over the past 2000 yrs. The noticeable increase in spruce pollen, which is sustained throughout the upper zones of the core and is dated sometime before 2890 B.P., fits in well with this regional picture. Local conditions during Zone II fluctuate dramatically between reduced *Sphagnum* percentages indicating a drying or shrinking of the wetland and sharp peaks in *Ilex/Nemopanthus* to 13%, which may indicate increased light levels at the site.

Zone III: This zone extends from 18cm to 12cm in the core. *Diploxylon* pine increases from 10-30% while *Pinus strobus* fluctuates between 15% and 25%. *Tsuga* and *Betula* decrease from 14-4% and 30-20% respectively. *Picea* increases slightly to around 5%; *Quercus* remains generally stable at 4%; and *Fagus* drops from 4 to 2% and remains at reduced levels throughout the rest of the core. A sharp increase in *Alnus* from 2 to 5% and *Gramineae* from 0 to 4% at the bottom of this zone may be associated with elevated microscopic charcoal levels that appear at this time.

Wetland indicators also increase during Zone III, with *Cyperaceae* rising from 1 to 10% *Sphagnum* declines from 40 to 15% and remains low to the top of the core.

Zone IV: This zone extends from 6 to 11cm in the core. A sharp increase in agricultural indicators (mostly *Ambrosia*) to 6% together with a smaller rise in the abundance of grass pollen indicate that Zone IV marks the time of European settlement and associated land clearances (ca. 1760 A.D.). *Diploxylon* pine drops sharply from 30% to less than 10%, while *Pinus strobus* remains at around 15%. Other tree species such as *Picea* and *Acer saccharum* reach their highest levels in the core. This is also true for *Cupressaceae, Abies, Fraxinus* and *Ulmus* and trace percentages of *Tilia, Juglans, Carya,* and*Castenea* also appear during this zone.

The wetland itself continues to change during Zone IV as percentages of *Cyperaceae* and other wetland types increase, while *Sphagnum* continues to decline. This shift from moss to sedge dominated bog may be related to the repeated fires in the area or other factors that have resulted in altered water relations and light conditions.

Zone V: This zone extends through the top 5cm of the core. The boundary between this zone and the preceding one is marked by the largest peak in microscopic charcoal values (Ch:P = ~3000) representing the 1947 Bar Harbor Fire. As with other peat fires at Whalesback and also Cadillac, the sample level immediately above the charcoal horizon shows sharp changes in the percentages of various pollen types compared to those in the level preceding the fire. The most noticeable of these changes in the Whalesback core is the rise to dominance of jack pine. Jack pine percentages rise to over 40% and remain at these levels to the present, as identified by the surface sample at 0-2 cm. *Pinus strobus* values remain relatively stable at around 20% during this zone. Other tree genera exhibit reduced pollen percentages, partly a result of the increased proportion of *Diploxylon* pine. However, percentages of most arboreal pollen types do demonstrate recovery to previous values in the top-most sample.

The peak of 24% in *Ericaceae* pollen which occurs at 2cm is probably due to the deposition of a whole flower or flowers of one of the many ericaceous shrubs directly into the bog. Other shrubs such as *Alnus* and *Myrica* decline in representation during Zone V as do a number of wetland genera. *Ilex-Nemopanthus* pollen disappears completely. *Sphagnum* once again dominates the local pollen.

Charcoal Analysis

Unlike the Cadillac Mtn. core, the Whalesback core has a charcoal layer at its base and an associated peak in microscopic charcoal. This basal charcoal layer indicates that a peat fire consumed much of the organic sediment that had previously been deposited at this site. Subsequent smaller charcoal peaks during the basal pollen assemblage zone may be due to deposition of airborne charcoal from fires possibly some distance from the deposition basin or washed in from local sources. A large charcoal peak occurs at 23cm and follows a rise in *Picea* pollen percentages. There is also a very high peak in *Betula* pollen following this charcoal level which suggests that the fire was large enough to affect the extra-local vegetation. These events coincide with a period of increased *Picea* and *Cupressaceae* pollen and fire occurrence identified in lake sediments from nearby Lake Wood (N. Drake unpublished data).

At 17cm the abundance of microscopic charcoal increase and remain high throughout the upper half of the core.

CHAPTER VI

DISCUSSION

Modern Stand Dynamics

The Point-Centered Quarter Method data characterize the jack pine stands at Cadillac Mtn. and Whalesback as being at quite different stages in their development. These differences in the present stands can be related to their recent histories; Whalesback burned during the 1947 fire whereas Cadillac Mtn. did not. Therefore the dense young stand at Whalesback is the product of regeneration on the site after the fire. There seems to be very little recent regeneration in the stand due to the lack of suitable substrate and shading from the recently established stand. The Cadillac Mtn. stand has not been burned since the late 1800's, as evidenced by the presence of several jack pines ~90 years old (Conkey et al. 1991). The stand has a lower density of jack pine with 491 stems/ha compared to 1806 stems/ha at Whalesback. This difference may be partly a function of age-dependent thinning occurring at Cadillac Mtn. but is more probably due to a greater proportion of exposed bedrock within this stand. The more open nature of the Cadillac stand is reflected in the lower mean crown closure of 39.7% vs. 63% for Whalesback. The greater availability of light at Cadillac Mtn. must be a significant factor in the establishment of shade-intolerant jack pine seedlings. Evidence for this hypothesis lies in a comparison of the seedling densities of the two stands; 6.97/100m^2 at Cadillac Mtn., and 0.98/100m^2 at Whalesback. Available substrate is also necessary for regeneration but does not seem to be the determining factor in these cases. Soil depth data for the two sites indicate that Whalesback has a high percentage of sample points characterized as shallow organic soil which is more conducive to jack pine establishment. Density, dominance and percent frequency of occurrence data for other tree species indicate that there are few competitors with the jack pine at these sites. At Whalesback the central portion of the stand occupying a knoll of often-exposed bedrock is dominated exclusively by jack pine. It is only in the peripheral sample points of the PCQM transects that a few, small red spruce, red pine and other species are found. A similar lack of associated tree species is identified by the PCQM analysis of Cadillac Mtn., but this study only covered the part of the jack pine stand closest to the pollen deposition basin. Conkey et al.'s (1991) transects through other parts of the Cadillac stand found mixtures of pitch pine and red spruce in some sections. A similar conclusion was reached, however; i.e. that Cadillac is an unevenaged stand of low density and dominated by jack pine.

In addition to the PCQM analyses for Cadillac Mtn. and Whalesback, stem maps of other Mount Desert Island jack pine stands were examined to compare competition between jack pine and other tree species at different sites. Competition indices calculated from these stem maps (Table 7) identify low levels of competition for jack pine on sites characterized both by deeper mineral soil - Whalesback (mineral soil) and The Tarn - and sites characterized by exposed bedrock - Norumbega and Whalesback (bare rock). The Norumbega jack pine stand is somewhat different in that there is a codominant population of pitch pine of greater basal area at the same site (Table 8). Pitch pine on this site occupy the same niche as the jack pine and compete with it as evidenced by the higher competition index - 4.7 for Norumbega compared with 0 for Whalesback (bare rock). The low competition indices of the mineral soil stands at Whalesback and The Tarn are the result of quite different conditions. At these sites, both of which were burned over by the 1947 fire, the dominant jack pines must have become established soon after the fire. However, unlike the situation on the exposed bedrock sites, the presence of deeper mineral soil was conducive to the establishment of shade tolerant species such as red oak, red maple and grey and paper birch (Table 8). Therefore, although the jack

Table 7. Competition indices calculated from stand maps of the jack pine stands at Norumbega Mtn., The Tarn and Whalesback .

	Site			
Mean Competition Index (CI)	Norumbega Mtn.	The Tarn	Whalesback (bare rock)	Whalesback (mineral soil)
Jack Pine	4.729	0.941	0	1.82

pines are dominant in crown class and basal area they are scattered throughout a subdominant population of these other species. The competitive pressure on these other trees is greater than on the jack pines but their shade tolerance and greater longevity (for red maple and red oak) will lead to their eventual dominance of these sites barring further disturbance. The continuous canopy of these stands on mineral soil is clearly incompatible with the light requirements of jack pine seedlings, and therefore there is no current regeneration.

Table 8. Basal areas (m^2/ha) by species for Mt. Desert Island jack pine stands.

	[-------Stem Map data---]		[-------PCQM data----------]		[----Stem Map data--------]	
Species	The Tarn[1]	Norumbega[2]	Cadillac Mtn[2]	Whalesback[2]	Whalesback (Mineral Soil)	Whalesback (Bare Rock)
Pinus banksiana	23.19	2.54	4.35	15.91	27.04	21.29
Pinus resinosa	--	--	--	0.98	--	--
Pinus rigida	--	4.95	--	--	--	--
Pinus strobus	--	--	0.08	--	--	--
Picea rubens	1.91	0.89	0.22	1.09	--	--
Picea mariana	--	--	0.01	--	--	--
Picea glauca	--	--	--	0.13	--	--
Betula populifolia	0.06	--	0.11	0.09	0.47	--
Betula papyrifera	1.10	--	--	--	0.06	--
Abies balsamea	--	--	0.02	--	--	--
Thuja occidentalis	--	--	0.13	--	--	--
Ilex montana	--	--	0.02	--	--	--
Quercus rubra	0.63	--	--	0.92	1.08	--
Acer rubrum	0.75	--	--	0.35	2.73	--
Acer saccharrum	0.19	--	--	--	--	--
Amelanchier sp.	0.08	--	--	--	--	--
Populus grandidentata	0.16	--	--	--	--	--

1 = on essentially mineral soil
2 = bare rock substrate dominant

Paleoecology of Jack Pine on MDI

The fossil pollen and microscopic charcoal analyses of the Cadillac Mtn. and Whalesback sediment cores provide insights into the vegetation and fire histories of both sites over the last ~3000 years. Radiocarbon dating in conjunction with pollen and charcoal indicators are used to identify the chronology of vegetation change within each core. In order to understand the relationship between the pollen collected from the cores and its representation of the surrounding vegetation one must try to assess the pollen source area of each basin.

The small size of the pollen deposition basin at the Cadillac Mtn. jack pine stand suggests that pollen produced locally rather than regionally dominates the pollen assemblages (Heidi & Bradshaw 1982, Jackson 1990, Jacobson & Bradshaw 1981, Prentice 1984). For this reason small bog and mor-humus analyses are considered useful in stand reconstruction studies (Bradshaw & Miller 1988). The pollen percentages of the surface samples from Cadillac Mtn. seem representative of the jack pine dominated stand identified in the PCQM analysis. However, the *Tsuga* pollen profile is remarkably similar to that identified from the Whalesback core, and bears a resemblance to the profiles in both The Bowl and Lake Wood cores analyzed by N.Drake (unpublished data). At certain times in the core there are also small quantities of arboreal pollen such as *Tilia, Carya, Ulmus etc*. which are more indicative of a richer lowland or valley situation than an exposed ridge top. *Castenea* pollen also occurs well north of the species' range limit, and the large quantities of *Ambrosia* pollen presumably come from agricultural activity in the low areas of Mount Desert Island (or beyond). These relatively light pollen types can be transported from far beyond the local area, even into canopy openings smaller than those at Cadillac and Whalesback (Sugita 1993). All these pollen types indicate that a certain amount of extralocal or regional pollen is finding its way into the site, presumably as airborne pollen being deposited through the canopy opening. Other studies have found that even in some closed-canopy mor-humus sites, there can be a significant extralocal pollen representation (Schoonmaker 1992). The position of the pollen deposition basin at high elevation, near the top of the southern ridge of Cadillac Mtn., undoubtedly results in relatively high proportions of extralocal pollen being incorporated into the sediment. The present open nature of the stand and surrounding low shrub vegetation will also increase the possibility of extralocal pollen reaching the basin. During periods when the local vegetation has been killed by fire, extralocal pollen representation would be particularly pronounced. Evidence for this situation is found in the increase in *Gramineae* and agricultural indicator pollen and the very high peak in *Betula* which occur following the charcoal peak at 9-11 cm in the Cadillac Mtn. core.

A comparison of species representations in the immediate vicinity of the pollen deposition basin (Table 3) and the pollen percentages of the surface sample in the pollen diagram (Figure 9) helps to identify the present pollen source area of this site. Jack pine pollen percentages are consistent with the species' cover in the surrounding vegetation, whereas white pine and birch are overrepresented. Although these species produce large quantities of pollen which could have been produced locally, the presence of pollen from hemlock, oak, beech and other tree species not present at the site indicates a considerable input from more distant, mixed-deciduous woodland. The low percentage of *Ericaceae* pollen at the surface confirms the underrepresentation in the pollen spectra of this family, which is well represented at the site by shrub genera such as *Gaylussacia, Vaccinium* and *Kalmia*.

The lower elevation, smaller basin size, denser nature of the stand and the surrounding woodland are all factors limiting the influence of extra-local or regional pollen rain in the Whalesback pollen analysis. The survey of species within 10m of the pollen deposition basin (Table 4) suggests the dominance of jack pine and an absence of substantial representation by any other anemophilous species. Ericaceous shrubs dominate the understory, but their low pollen production is clearly reflected in the pollen percentage diagram (Figure 10). The other tree species represented in the pollen diagram must be producing pollen that is being transported to the site from beyond the immediate jack pine stand. Some of this pollen must represent the more mesic mixed-hardwood stand that dominates the surrounding, deeper, mineral-soil sites. A stem map from part of this nearby stand shows substantial populations of red oak, red maple, and birch, which are reasonably well represented in the pollen diagram. Other pollen types such as *Cupressaceae* and *Abies* indicate long distance dispersal from the spruce-fir-cedar forests that cover a considerable portion of the island. *Castanea* pollen demonstrates transport from off-island to the south.

The pollen diagrams from the two jack pine stands at Cadillac Mtn. and Whalesback illustrate different vegetation and fire histories that have produced similar results in the dominance of jack pine at each site. During presettlement time, jack pine was less important in the vegetation surrounding the Cadillac Mtn. basin than at Whalesback. During this period the dominant pollen is of tree species typical of the northern hardwoods forest type: birch, white pine, oak and beech. It is unlikely that these species were important at high elevations on Cadillac Mtn., and therefore this pollen is probably derived from extralocal sources. This in turn suggests that the study site was more open in nature allowing the influx of extralocal pollen. Following a period of increased fire activity there was a dramatic change in the extralocal vegetation which led to a dominance by white pine, spruce, and hemlock for a short period. At the same time the composition of the wetland vegetation changed as evidenced by a large drop in *Ilex/Nemopanthus* pollen percentages and *Sphagnum* spores. The situation changes again with the appearance of grass and agricultural indicator pollen that denotes the period of European settlement. Throughout this period of changes in the composition of the extralocal vegetation community, jack pine was a minor component of the local vegetation. Although the earlier phase of the post-settlement period may not be represented due to possible removal of corresponding sediments by a fire that burned the surface of the peat, the subsequent vegetation change is clearly illustrated. This post-settlement fire probably occurred in the 1890's, as the peak in birch pollen suggests it was a large scale event. Two or three such fires are documented on Cadillac Mtn. around this time (Moore & Taylor 1927). After the fire, jack pine rose rapidly to its present dominance and the relative percentages of the other tree species dropped substantially. Because jack pine did not respond in a manner similar to any of several presettlement fires, the conditions associated with the 1890's fire must have particularly suited the expansion of jack pine over other species. These conditions included climatic and anthropogenic factors. European settlement led to an increase in ignitions and fuels due to timber harvesting which increased fire frequency and severity in the affected areas. The absence of coordinated fire suppression also led to increased fire frequency in the higher elevations. Major fires were probably associated with periods of extreme drought as was the case in 1947. Regional pollen diagrams from Mount Desert Island lake sediments (N. Drake unpublished data) identify a shift in forest composition that coincides with a change in climate to cooler, moister conditions about 2,000 B.P. (Table 9). This may have increased

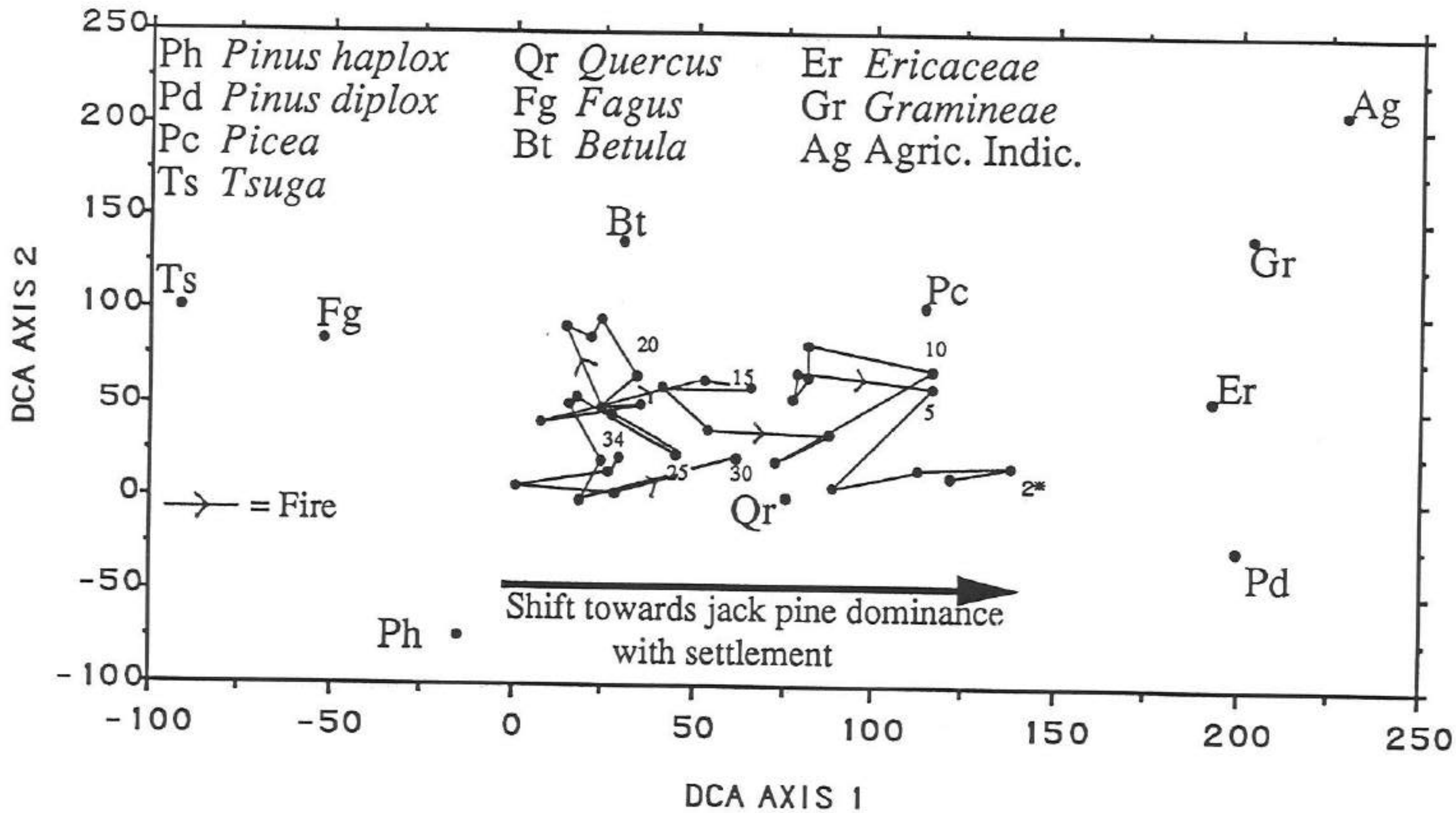
Table 9. Summary table of regional vegatation and fire history identified by sediment analyses of Lake Wood, MDI (N. Drake, unpublished data)

Depth (cm)	Age	Vegetation History	Fire History
			Sustained increase in microscopic charcoal.
50		Increase in agri-cultural indicators.	
	230 BP		Microscopic charcoal indicates increased fire activity.
	910 +/- 90 BP	Increase in spruce, cedar and alder. Decrease in beech, hemlock and sugar maple.	
100			
150	1970 +/- 90 BP		
200	2370 +/- 100 BP		
250		Forest dominated by northern hardwood species: white pine, hemlock, beech, sugar maple.	Microscopic charcoal indicates long periods without fire.
300	3090 +/- 90 BP		
350			
	3830 +/- 100 BP		

jack pine's ability to colonize these sites following suitable conditions as summer drought can severely limit seedling recruitment (Bergeron & Brisson 1990).

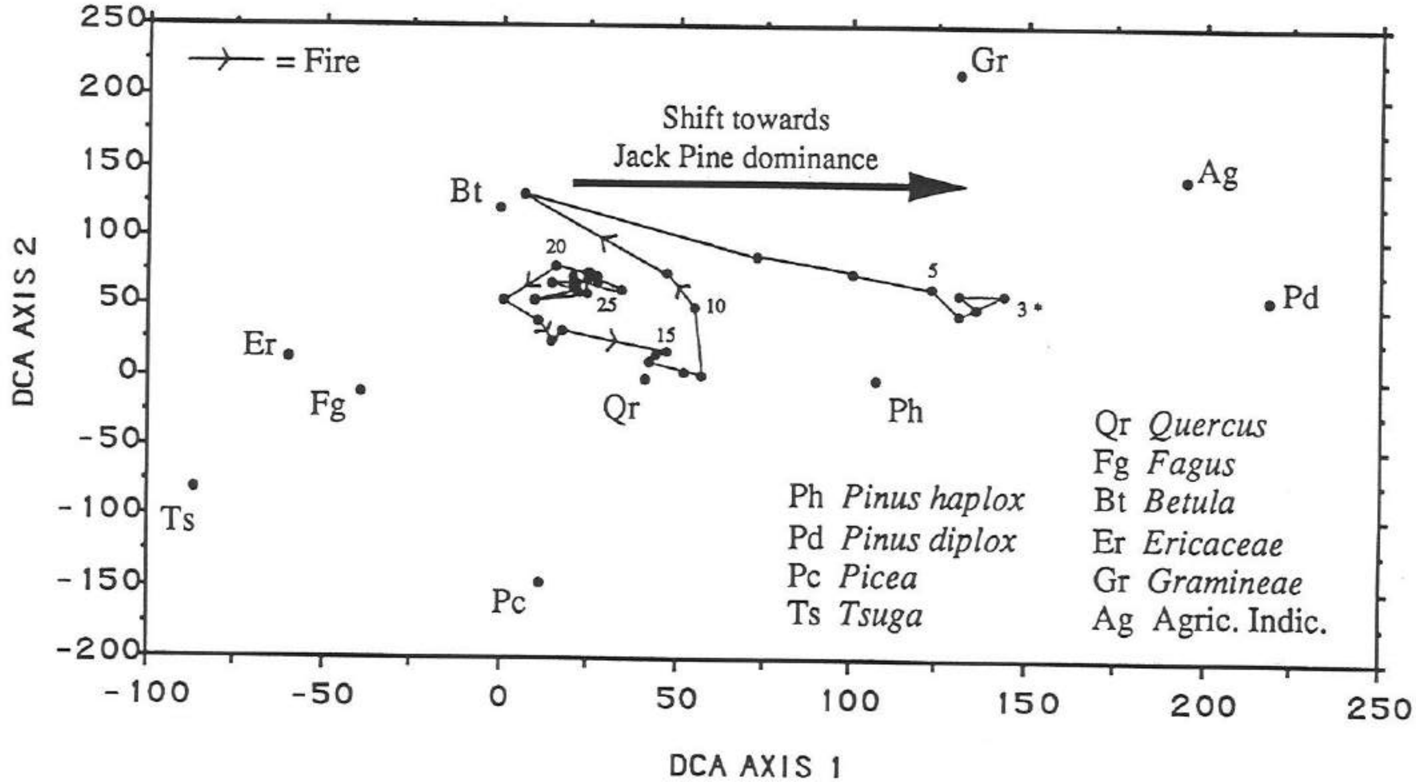
The Whalesback pollen analysis also identifies jack pine as being less important prior to European settlement. The period covered by the core shows an initial dominance of white pine together with other northern hardwood species. There follows a period of increased spruce and hemlock representation together with peaks in birch pollen associated with a number of fires. Although there is a short period of increased jack pine pollen values prior to European settlement, the species does not reach its maximum levels until some time after the rise in agricultural indicators. This jack pine increase corresponds with the charcoal peak that represents the severe 1947 Bar Harbor fire following a short but intense period of drought (Patterson et al. 1983). The fire resulted in complete soil removal on many sites. It burned out most competitors and created site conditions that clearly favored the dense establishment of jack pine on the shallow patches of mineral soil that remained.

The shift in vegetation to jack pine dominance at both Whalesback and Cadillac Mtn. is displayed in detrended correspondence analyses (DCA) of the upland pollen from the two sites (Figures 11&12). Both diagrams identify the shift towards jack pine dominance with European settlement. Younger samples occur further to the right on DCA axis 1 (representing increasing jack pine). At Cadillac Mtn. there are three distinct groups of plots representing three different vegetation communities. The largest, comprising the bottom 14 samples, shows minimal level-to-level change in stand composition. This group represents a northern hardwood forest community. After a series of fires the composition of this community changes resulting in increased proportions of spruce, hemlock and white pine.



* Numbers indicate level (cm) of sample.

Figure 11. Detrended correspondence analysis (DCA) species and sample scores of selected fossil pollen taxa from Whalesback.



* Numbers indicate level of sample

Figure 12. Detrended correspondence analysis (DCA) species and sample scores of selected fossil pollen taxa from Cadillac Mtn.

This community remains stable for some time before changing again with fire, first towards birch and then jack pine dominance. There is a general trend from mesic forest to xeric jack pine associated with European settlement.

This same trend from mesic forest to jack pine can be seen in the DCA of the Whalesback pollen data (Figure 12). There seem, however, to have been few periods of prolonged stability in the Whalesback community. The recurring evidence of fires in the core provides a reason for the frequent changes in community composition. Prior to European settlement repeated fires occurred and post-fire succession never followed exactly the same pathway. These variations in the post-fire development of the community could be the result of a combination of varying fire severity and seed availability. Birch generally dominates immediately after fire, but white pine regenerated under certain conditions. Because the length of time between fires varies, the composition of the forest varies with shade-tolerant species dominating as species with shorter lifespans die out. This pattern changes around the time of European settlement with a distinct shift towards more xeric conditions. The vegetation remains unstable, but the trend is towards jack pine dominance in response to frequent fires.

Importance of Cone Serotiny and Substrate on Regeneration Potential

The Whalesback and Cadillac Mtn. jack pine have more open than serotinous cones. Eighty-seven percent of the cones at Cadillac Mtn. were non-serotinous and 71.5% at Whalesback. The high level of non-serotiny within these isolated jack pine populations indicates an ability on the part of jack pine to regenerate in the absence of fire. These stands have clearly benefitted from an increased incidence of fire in post-settlement time, however. The dense stocking of Whalesback following the 1947 fire was probably the combined result of a serotinous cone seed source that survived and was activated by the heat of the flames and seed from a few non-serotinous trees that were not killed. The fire return intervals identified in the Whalesback and Cadillac Mtn. cores - approximately 375 yrs and 550 yrs respectively - clearly left prolonged periods, lasting a number of jack pine generations, when fires did not occur. During this time jack pine must have survived by regeneration from seeds from non-serotinous cones.

Jack pine regeneration requires the availability of suitable substrate in addition to an adequate seed source. The inability of the species to dominate the stands at Whalesback and Cadillac Mtn. in presettlement times was probably due in part to a scarcity of suitable substrate. Jack pine now dominate on scattered deposits of shallow mineral soil interspersed with exposed bedrock, but fewer fires in the past may have allowed shade-tolerant competitors to become established in a greater proportion of the stands. An increased incidence of human-ignited fires of the 19th and 20th centuries probably promoted fire-adapted jack pine and increased the area of available substrate on which jack pine could outcompete other species. In areas like The Tarn and the Whalesback mineral soil sites, the seedbed left by the 1947 fire was suitable for both jack pine and more shade-tolerant species.

Jack pine is actively regenerating within the present Cadillac Mtn. stand. The high density and proportion of open cones on the mature pines guarantees a plentiful seed source. However, as the availability of substrate declines with the growth of young jack pine so will the potential for continued regeneration. Senescence of the existing stand and litter accumulation eventually lead to increased proportions of jack pine's competitors barring further disturbance. Whalesback currently has little regeneration due to the density of the present stand. Seeds are present but space for the development of the shade-intolerant seedlings is not. In the absence of fire one might expect this situation to continue until the present jack pine cohort begins to break up due to old age. By this time, however, shade-tolerant species may have begun to invade the stand producing additional shade while a deeper litter layer impedes jack pine regeneration.

The present status of these two Mt. Desert Island stands seems more favorable to continued jack pine dominance than other stands in the area. On Schoodic Head there is extensive mortality among the older jack pine and little regeneration, perhaps due to deteriorating seedbed conditions (Patterson 1988; Conkey et al. 1991). However, at certain sites on Great Wass Island, jack pine forms an 'edaphic climax' on poor soils and is not likely to be replaced by other species, even in the absence of fire (Thompson 1982). This seems to be the case for Cadillac Mtn. and Whalesback, where fire is required less frequently to promote seedbed conditions favorable for jack pine.

Studies on the genetic variability of jack pine throughout its range in eastern North America (Lapp & von Rudloff 1982) and particularly on the relict jack pine populations in Acadia National Park (Hawley & DeHayes 1978) identify these jack pine stands as being genetically distinct. The Whalesback stand is the most unique of these populations, which represent a valuable repository of uncommon jack pine genes. The fossil pollen data for the Cadillac Mtn. and Whalesback stands provide evidence for these unique gene frequencies in the form of long periods of significantly reduced jack pine abundance. Periods when relatively few jack pine existed at either site would have clearly limited the proportion of genes passed on to the next generation.

Recommendations for Future Management

The uniqueness of the Mount Desert Island jack pine stands might be an important consideration for their conservation. These disjunct populations may produce new genotypes better suited to future conditions. Recent climate-models indicate that global warming would result in increased rates of forest disturbance which would promote early-successional species such as jack pine (Overpeck et al. 1990). However, an increase in mean annual temperature would not be expected to favor a boreal species such as jack pine at its present southern range limit. Changes in forest composition but also climate changes have already altered the 'natural' fire regimes of the Northeast (Clark 1988). However, the fragmentation of natural communities and absence of migration corridors adds impetus to the need to preserve extant populations that could be points of expansion during periods of future climate change (Graham 1988).

This study identifies post-settlement fires as important to the present extent and vigor of jack pine stands on Cadillac Mtn. and Whalesback. There has, however, been continuing recruitment within these stands, particularly at Cadillac Mtn., long after the conflagrations that gave rise to the dominant age classes. The high proportion of non-serotinous cones within each jack pine population, coupled with substrate availability, has promoted this recruitment in the absence of subsequent fires.

This study demonstrates that, at both study sites, jack pine is more abundant today than prior to $19^{th}/20^{th}$ century fires. The influence of European settlement on fire frequency and severity has undoubtedly played an important role in this, but climate change may also have been an important factor. Therefore, although jack pine has existed at both sites at lower densities for at least several millenia, the present stand densities are likely to be maintained only with recurrent fires.

APPENDIX A
COMPLETE POLLEN COUNTS

Site: Cadillac Mtn., MDI, ME Analyst: Charles Laing

	Depth (cm)									
Pollen Type	**0-2**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Cupressaceae	10	--	1	6	1	1	--	--	--	--
Picea	5	3	4	5	3	3	6	2	13	12
Abies	4	2	4	2	1	4	1	1	1	12
Tsuga	2	1	1	4	4	6	--	1	9	7
Pinus undiff	61	82	65	71	37	39	29	6	47	49
Pinus haplox	28	28	13	27	11	15	7	1	15	23
Pinus diplox	62	64	59	48	50	34	15	4	2	7
Betula	55	65	42	39	46	68	91	379	86	88
Populus	--	--	--	--	--	--	--	--	--	--
Fraxinus	2	--	--	--	--	1	2	--	3	--
Quercus	13	5	4	14	10	11	7	5	6	20
Ulmus	--	--	--	1	2	2	2	--	3	1
Ostrya-Carp.	--	--	--	--	--	--	--	--	--	--
Salix	--	--	--	--	--	1	1	27	8	2
Acer saccharum		--	2	1	1	1	2	--	1	3
Acer rubrum	--	2	--	--	--	--	--	--	--	--
A. undiff	--	--	--	--	--	1	--	--	--	--
Tilia	--	--	--	--	--	--	--	--	--	--
Juglans cinerea	--	--	--	--	--	--	--	--	--	
Carya	--	--	--	--	--	--	--	--	--	--
Fagus	3	2	2	2	1	6	4	3	8	12
Castanea	--	--	--	--	--	--	--	1	--	--
Ilex	109	75	101	88	66	110	76	49	31	105
Viburnum	--	2	1	--	--	--	--	--	2	--
Alnus	5	16	5	10	24	8	9	14	23	15
Myrica-Compt		1	1	--	3	23	3	80	1	8
Ericaceae	1	--	--	--	2	1	1	1	1	2
Gramineae	6	2	3	5	3	14	8	11	29	11

Site: Cadillac Mtn., MDI, ME

Analyst: Charles Laing

	Depth (cm)									
Pollen Type	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**
Cupressaceae	--	--	--	1	1	5	--	--	--	--
Picea	35	48	64	33	33	24	15	26	14	3
Abies	2	10	4	14	1	3	--	--	1	--
Tsuga	12	17	19	15	16	42	34	31	32	16
Pinus undiff	83	59	65	44	76	29	22	30	23	25
Pinus haplox	39	34	28	63	48	12	9	4	3	3
Pinus diplox	5	12	5	6	4	3	2	4	--	3
Betula	90	66	77	79	90	107	108	105	139	156
Populus	--	--	--	--	--	--	--	--	--	--
Fraxinus	1	3	--	4	5	7	4	1	3	1
Quercus	13	19	14	18	9	20	25	20	4	8
Ulmus	--	1	1	2	2	1	3	1	--	2
Ostrya-Carp.	--	--	--	--	--	1	--	--	--	--
Salix	2	--	1	2	1	2	2	1	1	--
Acer saccharum	1	2	5	4	3	2	3	1	1	1
Acer rubrum	1	--	--	--	1	--	--	1	--	--
A. undiff	--	--	--	--	--	--	--	--	--	--
Tilia	--	--	--	2	--	1	--	--	--	--
Juglans cinerea		--	--	--	1	--	--	--	--	--
Carya	1	3	--	--	--	3	2	--	1	1
Fagus	11	8	10	23	16	10	20	10	9	7
Castanea	4	3	--	2	2	1	1	--	--	--
Nyssa	--	--	--	--	--	1	--	--	--	--
Ilex	41	10	12	4	7	5	1	21	11	61
Viburnum	--	--	--	--	1	--	--	--	1	--
Alnus	18	12	9	9	6	28	61	19	20	15
Myrica-Com	9	5	3	17	19	17	2	74	10	21
Ericaceae	4	7	3	3	--	4	2	4	1	2
Gramineae	1	2	--	--	1	6	9	--	3	1

Site: Cadillac Mtn., MDI, ME Analyst: Charles Laing

	Depth (cm)									
Pollen Type	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**
Artemisia	--	2	--	--	--	1	--	--	--	--
Ambrosia	--	--	1	--	--	--	1	--	--	--
Tubuliflorae	--	--	--	--	--	--	--	1	--	1
Ligulaflorae	--	--	1	1	--	--	2	--	2	7
Chenopodiaceae		--	--	--	--	--	--	--	--	--
Polygonaceae		--	--	1	--	--	--	--	--	--
Rumex	--	--	1	--	--	--	--	--	--	--
Plantago	--	1	--	--	--	--	--	1	--	--
Rosaceae	--	--	--	--	--	1	--	--	--	--
Pteridium	2	1	2	3	2	--	--	--	--	--
Cyperaceae	3	1	2	--	--	14	11	11	7	--
Lycopodium	2	--	--	--	1	6	1	2	--	1
Sphagnum	192	387	261	149	275	287	42	93	152	267
Typha	--	--	--	--	--	--	--	--	--	--
Nuphar	--	1	--	--	1	1	--	--	--	--
Monolete	1	--	1	1	--	2	1	1	2	1
Trilete	3	1	4	9	1	4	2	2	1	2
Osmunda	--	--	--	--	2	1	--	--	--	--
Unidentified	10	9	13	18	11	14	18	20	25	22
Unknown	2	2	2	3	6	5	6	5	2	2
SUM	589	727	608	531	640	672	407	488	470	627
Exotic	104	138	156	131	142	115	119	51	93	39
Native/Exotic	5.66	5.27	3.90	4.05	4.51	5.84	3.42	9.57	5.05	16.08
Ch:P	**147**	**40**	**39**	**53**	**61**	**242**	**453**	**172**	**1976**	**306**

Site: Cadillac Mtn., MDI, ME

Analyst: Charles Laing

	Depth (cm)									
Pollen Type	**21**	**22**	**23**	**24**	**25**	**26**	**27**	**28**	**29**	**30**
Cupressaceae	--	--	--	--	--	--	--	--	--	--
Picea	5	6	5	9	4	4	9	6	6	8
Abies	1	1	--	--	1	4	--	2	1	1
Tsuga	20	18	14	11	24	25	20	19	20	16
Pinus undiff	46	38	49	32	41	29	41	46	44	63
Pinus haplox	16	6	8	4	11	13	15	15	13	22
Pinus diplox	2	4	1	4	4	--	3	5	10	2
Betula	174	172	169	173	154	132	171	178	141	188
Populus	--	--	--	--	--	--	--	--	--	--
Fraxinus	4	4	1	2	1	--	2	4	--	3
Quercus	15	20	14	18	16	19	13	33	23	23
Ulmus	1	4	--	1	--	1	--	1	5	1
Ostrya-Carp.	--	--	--	--	--	--	--	--	--	--
Salix	1	3	1	--	1	3	1	--	3	--
Acer saccha	4	1	2	2	4	2	3	3	5	4
Acer rubrum	1	--	--	--	--	--	--	--	2	--
A. undiff	--	1	--	--	1	--	1	--	--	--
Tilia	1	--	--	--	--	1	--	1	--	--
Juglans cinerea		--	--	--	--	1	1	--	--	1
Carya	--	--	--	1	1	2	--	--	1	--
Fagus	10	12	9	16	14	14	4	12	8	11
Castanea	--	--	--	--	--	--	--	2	--	1
Nyssa	--	--	--	--	--	--	--	--	1	--
Ilex	56	86	61	104	73	43	73	68	77	86
Vibernum	4	4	4	11	7	31	8	18	4	17
Alnus	16	9	10	11	9	16	9	2	10	6
Myrica-Com	36	15	27	14	27	9	15	15	23	26
Ericaceae	5	3	4	8	5	6	3	11	7	19
Gramineae	5	5	3	6	5	3	5	3	1	1

Site: Cadillac Mtn., MDI, ME

Analyst: Charles Laing

	Depth (cm)									
Pollen Type	**21**	**22**	**23**	**24**	**25**	**26**	**27**	**28**	**29**	**30**
Artemisia	--	1	--	--	--	--	--	--	1	--
Ambrosia	--	--	--	--	--	1	--	2	1	2
Iva	--	--	--	1	--	--	--	--	--	--
Tubuliflorae	--	--	--	1	--	2	--	--	--	--
Liguliflorae		13	3	3	8	1	7	6	4	5
Chenopodiaceae		--	--	--	--	--	--	--	--	--
Polygonaceae	--	--	--	--	--	--	--	--	--	--
Rumex	--	--	2	--	--	--	--	1	--	1
Plantago	--	--	--	--	--	--	--	--	--	--
Rosaceae	--	--	--	--	--	--	--	--	--	2
Pteridium	2	--	1	2	--	--	1	4	--	1
Cyperaceae	2	1	1	--	1	--	--	1	1	1
Lycopodium	--	2	--	1	--	--	--	--	--	2
Sphagnum	231	254	260	287	285	265	270	214	216	207
Typha	--	--	--	--	--	--	--	--	--	--
Nuphar	--	--	1	--	1	1	1	--	--	--
Monolete	4	1	1	1	--	--	2	5	3	1
Trilete	4	--	1	--	1	--	3	--	1	--
Osmunda	--	1	3	2	4	--	2	4	1	--
Unidentified	20	14	19	20	13	18	15	17	13	15
Unknown	7	5	5	4	4	8	4	5	9	3
SUM	693	706	677	749	720	654	703	702	656	738
Exotic	103	57	85	48	57	48	32	41	30	31
Native/Exotic	6.73	12.39	7.96	15.60	12.63	13.63	21.97	17.12	21.87	23.81
Ch:P	**340**	**422**	**269**	**572**	**195**	**434**	**144**	**87**	**35**	**90**

Site: Cadillac Mtn., MDI, ME

Analyst: Charles Laing

	Depth (cm)			
Pollen Type	**31**	**32**	**33**	**34**
Cupressaceae	--	--	--	--
Picea	3	5	4	5
Abies	1	1	--	--
Tsuga	19	8	10	20
Pinus undiff	48	55	33	40
Pinus haplox	18	14	13	10
Pinus diplox	6	4	5	8
Betula	163	194	140	173
Populus	--	--	--	--
Fraxinus	1	2	1	2
Quercus	24	37	25	22
Ulmus	1	1	1	2
Ostrya-Carp.	--	--	--	--
Salix	4	4	4	5
Acer saccharu	6	1	3	2
Acer rubrum	--	--	--	--
A. undiff	--	--	--	--
Tilia	--	--	--	--
Juglans cinerea		--	--	--
Carya	--	--	--	--
Fagus	7	12	11	9
Castanea	1	4	2	--
Nyssa	1	--	--	--
Ilex	102	70	42	48
Vibernum	5	6	7	--
Alnus	11	8	5	14
Myrica-Compt	26	34	39	56
Ericaceae	7	11	4	6
Stellaria	--	1	--	--
Spargenium	--	1	--	--
Gramineae	3	7	1	4

Site: Cadillac Mtn., MDI, ME

Analyst: Charles Laing

	Depth (cm)			
Pollen Type	**31**	**32**	**33**	**34**
Artemisia	--	--	--	--
Ambrosia	--	--	--	--
Tubuliflorae	--	--	1	--
Ligulaflorae	1	7	3	16
Chenopodiaceae		--	--	--
Rubus	--	--	--	1
Polygonaceae	--	1	--	5
Rumex	--	1	--	2
Plantago	--	--	--	--
Pteridium	--	1	1	1
Cyperaceae	--	--	6	2
Lycopodium	--	--	1	--
Sphagnum	220	158	122	66
Typha	--	--	--	--
Nuphar	--	--	--	--
Monolete	3	1	--	1
Trilete	2	--	--	--
Osmunda	--	1	--	2
Unidentified	12	19	11	13
Unknown	3	6	4	9
SUM	698	675	499	546
Exotic	38	39	30	70
Native/Exotic	18.37	17.31	16.63	7.8
Ch:P	**61**	**92**	**118**	**124**

APPENDIX A

COMPLETE POLLEN COUNTS

Site: Whalesback, MDI, ME — Analyst: Charles Laing

	Depth (cm)									
Pollen Type	**0-2**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Cupressaceae	2	1	2	--	--	1	--	3	5	--
Picea	15	6	8	11	18	19	10	11	9	5
Abies	2	3	3	5	1	5	4	4	4	4
Tsuga	3	4	3	4	2	3	6	6	10	9
Pinus undiff	77	48	53	79	59	31	53	31	26	19
Pinus haplox	36	26	44	49	14	16	11	21	19	4
Pinus diplox	91	74	109	75	49	6	10	17	19	55
Juniperus	1	--	1	--	--	--	3	--	--	7
Betula	39	26	66	49	82	51	58	70	98	72
Populus	--	--	--	--	--	--	1	--	--	--
Fraxinus	5	3	1	2	1	7	4	3	6	1
Quercus	20	6	10	8	4	11	9	11	12	5
Ulmus	--	3	--	--	4	3	--	1	3	1
Ostrya-Carp.	--	--	--	--	--	--	1	--	--	--
Salix	--	--	1	--	5	--	--	3	3	1
Acer saccharu	2	3	2	2	--	6	1	4	2	2
Acer rubrum	2	--	3	2	--	3	2	--	1	1
A. undiff	--	--	--	--	--	--	--	--	--	--
Tilia	--	--	--	--	--	1	--	--	1	--
Juglans cinerea		1	--	--	--	3	--	--	--	1
Carya	--	--	--	--	--	--	--	--	1	--
Fagus	2	4	3	2	4	7	6	3	1	6
Castanea	1	--	--	--	2	1	--	2	--	--
Nyssa	--	--	--	--	--	1	--	--	--	--
Ilex	--	--	--	--	--	--	3	1	--	1
Cornus	--	--	--	--	--	--	--	--	--	--
Alnus	18	11	14	9	14	22	19	19	28	17
Myrica-Com	4	4	4	14	9	10	4	12	8	10
Ericaceae	2	73	4	5	8	9	6	12	10	16
Galium	--	--	--	--	--	--	--	--	--	--
Gramineae	9	2	2	4	6	5	8	3	7	6

Site: Whalesback, MDI, ME Analyst: Charles Laing

	Depth (cm)									
Pollen Type	**0-2**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Artemisia	--	--	--	--	--	--	--	--	--	--
Ambrosia	6	1	4	3	21	16	9	13	16	10
Tubuliflorae	--	--	---	--	--	--	--	--	--	1
Ligulaflorae	1	--	--	--	--	1	--	2	1	--
Chenopodiaceae		1	--	1	1	--	--	--	2	3
Polygonaceae	1	--	1	--	--	--	--	--	--	--
Rumex	2	2	2	1	--	1	--	3	4	2
Plantago	--	--	--	--	--	--	--	--	--	--
Pteridium	1	--	--	1	2	--	3	3	9	1
Cyperaceae	13	1	6	9	26	56	42	55	33	57
Lycopodium	--	--	--	1	1	--	1	1	4	1
Sphagnum	73	20	36	21	14	26	33	34	37	53
Typha	--	--	--	--	--	--	--	1	--	--
Nuphar	--	--	--	--	--	2	1	--	1	2
Monolete	1	1	--	--	1	1	--	--	1	1
Trilete	--	1	1	--	--	12	8	17	12	4
Osmunda	--	--	--	--	1	--	--	--	1	--
Unidentified	15	15	13	13	21	12	18	16	15	20
Unknown	3	1	1	2	2	1	4	1	4	1
SUM	448	340	397	372	375	346	338	381	414	398
Exotic	324	203	160	145	194	146	127	142	144	102
Native/Exotic	1.38	1.67	2.48	2.57	1.93	2.37	2.66	2.68	2.88	3.90
Ch:P	**213**	**150**	**91**	**264**	**2766**	**478**	**608**	**156**	**236**	**210**

Site: Whalesback, MDI, ME

Analyst: Charles Laing

	Depth (cm)									
Pollen Type	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**
Cupressaceae	1	1	1	--	--	4	1	--	--	1
Picea	15	18	10	22	21	7	9	8	15	17
Abies	6	4	4	4	--	4	4	1	1	2
Tsuga	18	25	35	44	31	23	58	53	38	46
Pinus undiff	68	59	49	41	58	32	52	46	52	53
Pinus haplox	61	24	39	34	28	27	41	35	49	39
Pinus diplox	59	56	30	25	31	19	10	35	13	23
Juniperus	--	2	--	--	--	--	--	--	--	--
Betula	73	64	69	97	108	81	65	100	113	167
Populus	--	--	--	1	1	--	--	--	--	--
Fraxinus	2	3	4	4	2	4	5	5	--	4
Quercus	17	16	23	15	12	13	7	18	14	16
Ulmus	2	1	2	5	1	1	--	1	1	3
Ostrya-Carp.	--	--	--	1	--	--	--	--	--	--
Salix	1	2	1	--	3	--	--	1	1	--
Acer sacchar	1	3	2	2	--	1	--	9	2	4
Acer rubrum	--	--	2	--	3	2	1	--	3	--
A. undiff	--	--	--	--	--	--	--	--	--	--
Tilia	--	--	--	--	--	--	--	--	--	--
Juglans cinerea		--	--	--	--	--	1	--	--	--
Carya	--	--	--	--	--	--	--	--	--	--
Fagus	8	4	6	16	16	13	12	21	9	15
Castanea	--	--	1	2	3	--	1	--	--	1
Ilex	--	--	1	2	1	3	51	70	27	5
Cornus	--	--	--	--	--	--	--	--	--	--
Alnus	11	12	13	15	23	17	6	10	6	18
Myrica-Com	2	5	4	10	14	6	9	11	4	10
Ericaceae	9	7	11	6	20	4	2	2	4	10
Galium	--	--	--	--	--	--	--	--	--	--
Gramineae	8	3	5	3	18	7	--	--	--	--

Site: Whalesback, MDI, ME

Analyst: Charles Laing

	Depth (cm)									
Pollen Type	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**
Artemisia	--	--	--	--	--	--	--	--	--	--
Ambrosia	1	--	--	2	--	2	--	--	1	--
Tubuliflorae	--	1	1	2	5	--	--	--	--	--
Ligulaflorae	--	--	--	1	1	1	2	8	5	--
Chenopodiaceae		--	1	--	2	--	--	--	--	--
Polygonaceae	--	--	--	--	--	--	--	--	--	--
Rumex	--	--	--	--	1	--	4	--	--	2
Plantago	--	--	--	--	--	--	--	--	--	--
Pteridium	4	2	5	4	10	--	--	--	1	--
Cyperaceae	15	29	14	20	31	13	3	1	1	1
*Lycopodium*1	--	--	1	--	--	1	--	--	--	--
Sphagnum	67	37	54	92	89	181	38	29	130	110
Typha	--	--	--	--	--	--	--	--	--	--
Nuphar	--	--	--	--	1	1	--	--	--	--
Monolete	--	--	1	1	1	1	--	--	--	2
Trilete	6	6	5	4	--	1	2	--	1	--
Potemogeton	--	--	--	--	--	--	--	1	--	--
Osmunda	--	--	--	--	--	--	--	--	--	1
Unidentified	18	20	17	16	25	23	38	18	12	14
Unknown	2	1	3	1	3	--	4	5	4	1
SUM	476	405	413	495	563	497	421	488	509	563
Exotic	80	84	48	54	68	192	69	51	52	59
Native/Exotic	5.95	4.82	8.60	9.17	8.28	2.59	6.10	9.57	9.79	9.54
Ch:P	**288**	**627**	**212**	**210**	**225**	**419**	**247**	**42**	**11**	**63**

Site: Whalesback, MDI, ME

Analyst: Charles Laing

	Depth (cm)									
Pollen Type	**21**	**22**	**23**	**24**	**25**	**26**	**27**	**28**	**29**	**30**
Cupressaceae	2	--	--	--	--	--	--	--	--	--
Picea	11	10	7	27	14	19	2	7	7	3
Abies	1	1	--	5	1	4	1	3	3	--
Tsuga	24	40	34	57	32	17	39	16	20	16
Pinus undiff	20	21	11	44	72	40	59	92	88	110
Pinus haplox	20	48	15	63	59	47	83	74	78	28
Pinus diplox	3	5	3	29	37	3	12	9	9	22
Juniperus	--	--	--	--	--	--	--	---	--	--
Betula	179	229	110	104	87	114	180	104	57	75
Populus	--	--	--	--	--	--	--	--	--	--
Fraxinus	1	11	2	--	4	1	5	9	1	5
Quercus	9	19	10	11	13	12	14	14	13	27
Ulmus	2	2	--	--	1	--	--	1	--	3
Ostrya-Carp.	--	--	--	--	--	--	--	--	--	--
Salix	3	2	--	1	--	--	3	1	--	2
Acer sacchar	2	3	1	4	--	1	4	4	2	2
Acer rubrum	1	--	1	3	9	--	1	1	--	--
A. undiff	--	--	--	--	--	--	--	--	2	--
Tilia	--	--	--	--	--	--	--	--	--	-
Juglans ciner	--	--	--	--	--	--	--	--	--	1
Carya	--	--	2	2	--	--	1	--	--	--
Fagus	14	17	5	13	7	32	18	7	7	12
Castanea	1	3	1	--	--	--	--	--	--	1
Ilex	4	2	5	43	65	26	14	13	--	1
Cornus	--	4	26	--	--	3	--	--	--	2
Alnus	17	12	10	7	6	5	19	6	1	8
Myrica-Comp	10	10	2	6	10	7	31	35	6	102
Ericaceae	2	7	4	5	3	8	9	11	12	16
Galium	--	--	1	--	--	--	--	--	--	--
Gramineae	1	--	1	--	--	--	--	--	--	--

Site: Whalesback, MDI, ME

Analyst: Charles Laing

	Depth (cm)									
Pollen Type	**21**	**22**	**23**	**24**	**25**	**26**	**27**	**28**	**29**	**30**
Artemisia	--	--	--	--	--	--	--	--	--	--
Ambrosia	--	--	--	--	-	--	--	--	--	--
Tubuliflorae	--	--	3	1	--	--	--	--	--	3
Ligulaflorae	--	1	--	1	--	--	2	--	--	--
Chenopodiaceae		--	--	--	--	--	--	--	--	--
Polygonaceae	--	--	--	--	--	--	--	--	--	--
Rumex	--	--	--	--	--	--	--	--	--	--
Plantago	--	1	--	--	--	--	--	--	--	--
Pteridium	3	2	1	--	--	--	--	1	1	--
Cyperaceae	5	13	1	--	--	--	7	--	--	--
Lycopodium	--	2	--	--	--	--	--	1	--	--
Sphagnum	200	450	54	77	9	18	108	282	198	239
Typha	--	--	4	--	--	--	--	--	--	--
Nuphar	1	2	--	--	1	--	--	--	--	--
Monolete	---	--	--	--	1	--	1	1	4	--
Trilete	6	2	2	--	--	--	3	5	3	3
Potemogeton	--	--	--	--	--	--	--	--	--	--
Osmunda	--	--	--	--	--	--	2	--	1	3
Unidentified	7	13	20	8	21	13	13	12	10	19
Unknown	2	1	5	1	1	3	4	6	3	--
SUM	551	934	340	512	453	373	626	715	526	703
Exotic	48	80	158	98	64	40	50	63	52	29
Native/Exotic	11.48	11.68	2.15	5.22	7.08	9.33	12.52	11.35	10.12	24.24
Ch:P	**131**	**49**	**1111**	**78**	**9**	**0**	**87**	**288**	**56**	**249**

Site: Whalesback, MDI, ME

Analyst: Charles Laing

	Depth (cm)			
Pollen Type	**31**	**32**	**33**	**34**
Cupressaceae	--	--	--	--
Picea	2	3	2	3
Abies	4	2	6	--
Tsuga	11	26	21	27
Pinus undiff	87	68	96	55
Pinus haplox	92	100	64	62
Pinus diplox	22	1	17	16
Juniperus	--	--	--	--
Betula	77	68	82	66
Populus	--	1	--	--
Fraxinus	1	1	2	8
Quercus	20	14	16	21
Ulmus	1	1	--	3
Ostrya-Carp.	--	--	-	--
Salix	2	2	1	1
Acer saccharu	2	3	1	6
Acer rubrum	--	1	--	1
A. undiff	--	--	--	--
Tilia	--	--	--	--
Juglans cinerea		1	--	--
Carya	2	1	--	--
Fagus	13	14	15	6
Castanea	--	--	1	--
Ilex	--	4	6	11
Cornus	--	--	--	--
Alnus	8	12	3	10
Myrica-Com	30	24	16	29
Ericaceae	8	6	4	7
Galium	--	--	--	--
Gramineae	--	--	--	--

Site: Whalesback, MDI, ME

Analyst: Charles Laing

	Depth (cm)			
Pollen Type	**31**	**32**	**33**	**34**
Artemisia	--	--	--	--
Ambrosia	--	--	1	--
Tubuliflorae	--	--	--	--
Ligulaflorae	1	--	3	1
Chenopodiaceae		--	--	--
Polygonaceae	1	--	--	--
Rumex	--	--	--	1
Plantago	--	--	--	--
Pteridium	1	--	1	2
Cyperaceae	--	3	--	4
Lycopodium	--	--	1	1
Sphagnum	137	103	113	92
Typha	--	--	--	--
Nuphar	--	--	--	--
Monolete	1	1	--	1
Trilete	3	4	3	1
Potemogeton	--	--	--	--
Osmunda	5	3	1	--
Unidentified	**15**	**15**	**15**	**21**
Unknown	2	2	2	3
SUM	549	483	493	459
Exotic	59	57	92	278
Native/Exotic	9.31	8.47	5.36	1.65
Ch:P	**27**	**67**	**370**	**879**

APPENDIX B

POINT-CENTERED QUARTER METHOD STAND DATA

Site: Cadillac Mtn., MDI, ME. Date: 6-16-92 Analysts: C.P.L., W.A.P., III, M.E.M.

Transect & Plot Number	Quadrat	Species	Class	Live or Dead	Distance (m)	DBH (cm)	Cones Closed	Cones Open	Soil Depth Organic	Soil Depth Mineral	Seedlings Height	Seedlings DBH	Canopy Closure
A1	NE	Jack Pine	CD	L	2.88	5.7	6	370	0"	0"	*see below		0%
	SE	Jack Pine	D	L	6.62	3.0	--	22					
	SW	Jack Pine	D	L	7.92	3.0	--	45					
	NW	Jack Pine	D	L	5.60	7.0	--	208					
A2	NE	White Pine	CD	L	1.45	4.3			>11.5"			89cm	43.3%
	SE	Grey Birch	CD	L	2.34	2.5							
	SW	Grey Birch	CD	L	2.02	2.9							
	NW	Grey Birch	CD	L	1.28	4.3							
A3	NE	Jack Pine	D	L	6.65	2.5	1	11	>11.5"		None		0%
	SE	Jack Pine	D	L	1.08	11.0	34	1					
	SW	Grey Birch	S	D	4.61	4.7							
	NW	Grey Birch	CD	L	3.80	3.8							
A4	NE	Black Spruce	I	L	1.98	3.0			>11.5"			1.31cm	70.2%
	SE	White Pine	D	L	2.70	10.2						1.5cm	
	SW	Mtn. Holly	I	L	1.29	3.2						0.8cm	
	NW	Mtn. Holly	CD	L	1.14	2.6							
A5	NE	Jack Pine	I	L	1.97	3.4	--	--	>11.5"			1.5cm	47.2%
	SE	Mtn. Holly	I	L	3.45	2.7						0.8cm	
	SW	Jack Pine	CD	L	0.48	7.9	--	3					
	NW	Jack Pine	D	L	1.73	9.8	--	37					
A6	NE	Jack Pine	CD	L	3.79	25	4	--	2"	0"		0.9cm	79,9%
	SE	Grey Birch	S	L	1.89	6.5						0.8cm	
	SW	Jack Pine	CD	L	1.43	9.8	14	80					
	NW	Jack Pine	I	L	6.01	22.3	9	190					
A7	NE	Jack Pine	CD	L	10.22	11.2	3	87	4.5"	6"		1.5cm	81.8%
	SE	Jack Pine	CD	L	3.85	16.2	3	123					
	SW	Jack Pine	CD	L	2.65	4.8	3	--					
	NW	Jack Pine	CD	L	2.83	6.2	3	98					
A8	NE	Jack Pine	CD	L	4.78	23.3	34	110	2"	7.5"	0.70m		29%
	SE	Jack Pine	S	L	4.23	5.0	--	16			0.69m		
	SW	Jack Pine	I	L	2.97	8.9	--	25			1.07m		
	NW	Jack Pine	CD	L	3.33	11.8	1	40					
A9	NE	Jack Pine	CD	L	7.62	4.2	--	23	3"	3"	0.53m		66.4%
	SE	Jack Pine	CD	L	4.40	14.5	110	15			0.29m		
	SW	Jack Pine	CD	L	3.60	4.9	--	5			1.10m		
	NW	Jack Pine	CD	L	0.60	12.1	--	310			0.57m		
A10	NE	Jack Pine	CD	L	0.64	13.6	66	34	5"	5"	1.16m	0.10m	64.5%
	SE	Jack Pine	CD	L	3.36	17.4	41	146			1.43m		
	SW	Jack Pine	CD	D	4.45	3.0	--	6			0.24m		
	NW	Grey Birch	I	L	2.94	4.0					0.39m		
A11	NE	Jack Pine	S	L	2.42	4.2	--	8	2.5"	6.5"	0.99m	0.6cm	27%
	SE	Jack Pine	CD	L	2.19	10.7	37	39			0.38m	0.1cm	
	SW	Red Spruce	CD	L	3.20	8.4					0.41m	0.3cm	
	NW	Jack Pine	CD	L	2.08	5.2	--	73					

*	0.033m	0.91m	0.50m	0.13m
	0.23m	0.17m	0.98m	0.04m
	0.69m	0.49m	0.45m	0.20m
	0.07m	0.21m	0.67m	0.27m
	0.13m	0.14m	0.58m	0.29m
	0.14m	0.09m	0.13m	0.17m
	0.19m	0.64m	0.88m	0.62m
	0.12m	0.21m	0.09m	0.56m
	0.48m	0.22m	0.19m	

Site: Cadillac Mtn., MDI, ME. Date: 6-16-92 Analysts: C.P.L., W.A.P., III, M.E.M.

Transect & Plot Number	Quadrat	Species	Class	Live or Dead	Distance (m)	DBH (cm)	Cones Closed	Cones Open	Soil Depth Organic	Soil Depth Mineral	Seedlings Height	Seedlings DBH	Canopy Closure
B1	NE	Red Spruce	CD	L	9.39	11.1			2"	9.5"	1.06m	0.69m	0%
	SE	Red Spruce	CD	L	3.64	7.6					0.60m	0.94m	
	SW	Jack Pine	CD	L	3.63	5.2	--	103			0.65	1.7cm	
	NW	Jack Pine	CD	L	14.3	7.8	25	26			0.44	1.1cm	
B2	NE	N.W. Cedar	D	L	3.14	13.8			4"	>11.5"	1.41m		89.5%
	SE	Jack Pine	CD	L	7.10	4.6	--	32					
	SW	Grey Birch	CD	L	2.68	3.9							
	NW	Jack Pine	CD	L	6.18	9.9	16	70					
B3	NE	Jack Pine	CD	L	1.87	13.4	50	250	4"	4"	0.90m	0.4cm	79.9%
	SE	Balsam Fir	I	L	4.25	6.1					0.78m	0.6cm	
	SW	Grey Birch	S	D	4.25	3.1					0.83m	0.4cm	
	NW	Jack Pine	I	L	4.15	6.1	--	16			0.37m		
B4	NE	Grey Birch	CD	L	4.70	3.7			10"	11"	0.91m	2.2cm	58.8%
	SE	Jack Pine	D	L	2.53	18.5	1	180			0.97m	0.9cm	
	SW	Jack Pine	S	L	0.27	2.5	--	2			0.81m		
	NW	Jack Pine	CD	L	2.54	10.9	3	15			0.08m		
B5	NE	Jack Pine	CD	L	2.59	22.8	12	160	3"	9.5"	1.01m		36.3%
	SE	N.W. Cedar	S	D	4.24	3.5					1.11m		
	SW	Jack Pine	CD	L	3.75	13.5	15	57					
	NW	Jack Pine	I	L	2.94	10.9	1	32					
B6	NE	Jack Pine	CD	L	2.42	15.0	60	75	1.5"	1.5"	1.06m	1.6cm	45.3%
	SE	Jack Pine	S	D	2.55	2.6	--	3			1.02m	1.1cm	
	SW	Jack Pine	S	L	0.81	5.9	1	16			1.05m		
	NW	Jack Pine	CD	L	5.54	6.2	20	30			0.75m		
B7	NE	Jack Pine	CD	L	8.36	6.9	10	220	0"	0"	1.06m	2.2cm	0%
	SE	Jack Pine	CD	L	4.75	6.8	--	32			0.95m		
	SW	Jack Pine	CD	L	2.45	6.3	--	46					
	NW	Jack Pine	CD	L	8.00	9.3	--	25					
B8	NE	Jack Pine	CD	L	7.90	11.5	55	225	3"	3.5"	0.90m		0%
	SE	Jack Pine	CD	L	7.25	3.7	1	30					
	SW	Jack Pine	I	L	6.12	3.0	--	11					
	NW	Jack Pine	CD	L	1.73	4.2	--	99					
B9	NE	Jack Pine	I	L	6.90	2.5	--	10	10"	10"	* see below		15.5%
	SE	Jack Pine	S	L	1.83	6.2	3	140					
	SW	Jack Pine	D	L	5.25	2.7	--	6					
	NW	Jack Pine	CD	L	0.59	6.2	--	39					
B10	NE	Jack Pine	CD	L	3.10	8.7	21	73	2"	2"	1.21m	0.8cm	0%
	SE	Jack Pine	CD	L	2.71	10.7	13	7			1.16m		
	SW	Red Spruce	S	L	5.95	10.1					0.65m		
	NW	Jack Pine	CD	L	4.22	11.0	4	400			1.05m		

*	0.49m	0.75m	2.3cm
	0.98m	0.62m	0.3cm
	0.86m	0.56m	0.9cm
	0.58m		2.4cm
	0.94m		
	0.45m		
	0.63m		

Site: Whalesback, MDI, ME. Date: 6-16-92 Analysts: C.P.L., W.A.P., III, M.E.M.

Transect & Plot Number	Quadrat	Species	Class	Live or Dead	Distance (m)	DBH (cm)	Cones Closed	Cones Open	Soil Depth Organic	Soil Depth Mineral	Seedlings Height	Seedlings DBH	Canopy Closure
A1	NE	Red Oak	S	L	0.59	6.1	--	--	1"	>11.5"	None		86.6%
	SE	Jack Pine	D	L	9.14	15.7	--	50					
	SW	Jack Pine	CD	L	1.19	13.7	2	19					
	NW	Jack Pine	S	D	1.09	3.5	--	--					
A2	NE	Jack Pine	CD	L	1.25	11.2	1	--	1"	>11.5"	None		91.4%
	SE	Jack Pine	S	D	1.19	2.2	--	--					
	SW	Jack Pine	CD	L	1.90	8.3	6	--					
	NW	Jack Pine	CD	L	0.52	10.3	11	12					
A3	NE	Jack Pine	I	L	2.94	7.7	1	--	1"	10.5"	None		59.7%
	SE	Jack Pine	I	L	2.16	10.3	--	58					
	SW	Jack Pine	S	L	0.25	3.7	--	6					
	NW	Jack Pine	S	L	1.70	4.7	2	--					
A4	NE	Jack Pine	I	L	1.25	7.9	1	6	1"	5"	None		92.3%
	SE	Jack Pine	S	L	2.12	5.9	--	14					
	SW	Jack Pine	D	L	1.89	16.4	9	20					
	NW	Jack Pine	D	D	1.07	2.8	--	--					
A5	NE	Jack Pine	CD	L	2.69	15.4	25	22	1"	10.5"	None		62.2%
	SE	Red Oak	CD	L	3.99	7.8	--	--					
	SW	Jack Pine	S	D	1.22	6.8	--	--					
	NW	Jack Pine	I	L	1.78	11.5	--	--					
A6	NE	Jack Pine	CD	L	0.15	8.4	2	10	3"	9"	None		79.9%
	SE	Jack Pine	CD	L	0.83	9.2	4	5					
	SW	Jack Pine	I	L	1.88	6.0	--	--					
	NW	Jack Pine	I	L	1.58	8.2	1	1					
A7	NE	Red Maple	S	L	1.35	7.1	--	--	1.5"	>11.5"	3.23m		88.5%
	SE	Red Oak	S	D	0.96	5.9	--	--			0.13m		
	SW	Red Oak	S	D	1.28	4.8	--	--					
	NW	Jack Pine	CD	L	2.28	14.4	85	--					
A8	NE	Jack Pine	S	D	1.25	2.6	3	--	2.5"	>11.5"	None		76%
	SE	Jack Pine	CD	L	2.95	12.6	3	4					
	SW	Jack Pine	S	D	2.95	5.1	--	1					
	NW	Jack Pine	CD	L	1.30	12.7	1	48					
A9	NE	Jack Pine	CD	L	4.25	14.6	--	22	1.5"	10.5"	None		54.9%
	SE	Jack Pine	CD	L	2.80	12.6	1	42					
	SW	Jack Pine	D	L	2.88	18.7	15	3					
	NW	Jack Pine	D	D	1.42	3.5	--	--					
A10	NE	Red Pine	S	L	1.13	4.5	--	--	2.5"	10"	None		85.6%
	SE	Jack Pine	S	L	0.59	8.9	--	5					
	SW	Jack Pine	CD	L	1.30	13.3	5	1					
	NW	Jack Pine	CD	L	0.45	13.4	6	30					

Site: Whalesback, MDI, ME. Date: 6-16-92 Analysts: C.P.L., W.A.P., III, M.E.M.

Transect & Plot Number	Quadrat	Species	Class	Live or Dead	Distance (m)	DBH (cm)	Cones Closed	Cones Open	Soil Depth Organic	Soil Depth Mineral	Seedlings Height	Seedlings DBH	Canopy Closure
B1	NE	Jack Pine	I	L	0.77	13.0	--	28	1.5"	8"	None		68.3%
	SE	Jack Pine	CD	L	0.73	11.2	2	35					
	SW	Jack Pine	CD	L	1.12	9.1	12	28					
	NW	Jack Pine	S	L	1.26	5.0	--	5					
B2	NE	Jack Pine	S	D	0.49	4.7	--	2	2.5"	>11.5"	None		70.2%
	SE	Jack Pine	S	D	1.69	3.3	--	3					
	SW	Jack Pine	S	L	0.95	7.7	--	--					
	NW	Jack Pine	I	L	3.09	7.9	--	8					
B3	NE	Jack Pine	S	D	2.47	5.3	--	29	3.5"	10.5"	None		90.4%
	SE	Red Maple	CD	L	0.86	6.1	--	--					
	SW	Red Spruce	S	L	0.71	6.2	--	--					
	NW	Jack Pine	D	L	0.88	12.2	9	95					
B4	NE	Jack Pine	I	L	2.35	9.9	1	4	4.5"	8.5"	None		65.4%
	SE	Jack Pine	CD	L	0.59	12.3	11	14					
	SW	Jack Pine	S	L	2.10	4.4	--	2					
	NW	Jack Pine	CD	L	4.65	12.9	4	30					
B5	NE	Jack Pine	I	L	3.59	7.0	--	12	2.5"	6.5"	None		69.3%
	SE	Jack Pine	I	L	1.82	8.1	--	35					
	SW	Jack Pine	I	L	0.69	8.9	--	15					
	NW	Jack Pine	CD	L	3.23	13.6	7	36					
B6	NE	Jack Pine	I	L	1.83	5.8	--	10	2"	9"	None		67.4%
	SE	Jack Pine	CD	L	2.19	10.5	4	10					
	SW	Jack Pine	CD	L	1.58	17.2	4	--					
	NW	Jack Pine	CD	L	1.76	15.4	--	60					
B7	NE	Jack Pine	CD	L	2.90	15.3	10	--	2.5"	2.5"	None		84.6%
	SE	Jack Pine	CD	L	3.00	16.8	10	21					
	SW	Jack Pine	CD	L	2.35	13.3	8	25					
	NW	Jack Pine	CD	L	1.36	13.8	2	--					
B8	NE	Jack Pine	CD	L	4.40	16.8	3	80	5.5"	>11.5"	None		32%
	SE	Jack Pine	CD	L	6.60	15.7	11	7					
	SW	Jack Pine	D	L	0.89	14.5	10	15					
	NW	Jack Pine	I	L	1.36	14.7	4	--					
B9	NE	Jack Pine	CD	L	0.69	11.3	--	4	1.5"	4.5"	None		17%
	SE	Jack Pine	CD	L	4.67	12.6	--	8					
	SW	Jack Pine	I	L	6.80	8.1	2	--					
	NW	Jack Pine	S	L	1.39	8.5	--	5					
B10	NE	Red Spruce	S	L	1.95	10.9	--	--	4"	>11.5"	None		14%
	SE	Jack Pine	I	L	3.01	12.8	1	20					
	SW	Red Spruce	S	L	1.27	10.6	--	--					
	NW	Jack Pine	D	L	0.66	19.1	1	2					
B11	NE	Jack Pine	I	L	1.08	14.8	4	--	2"	>11.5"	None		64.5%
	SE	Grey Birch	S	D	4.56	2.5	--	--					
	SW	Jack Pine	CD	L	3.80	21.3	--	90					
	NW	Jack Pine	D	L	2.07	23.1	12	32					

Site: Whalesback, MDI, ME. Date: 6-16-92 Analysts: C.P.L., W.A.P., III, M.E.M.

Transect & Plot Number	Quadrat	Species	Class	Live or Dead	Distance (m)	DBH (cm)	Cones Closed	Cones Open	Soil Depth Organic	Soil Depth Mineral	Seedlings Height	Seedlings DBH	Canopy Closure
C1	NE	Jack Pine	CD	L	6.63	19.1	6	--		>11.5"	None		75%
	SE	Red Oak	CD	L	4.30	17.2							
	SW	Red Spruce	S	L	3.08	6.2							
	NW	Jack Pine	S	L	0.68	2.8	--	1					
C2	NE	Jack Pine	CD	L	2.98	14.5	--	14	1"	1"	0.15m		10.7%
	SE	Red Spruce	I	L	6.55	13					0.56m		
	SW	Red Spruce	I	L	2.37	11.6							
	NW	Red Spruce	I	L	2.23	10.4							
C3	NE	Jack Pine	CD	L	2.50	13.3	--	--	4.5"	4.5"	0.17m	1.3cm	51%
	SE	Red Maple	I	L	3.76	6.9					0.56m	1.2cm	
	SW	Jack Pine	CD	L	2.59	15.5	13	113					
	NW	Jack Pine	CD	L	6.63	12.7	--	--					
C4	NE	Jack Pine	CD	L	4.26	11.2	1	--	2.5"	7.5"	0.74m		60.6%
	SE	Red Spruce	I	L	2.27	5.2							
	SW	Jack Pine	CD	L	1.13	10.4	2	13					
	NW	Jack Pine	D	L	1.36	15.5	60	17					
C5	NE	Jack Pine	CD	L	1.47	9.9	10	18	2.5"	10.5"	0.29m	0.50m	64.5%
	SE	Jack Pine	CD	L	0.48	9.8	19	21			0.32m	0.36m	
	SW	Jack Pine	I	L	1.69	6.9	1	--			0.60m		
	NW	Jack Pine	S	D	13.82	5.2	--	2			1.21m		
C6	NE	Jack Pine	I	L	3.53	6.0	1	--	2"	2"	None		74.2%
	SE	Jack Pine	CD	L	0.91	7.6	1	1					
	SW	Jack Pine	I	L	6.88	5.2	--	3					
	NW	Jack Pine	D	L	2.21	17.1	10	27					
C7	NE	Jack Pine	S	L	0.73	3.8	--	--	2.5"	5.5"	None		56.8 %
	SE	Jack Pine	CD	L	0.68	6.9	--	11					
	SW	Jack Pine	CD	L	0.62	10.5	4	--					
	NW	Jack Pine	D	L	1.59	10.6	6	--					
C8	NE	Jack Pine	CD	L	2.35	6.7	3	11	3.5"	4.5"	None		23.2%
	SE	Jack Pine	CD	L	1.76	7.6	--	1					
	SW	Jack Pine	CD	L	0.88	7.2	4	26					
	NW	Jack Pine	CD	L	4.43	5.3	4	1					
C9	NE	Red Spruce	CD	L	0.77	6.2	2	--	3.5"	6"	0.57m		76%
	SE	Jack Pine	CD	L	0.16	4.0	--	--			0.55m		
	SW	Red Spruce	I	L	0.91	4.2	8	--					
	NW	Jack Pine	S	L	0.15	3.8	--	10					
C10	NE	Jack Pine	CD	L	2.92	3.4	3	--	--	--	None		19.4%
	SE	Jack Pine	I	L	3.02	2.6	--	8					
	SW	Jack Pine	CD	L	1.23	4.4	7	--					
	NW	Jack Pine	CD	L	1.14	9.1	2	48					
C11	NE	Jack Pine	D	L	2.71	14.8	11	--	--	--		1.0cm	30.9%
	SE	Jack Pine	CD	L	2.41	4.3	3	--				0.8cm	
	SW	Jack Pine	CD	L	1.07	9.5	16	22					
	NW	Jack Pine	CD	L	1.20	7.7	1	8					

Site: Whalesback, MDI, ME.   Date: 6-16-92   Analysts: C.P.L., W.A.P., III, M.E.M.

Transect & Plot Number	Quadrat	Species	Class	Live or Dead	Distance (m)	DBH (cm)	Cones Closed	Cones Open	Soil Depth Organic	Soil Depth Mineral	Seedlings Height	Seedlings DBH	Canopy Closure
D1	NE	Jack Pine	I	L	1.04	6.4	4	2	1"	7"	None		85.6%
	SE	Red Maple	I	L	2.85	4.2							
	SW	Jack Pine	S	L	2.49	6.1	--	1					
	NW	Jack Pine	S	D	1.07	4.3	--	--					
D2	NE	Jack Pine	S	L	0.27	9.6	1	15	5.5"	10"	None		64.6%
	SE	Jack Pine	CD	L	1.75	8.5	--	6					
	SW	Jack Pine	CD	L	2.53	14.3	6	47					
	NW	Jack Pine	D	L	1.68	14.3	20	13					
D3	NE	Jack Pine	I	L	0.26	8.6	1	9	3.5"	9.5"	None		73.6%
	SE	Jack Pine	S	L	0.57	5.6	1	3					
	SW	Jack Pine	CD	L	1.68	14.8	8	65					
	NW	Jack Pine	I	L	1.58	7.5	3	1					
D4	NE	Jack Pine	S	D	0.75	4.6	--	--	2"	2"	None		55.9%
	SE	Jack Pine	D	L	4.73	13.4	8	4					
	SW	Jack Pine	I	L	0.81	8.1	6	53					
	NW	Jack Pine	CD	L	1.56	10.3	--	54					
D5	NE	Jack Pine	CD	L	2.64	7.8	8	35	1"	1"	1.12m		64.5%
	SE	Jack Pine	CD	L	0.63	9.1	8	110					
	SW	Jack Pine	CD	L	1.63	8.1	1	7					
	NW	Jack Pine	CD	L	3.00	4.1	1	49					
D6	NE	Jack Pine	I	L	0.39	5.1	--	2	2"	2.5"	1.1m	1.1cm	74.2%
	SE	Jack Pine	CD	L	2.98	7.9	1	56				1.0cm	
	SW	Jack Pine	CD	L	1.59	6.4	--	73					
	NW	Jack Pine	S	L	1.92	3.5	--	5					
D7	NE	Jack Pine	I	L	1.07	2.5	--	2	2"	7"	1.4m	1.1cm	56.8%
	SE	Jack Pine	S	L	0.68	2.9	--	--				2.0cm	
	SW	Jack Pine	S	D	0.96	3.3	--	8			0.6cm	1.5cm	
	NW	Jack Pine	S	L	0.46	5.9	1	28			2.2cm		
D8	NE	Jack Pine	S	L	0.53	3.2	--	--	4"	>11.5"		0.9cm	23.2%
	SE	Jack Pine	I	L	1.62	5.0	--	13					
	SW	Jack Pine	CD	L	0.32	11.7	--	19					
	NW	Jack Pine	I	L	0.71	9.6	1	--					
D9	NE	Red Spruce	S	L	0.51	4.4			3.5"	6"	0.57m		76%
	SE	Jack Pine	S	L	0.68	5.1	--	5			0.55m		
	SW	Red Spruce	S	L	0.62	4.1							
	NW	Jack Pine	S	D	1.37	6.0	--	4					
D10	NE	Jack Pine	I	L	0.86	12.3	--	16	--	--	None		19.4%
	SE	Jack Pine	CD	L	0.94	16.0	5	4					
	SW	Jack Pine	CD	L	2.93	17.2	10	5					
	NW	Red Maple	S	L	0.99	6.6							
D11	NE	Jack Pine	CD	L	3.39	10.0	--	4	--	--		1.0cm	30.9%
	SE	Jack Pine	D	L	1.78	18.4	11	--				0.8cm	
	SW	Jack Pine	CD	L	3.05	13.5	5	--					
	NW	Red Oak	CD	L	4.25	12.1							

Site: Whalesback, MDI, ME. Date: 6-16-92 Analysts: C.P.L., W.A.P., III, M.E.M.

Transect & Plot Number	Quadrat	Species	Class	Live or Dead	Distance (m)	DBH (cm)	Cones Closed	Cones Open	Soil Depth Organic	Soil Depth Mineral	Seedlings Height	Seedlings DBH	Canopy Closure
E1	NE	Red Maple	CD	L	2.69	7.6			1"	7"	None		85.6%
	SE	Red Oak	CD	L	2.90	15.7							
	SW	Grey Birch	S	L	1.06	5.0							
	NW	Grey Birch	S	L	2.53	3.7							
E2	NE	Red Spruce	S	L	4.26	10.3			5.5"	10"	None		64.6%
	SE	Grey Birch	I	L	1.23	4.0							
	SW	Grey Birch	I	L	2.97	4.6							
	NW	Red Spruce	CD	L	0.45	13.8							
E3	NE	Red Spruce	S	L	1.52	4.3			3.5"	9.5"	None		73.6%
	SE	Jack Pine	CD	L	0.83	9.9	--	--					
	SW	Jack Pine	CD	L	2.66	8.9	6	20					
	NW	Jack Pine	I	L	0.47	9.2	--	3					
E4	NE	Red Pine	D	L	2.09	17.4			2"	2"	None		55.9%
	SE	Jack Pine	CD	L	3.96	12.5	1	17					
	SW	Jack Pine	S	L	1.89	6.5	--	--					
	NW	Jack Pine	I	L	3.87	7.0	--	20					
E5	NE	Jack Pine	I	L	0.43	3.6	--	--	2"	2"	1.1m		60.6%
	SE	Jack Pine	S	L	1.42	3.4	--	3			1.11m		
	SW	Jack Pine	CD	L	0.53	7.4	--	6			1.1m		
	NW	Jack Pine	I	L	1.45	3.6	--	--			0.9m		
E6	NE	Jack Pine	I	L	1.33	6.8	--	7	1"	6"	0.91m	1.29m	67.4%
	SE	Jack Pine	CD	L	0.84	6.7	4	5			0.76m		
	SW	Jack Pine	S	L	0.86	4.1	7	--			1.3m	1.8cm	
	NW	Jack Pine	CD	L	2.00	4.6	2	6			1.4m		
E7	NE	Jack Pine	S	D	1.69	3.7	--	--	2.5"	11.5"	None		54.9%
	SE	Jack Pine	S	D	1.34	4.0	--	--					
	SW	Jack Pine	S	D	2.43	3.7	--	13					
	NW	Jack Pine	S	L	0.70	2.8	--	--					
E8	NE	Red Pine	CD	L	1.23	17.3			2.5"	>11.5"	None		81.9%
	SE	Jack Pine	CD	L	3.03	17.6	12	31					
	SW	Jack Pine	S	L	1.27	7.2	--	2					
	NW	Red Oak	I	L	1.07	10.5							
E9	NE	Jack Pine	CD	L	1.50	13.5	36	12	3.5"	6"	0.57m		76%
	SE	Grey Birch	I	L	3.85	3.7					0.55m		
	SW	Grey Birch	S	L	1.90	3.3							
	NW	Jack Pine	CD	L	1.06	14.0	4	--					
E10	NE	Red Maple	CD	L	3.52	7.1			--	--	None		19.4%
	SE	Jack Pine	D	L	1.17	24.6	30	18					
	SW	Jack Pine	S	D	2.94	3.0	--	--					
	NW	Red Pine	CD	L	1.80	17.4							
E11	NE	Jack Pine	D	L	4.10	20.8	270	--	--	--		1.0cm	30.9%
	SE	Red Pine	CD	L	3.22	17.5						0.8cm	
	SW	Red Pine	CD	L	3.30	5.7							
	NW	Red Oak	CD	L	7.95	13.2							

Site: Whalesback, MDI, ME. Date: 6-16-92 Analysts: C.P.L., W.A.P., III, M.E.M.

Transect & Plot Number	Quadrat	Species	Class	Live or Dead	Distance (m)	DBH (cm)	Cones		Soil Depth		Seedlings		Canopy Closure
							Closed	Open	Organic	Mineral	Height	DBH	
F1	NE	Red Spruce	CD	L	3.85	13.0			2.5"	7.5"	None		86.6%
	SE	Red Maple	CD	L	4.61	12.5							
	SW	Grey Birch	S	L	1.50	2.7							
	NW	White Spruce	CD	L	1.17	13.3							
F2	NE	Jack Pine	D	L	3.29	11.3	22	16	1.5"	1.5"		1.2cm	7.8%
	SE	Jack Pine	CD	L	4.15	8.8	--	1					
	SW	Jack Pine	D	L	5.28	20.5	2	--					
	NW	Jack Pine	CD	L	2.40	2.6	--	17					
F3	NE	Red Oak	CD	L	2.56	5.0			3.5"	9.5"	None		75%
	SE	Jack Pine	CD	L	2.10	6.1	1	3					
	SW	Jack Pine	I	L	2.42	4.4	--	1					
	NW	Red Spruce	I	L	3.21	10.5							

APPENDIX C

DIPLOXYLON PINE POLLEN MEASUREMENTS

Measurements in graticule units of whole, unadulterated grains.

[x1.63 for width in microns (μm)]

Jack Pine: Whalesback

	# of grains of each size per sample				
Size	A1	B1	C1	D1	E1
25	--	--	--	--	--
26	--	--	--	--	--
27	--	--	--	--	--
28	--	--	--	--	--
29	2	--	2	2	--
30	3	--	9	9	1
31	10	7	9	10	3
32	13	13	22	15	6
33	15	19	19	19	13
34	22	25	16	23	21
35	15	19	10	13	20
36	9	9	8	4	16
37	7	6	--	2	14
38	2	--	--	--	5
39	2	1	--	--	1
40	--	--	1	--	--
41	--	--	--	--	--
42	--	--	--	--	--
43	--	--	--	--	--
44	--	--	--	--	--
45	--	--	--	--	--

APPENDIX C

DIPLOXYLON PINE POLLEN MEASUREMENTS

Measurements in graticule units of whole, unadulterated grains.

[x1.63 for width in microns (μm)]

Jack Pine: The Tarn

	# of grains of each size per sample				
Size	A5	B5	C5	D5*	E5
25	--	--	--		--
26	--	--	--		--
27	--	1	--		--
28	--	--	1		--
29	2	2	8		5
30	3	8	16		4
31	4	13	16		5
32	10	18	20		8
33	21	18	10		17
34	27	16	13		20
35	19	15	7		21
36	9	5	6		10
37	4	3	2		6
38	--	--	1		5
39	1	1	--		3
40	--	--	--		--
41	--	--	--		1
42	--	--	--		--
43	--	--	--		--
44	--	--	--		--
45	--	--	--		--

* slide not analyzeable

APPENDIX C

DIPLOXYLON PINE POLLEN MEASUREMENTS

Measurements in graticule units of whole, unadulterated grains.

[x1.63 for width in microns (μm)]

Jack Pine: Cadillac Mtn.

	# of grains of each size per sample				
Size	A4	B4	C4	D4	E4
25	--	--	--	--	--
26	--	--	--	--	--
27	--	--	--	--	--
28	--	--	--	--	--
29	--	--	1	2	--
30	--	--	4	4	--
31	2	--	4	4	2
32	2	1	8	12	5
33	5	10	18	24	2
34	10	16	17	20	8
35	19	19	23	10	19
36	19	20	9	16	20
37	15	15	12	4	16
38	11	8	2	2	10
39	9	8	2	2	9
40	3	2	--	--	7
41	3	1	--	--	2
42	1	--	--	--	--
43	1	--	--	--	--
44	--	--	--	--	--
45	--	--	--	--	--

APPENDIX C

DIPLOXYLON PINE POLLEN MEASUREMENTS

Measurements in graticule units of whole, unadulterated grains.

[x1.63 for width in microns (µm)]

Jack Pine: Park Service Headquarters

	# of grains of each size per sample				
Size	A6	B6	C6	D6	E6
25	--	--	--	--	--
26	--	--	--	--	--
27	--	--	--	--	--
28	--	1	--	--	--
29	--	2	1	--	--
30	1	5	1	2	2
31	1	9	--	9	5
32	5	18	3	10	9
33	8	22	9	21	14
34	17	18	9	22	23
35	20	19	23	24	23
36	16	6	20	7	12
37	13	--	17	3	8
38	5	--	12	1	4
39	3	--	5	1	2
40	1	--	--	--	--
41	--	--	1	--	1
42	--	--	--	--	--
43	--	--	--	--	--
44	--	--	--	--	--
45	--	--	--	--	--

APPENDIX C

DIPLOXYLON PINE POLLEN MEASUREMENTS

Measurements in graticule units of whole, unadulterated grains.

[x1.63 for width in microns (μm)]

Jack Pine: Norumbega

	# of grains of each size per sample				
Size	A3*	B3	C3	D3	E3
25		--	--	--	--
26		--	--	--	--
27		--	--	--	--
28		--	--	1	--
29		2	--	4	5
30		2	4	8	8
31		3	3	4	10
32		9	10	11	11
33		14	12	12	14
34		24	17	20	19
35		21	25	14	19
36		14	14	8	6
37		4	6	6	2
38		4	6	5	3
39		--	2	5	3
40		--	1	2	--
41		--	--	--	--
42		--	--	--	--
43		--	--	--	--
44		--	3#	--	--
45		--	--	--	--

* slide unexaminable

possible pitch pine or red pine pollen contamination

APPENDIX C

DIPLOXYLON PINE POLLEN MEASUREMENTS

Measurements in graticule units of whole, unadulterated grains.

[x1.63 for width in microns (μm)]

Jack Pine: Park Loop Overpass

	# of grains of each size per sample				
Size	F1	F2	F3	F4	F5
25	--	--	--	--	--
26	--	--	--	--	--
27	--	--	--	--	--
28	--	--	--	1	--
29	--	--	1	--	2
30	--	5	1	--	2
31	--	5	1	2	5
32	4	11	5	7	6
33	6	13	8	8	13
34	9	20	11	17	17
35	12	19	13	20	26
36	11	7	18	13	13
37	21	9	16	15	9
38	22	7	15	7	4
39	12	3	7	6	3
40	3	1	3	2	--
41	--	--	1	2	--
42	--	--	--	--	--
43	--	--	--	--	--
44	--	--	--	--	--
45	--	--	--	--	--

APPENDIX C

DIPLOXYLON PINE POLLEN MEASUREMENTS

Measurements in graticule units of whole, unadulterated grains.

[x1.63 for width in microns (μm)]

Jack Pine: Schoodic Head

	# of grains of each size per sample				
Size	A2	B2	C2	D2	E2
25	--	--	--	--	--
26	--	--	--	--	--
27	--	--	--	--	--
28	--	--	--	--	--
29	2	--	--	--	--
30	2	--	--	--	--
31	2	1	--	--	--
32	4	--	--	2	1
33	6	5	1	2	4
34	17	12	2	13	14
35	27	19	7	19	15
36	19	14	17	21	16
37	14	16	16	20	15
38	4	12	16	10	15
39	1	11	17	8	11
40	2	7	14	4	6
41	--	3	7	1	3
42	--	--	1	--	--
43	--	--	1	--	--
44	--	--	1	--	--
45	--	--	--	--	--

APPENDIX C

DIPLOXYLON PINE POLLEN MEASUREMENTS

Measurements in graticule units of whole, unadulterated grains.

[x1.63 for width in microns (μm)]

Pitch Pine # of grains of each size per sample

Size	I8	J8	K8	L8	F6
35	--	--	--	--	--
36	--	--	--	--	--
37	--	1	--	--	--
38	--	--	--	--	2
39	--	1	--	--	2
40	--	2	--	1	5
41	--	6	--	1	8
42	--	7	--	--	10
43	--	8	1	--	15
44	1	3	1	--	14
45	2	14	2	2	22
46	3	11	6	3	13
47	6	13	11	2	6
48	7	15	14	3	1
49	10	7	12	6	1
50	10	8	18	15	--
51	10	2	11	19	--
52	5	2	7	12	1
53	11	--	12	9	--
54	6	--	3	9	--
55	7	--	2	9	--
56	4	--	--	--	--
57	3	--	--	7	--
58	3	--	--	1	--
59	4	--	--	1	--
60	2	--	--	--	--
61	2	--	--	--	--
62	2	--	--	--	--
63	--	--	--	--	--
64	2	--	--	--	--
65	--	--	--	--	--

APPENDIX C

DIPLOXYLON PINE POLLEN MEASUREMENTS

Measurements in graticule units of whole, unadulterated grains.

[x1.63 for width in microns (μm)]

Red Pine	# of grains of each size per sample				
Size	A7	B7	D7*	E7	F7
32	--	--		--	--
33	1	--		1	--
34	2	--		--	--
35	2	--		2	--
36	5	1		3	
37	4	3		6	4
38	4	2		10	3
39	11	4		23	4
40	21	13		26	9
41	16	14		13	13
42	11	15		9	16
43	5	11		3	16
44	4	11		3	8
45	5	12		1	10
46	2	11		--	11
47	1	1		--	3
48	4	2		--	1
49	--	1		--	1
50	2	--		--	1
51	--	--		--	--
52	--	--		--	--

* most grains unmeasureable, bladders not fully formed.

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