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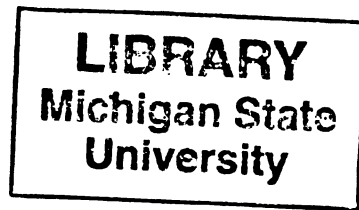
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**Vegetation distribution on an inland dune in Ross Preserve,
Southwestern Michigan.**

By Ann Colt

A THESIS

**Submitted to
Michigan State University
in partial fulfillment of the requirements
for the degree of**

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ABSTRACT

Vegetation distribution on an inland dune in Ross Preserve, Southwestern Michigan.

By Ann Colt

This study examined the effects of overstory trees on understory plant cover on an inland dune system, near the eastern shore of Lake Michigan. The dune community was divided into three overstory categories: pine, hardwood and a mix of pine and hardwood. The three categories were compared for differences in abundance and size of seedling and sapling trees in the understory. The ground flora was compared for diversity, species richness and amount of plant cover.

The understories of all the stands contained at least five genera of seedlings under one meter in height: *Sassafras*, *Prunus*, *Acer*, *Quercus* and *Fraxinus*. None of these trees was found growing above one meter in height: in the pine stand, but they were present in both the hardwood and mixed stands as saplings. This finding suggests that although the seeds are able to infiltrate and germinate in all areas, survival under the pines may be more limited. The ground flora under the pine showed less diversity, less species richness and lower ground cover compared to both the hardwood and mixed areas.

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Introduction

This thesis is about a vegetative survey on a wooded sand dune ridge in the Ross Preserve, a 560 acre preserve located in the southwestern corner of Covert Township in Van Buren county MI, less than a kilometer from Lake Michigan. The Nature Conservancy (TNC) acquired the preserve in 1994 to preserve its coastal wetland areas. TNC is interested in managing the ridge to encourage pre-European settlement conditions. TNC acquired Ross Preserve because the region is under heavy threat from developers for second homes or vacation areas close to Lake Michigan in a bucolic setting. The Sarett Nature Center has been given stewardship of Ross Preserve and has been using it to educate elementary school children.

Ross is within 0.8 and 1.2 km from the lakeshore, contains approximately 560 hectares and a wide variety of species-rich habitats. It is located on an inland dune system, which, although common around Great Lakes, is rare on a global scale. The habitats include wooded inland dunes, wetlands, small lakes and northern hardwood forests. It contains the best coastal plain marshes in Michigan, a habitat common to the Atlantic Coast, with rare plants such as Virginia meadow beauty and the globe fruited seedbox (Venner, 1991; TNC, 1996). The interdunal wetland communities have remained virtually untouched since European settlement, and have been a haven for seven state-threatened plants, three special-concern plants and three special-concern vertebrate species (TNC documentation).

Between the preserve's lowland areas there are upland dunal ridges that harbor a plantation of red and mixed pines. The ridge includes red pines, which are outside of their natural range and some European imports such as Austrian and scotch pines. TNC

expressed interest in managing this upland ridge in a way that will discourage exotic pines in favor of species that were prevalent before European settlement.

An interdunal ridge was studied for the purpose of collecting information that would help managers of Ross Preserve in their efforts to reconvert the upland dunes. A census was taken of overstory trees and the understory vegetation on the ridge, which could be used by managers to compare the progress of the dune flora over time. The data was used to address two questions. Does the overstory tree composition affect the process of succession within Ross Preserve? Does the overstory differ in characteristics of the ground cover between the pine and hardwood forests, including: species richness and distribution, abundance of ground cover, and species diversity?

Literature review of the Ross Preserve area

The history of Ross Preserve affects how it should be managed to recreate conditions of the past. This chapter contains a history of geology and human impact in southwestern Michigan. It also contains the preservation issues of Michigan Dunes, description of plant distribution on the dunes, a description of Ross Preserve, description of the pre-European settlement tree cover at Ross Preserve, a project justification, and the study questions.

Geological History of Southwestern Michigan

Events in the geological history of Ross formed the soil and terrain that has affects the ecology of the preserve. The soils at Ross are a direct result of the Pleistocene Ice Age in North America. Lake Michigan and the sand dunes surrounding it were formed as a series of glaciers advanced and retreated over the current Great Lakes Basin beginning 500,000 years ago and ending with the retreat of the Wisconsin Glacier 12,000 years ago. The Wisconsin ice sheet gouged through pre-glacial drainage valleys and depressions as it advanced southward from Canada with an uneven front consisting of the Erie, Saginaw-Huron and Michigan lobes. The Great Lakes Basin filled with melt water as the Glacier retreated. The water eventually found an outlet near Chicago, which emptied into the Mississippi River. This outlet lasted until another outlet was formed in the north at the Strait of Mackinaw. As different outlets opened and deepened, the surface levels of the ancient Great Lakes Basin lakes progressively

lowered, depositing a discontinuous ring of sand around the current shoreline, before rising again to their current elevations. The ancient Lake Michigan water basin reached its highest elevation, 605 feet above sea level, during the Algonquin stage around 11,500 years ago. During the Lake Chippewa stage, 9,500 years ago, it reached its lowest level at 230 feet above sea level. The Lake rose again to attain 595 feet during the Lake Nipissing era around 4,500 years ago, during which era the tall dune ridges at Ross Preserve were formed (Dorr and Eschman, 1979).

Since the Nipissing stage, Lake Michigan has receded gradually to its current elevation of approximately 580 feet. The bedrock below the sand was formed during the Paleozoic era when a series of inland seas covered and retreated across North America (Dorr and Eschman, 1979). As a result of the glaciers and favorable wind conditions, the dunes along Lake Michigan collectively represent one of the largest accumulations of sand along any fresh water body in the world. This is particularly true of the eastern shoreline of Lake Michigan where coastal dune comprises 13% of the 450 km long shoreline, in a strip between 1.6 and 4.8 km (Wells and Thompson, 1982).

Human Impact on Southwestern Michigan

The southwest region of Michigan where the study took place had long been impacted by human activity. The land had been occupied by agriculturally based American Indians at least as far back as 1,000 to 1,500 years ago (Bowman, 1986). When American colonialists arrived in the 1800's, the area held people of the Potawatomi, Odawa, and Ojibiwe Nations. The Nature Conservancy (TNC) sources

estimate that there were between 60,000 to 117,000 Native Americans residing in the Great Lakes area when the first European settlers arrived in the late 1820's. These European settlers arrived in Van Buren County after the local Native Americans ceded all the land within Van Buren County to the American Government as a result of a treaty signed in 1821 (Bowman, 1986).

Characteristics of the area, including the dominant tree cover, had been extensively surveyed in Michigan between the dates of 1816 and 1865 by the General Land Office (Comer *et al.*, 1995). The purpose of these surveys was to delineate parcels of land for sale to settlers by carefully recording natural features. The survey was completed in Van Buren County before the arrival of Euro-Americans. Information from these surveys includes dominant tree species, landform, human impact, and location of American Indian villages during the time of the survey.

Logging throughout the State of Michigan began in 1830 and was the state's first commercial enterprise. The first loggers in Michigan harvested white pine, which in some areas grew up to 60 meters in height and contained 6,000 board feet of lumber in each tree (TNC, 1994). Once the pines were exhausted, settlers harvested other available species such as maples, walnuts and oaks (TNC, 1994). Settlers in Van Buren County switched to agriculture after the timber resources were consumed (Bowman, 1986). Since then, forest have been confined to small farm woodlots and narrow bands along wet stream bottoms (Bowman, 1986). Land in Van Buren County was quickly claimed and put to use, so that by the mid 1800's no more additional land was available for agriculture (TNC, 1994).

The soils derived from primarily sandy glacial deposits are more suited to forests than they are to European-style agriculture (Bowman, 1986; Lehotsky, 1942). Once released from tree cover they are subject to heavy wind erosion. The effects of forest removal and the process of recovering the land was documented in Lehotsky's writings in 1942 and 1972 for Ottawa and Muskegon Counties. The largest town in Ottawa County in the early 1900's was Sullivan, which had 100 households and numerous businesses in 1890. In 1939 Sullivan had 1,610 acres of wind-affected land. By 1941 there were only eight scattered houses left on the periphery of Sullivan, which became known as the "Sullivan Sahara." Muskegon and Ottawa Counties had a combined total of 39,000 acres of freed sand dunes in 1942. Lehotsky cited one extreme example of a 75-acre farm where by 1939 only five acres of the land were still capable of sustaining agriculture while the other 70 acres had become a tax liability. The region became uninhabitable during windstorms because houses could not be built tightly enough to keep out blowing sand. Land values became severely depressed, dropping from \$31 per acre in Muskegon County in 1920 to \$1 or less per acre in 1940.

The first attempt at land stabilization in the Ottawa-Muskegon area was in 1920 when a private landowner and a railroad company temporarily stabilized some land using beach grasses. Lehotsky, an employee of the Forest Service, studied the sand dune stabilization efforts in Germany and transferred the knowledge to the Ottawa-Muskegon community soil stabilization. This included establishing a ground cover of either beach grasses or dead brush material or picket fencing, and planting a mixture of pine species at a spacing of 1.2 by 1.5 meters to ensure that the canopy would close quickly, expediting the stabilization process. Pine was considered the best choice for

land stabilization because other dune species such as poplars and willow tended to experience blowouts after several years of successful stabilization (Lehotsky, 1942). The Soil Conservation Districts were created in the 1930's in Ottawa and Muskegon Counties for the purpose of stabilizing soil using Lehotsky's techniques. County agricultural agents, landowners and volunteers undertook a concerted effort to stabilize moving sand in the late 1930's and 40's. Agricultural agents established pine tree nurseries, and landowners were encouraged to plant a mix of pines on both private and public lands. The original plan called for the trees to be thinned along the way and harvested on an 80-year saw log rotation. This time frame was chosen to balance out the need to build a layer of organic matter and bring a monetary profit to the landowner. By 1940 close to two million trees were planted in Muskegon and Ottawa Counties. By 1972 the problem of blowing sand had been long solved and industries based on woody species became profitable. Christmas tree farming and blueberry production are now common industries in Van Buren County (Bowman, 1986). Although afforestation efforts in Ross Preserve are not as well documented as in Ottawa or Muskegon County, Ross has gone through the same changes. According to Chuck Nelson of the Sarrett Nature Center, the original owners of Ross Preserve were farmers, who gradually experienced diminishing yields as the soil gradually gave way to freely moving sand. As a result the farmers sold the land to the Ross family in the mid 1900's. The Ross family bought the property for a vacation area. On a ridge that had been cleared and was subject to heavily blowing sand, they planted a mixture of red pines, Austrian pines, Scotch pines and white pines in a spacing of 3 by 3 meters.

The Preservation and Ecology of Michigan Sand Dune Areas

Before considering a management plan for Ross Preserve, it is important to consider legal, social, and economic issues. In 1976 Governor Milliken signed into law the Sand Dune Protection and Management Act, PA 222, which calls for the wise use and protection of Michigan's dunes and dune-like formations. Sand dunes areas were legally defined as "geomorphic features composed primarily of sand, whether wind blown or other origin and which lie within two miles of the ordinary high water mark on a Great Lake." (Wells and Thompson, 1982). Sand dunes in Michigan are under legal protection primarily as a result of the formerly thriving Michigan sand mining industry. In 1976 more than 5 million tons of sand were mined, creating a profit of 40 million dollars (Wells and Thompson, 1982). Michigan sand is considered to be of high quality because of its purity and rounded grain structure; the grains range in size from 1/16th to 2 millimeters in size (Holland and Reid, 1996). Previous to 1976, mining became perceived as a threat to dune preservation and was the center of a controversy between the industry and conservationists (Buckler, 1979), until sand mining was banned.

Since the passage of the act, the State has made efforts to evaluate dune ecosystems' sensitivity to residential, recreational, and industrial development and environmental value of lake shore dunes through the Land Resource Programs' Coastal Zone Management Unit within the Michigan Department of Natural Resources and the TNC. The Michigan Natural Features Inventory (MNFI) was founded in 1980 as a joint venture of the TNC and the Michigan Department of Natural Resources to collect extensive information on the biological resources in Michigan dunelands. Since then the

MNFI has become Michigan's storehouse of information on natural communities, sensitive plant and animal species and other noteworthy features.

The region is of concern to Michigan natural history because it contains high levels of species richness, and is the last refuge for some plant and animal assemblages.

Southwestern Michigan dunes contain imperiled species, species vulnerable to extinction within their own ranges through the entire Great Lakes Basin (Fuller and Shear, 1996).

They are situated along a heavily traveled migration route for neotropical birds. At least 117 different bird species were sighted in the area between 1935 and 1973, and the region serves as a breeding ground for at least 14 species of birds (Medley and Booth).

The potential for biodiversity in the region is demonstrated in the well-documented Indiana Dunes National Lakeshore, which ranks third in plant species richness of all US National Parks in spite of its relatively small size.

The MNFI has identified six major cover types within the designated dune areas of southwest Michigan: open dune, interdunal wetland, boreal forest, mesic northern forest, Great Lakes barrens and sand/gravel beach (Reese *et al.*, 1986; Chapman *et al.*, 1985). Forested areas in southwest Michigan are predominately beech - sugar maple forests, oak forests, savannas or open dune (Albert, 1994). More localized area around Ross Preserve is characterized as dominated by beech/sugar maple mix with some white and black oak, with several large areas of open, blowing sand (Albert, 1994).

Distribution of Plants on the Eastern Shore of Lake Michigan

The area where the study took place is on a stabilized dune. If the area were denuded of vegetation, reinvading plant species would have to respond to the changed environment. The following is a discussion of open to semi-stabilized dunes on the Eastern Shore of Lake Michigan.

The biological processes in dune ecosystems inspire interesting questions about species selection, adaptation environments and succession. The dunes in the Lake Michigan Basin first drew scientific interest when Cowles published his observations in 1899, characterizing succession of plant assemblages on Indiana dunes. Cowles observed that near the waters' edge there are few plants, as potential growth processes are continually disturbed beyond the capacity of plants to overcome. These sands are constantly moving and shifting, are poor in mineral nutrients, heat and cool rapidly, and do not readily develop a humus layer because of rapid oxidation. A few species of plants, such as marram grasses and milkweed will survive in these harsh conditions because they have a deep root system, and they elongate their stems to keep pace with constant sand deposition. These plants are considered dune builders because they capture slowly moving dunes or at least slow their passage. However, they cannot contain fast moving dunes and eventually blowouts occur.

Shoreward plants and topographical features work to create buffers that improve and stabilize conditions allowing longer lived species to thrive further inland (Cowles, 1899). Slightly inland, where the wind is buffered by one or more previous dune formations, dunes are more strongly stabilized by vegetation. The grasses are replaced

by shrubs of the genera *Cornus*, *Salix* and *Prunus* which are able to elongate their stems to adapt to the changing dune height and are the first woody species to colonize dunes (Marino, 1980; Olsen 1958; Cowles, 1899). Under these conditions humus starts to accumulate, further stabilizing the soil, which allows low vegetation such as lichens, mosses and forest herbs to grow. The aggregation of plants and the topographical relief caused by windward dunes shelter leeward areas so that growing conditions improve away from the beach. All areas, however, are still subject to periodic random blowouts. Places where long-lived forest species have replaced the early successional trees are able to maintain a comparatively stable soil environment.

Generalizing the patterns of species distribution is difficult. Dunes are complicated because of their physical features, such as the air flow over the dunes, topography (which is in the process of general or intermittent change through wind action), and the distribution of the vegetation which influences both air flow and soil stability. While early successional build up soil near the shore, inland, primary successional species such as basswood, poplar and hophornbean continually invade the dunes from the sheltered forest edge. As humus builds and the soil stabilizes the trees are able to encroach slowly towards the shore. Soil structure on dune areas can evidently be made amenable for late successional species as, evidenced by the presence of maple and beech on the older inland dunes that are lower and sheltered by the tall dunes formed during the Lake Nipissing era. The factor most responsible for precluding a climax community of maple and beech from inhabiting areas closer to the shoreline appears to be the frequent periodicity of disturbance.

Disturbance patterns are instrumental in maintaining certain species within communities, thus increasing biodiversity (Riece, 1994; Goldberg and Gross, 1988). Riece (1994) wrote that periodicity of disturbance is a strong component in determining natural communities, that “community structure is primarily determined in a nonequilibrium fashion by the interactions of the heterogeneity of the physical-chemical environment, disturbance and recruitment.” He also suggested that “the normal state of communities and ecosystems is to be recovering from the last disturbance.” This view applies to the dune area, where frequent disturbances are pushing communities back from the so-called “climax communities.”

The windward and leeward slopes differ in environment and species based on disturbance patterns (Marino, 1980; Olsen, 1958; Cowles 1899). Windward slopes face desiccating winds, an influx of sand, burial and root exposure, especially close to the lake shore. Leeward areas are buffered from direct wind and constant direct sand blasting and scouring. Trees and shrubs that grow on foredunes, such as poplar, cherry and hophornbean, generally start their growth on the lee side of the dunes that have been captured by beech grasses (Cowles, 1899). Conifers often settle on the windward side of the slopes and in general are associated with steep slopes and dry summits, while deciduous trees occupy more mesic areas (Cowles, 1899). Occasional deciduous trees mix in with the evergreens, but only on protected forest margins (Cowles, 1899). Neither maple nor beech are common or well-adapted on the foredune areas.

The most extensive period of dune development occurred during the waning of the Lake Nipissing glacial lake stage (Dorr and Eschman, 1979); the largest dunes of today are believed to be associated with this period. The Nipissing dunes commonly appear

as impressive barriers separating the shoreline and inland environments (Buckler, 1979). These dunes are permanent, even though small portions may be lost to wave erosion during prolonged high water periods (Buckler, 1979). Upland regions of the Nippissing dunes are relatively stable and are dominated by a stable maple-beech forest. Oak forests grow on older dunes behind the Nippissing formation, creating an open scrubby forest (Cowles 1899). These oak forests are located on low, relatively flat dunes, where he observed few shrubs present in the oaks except along the edge of marshes, and a large presence of herbaceous plants. Shrubs that did occur were blueberry, willow, viburnum, rose and sumac species. Other trees he found in association with the oak dunes were sassafras, redbud, flowering dogwood, and witch hazel. Jack pine, traditionally found in more northern latitudes, is present in low depressions or “pine bottoms” where the soil is hydrophytic.

Burial of forests occurs when established dunes are released, killing the vegetation as the dune passes again into a state of activity. Cowles (1899) termed released dunes “rejuvenated dunes”, which can occur on any dune regardless of the type of vegetative cover or phase of establishment, even forested dunes. A disproportionately high number of these blowouts on forested dunes occur on conifer dunes as compared to deciduous dunes (Cowles, 1899). Once a patch of soil is exposed in the stand and a sweep is formed, there is a tendency for the sweep to self perpetuate with progressively stronger force as the wind becomes more concentrated and the sweep becomes deeper. As the wind becomes more concentrated, the blasting sand tears the soft parts of trees away. The removal of sand undermines the tree roots and removes support so that the tree falls, further reducing the soil resistance to wind effects. Sometimes a buried forest

becomes unburied as the freed dune progresses across the landscape. These forests generally are jack pine, oak and silver maple, according to Cowles (1899).

Dunes in southwest Michigan are a dynamic system, where patterns of herbaceous plant distribution are determined by life history strategy (Marino, 1980). The three strategies identified by Marino (1980) on the dunes were early successional “r-selected” species, late successional or “K-selected” species and “stress tolerators”.

Species classified as “stress tolerators”, exist in harsh, high-disturbance areas where they don’t face competition from other species. Natural selection gives them certain characteristics that enable their survival in harsh conditions. These plants take longer until first reproduction in order to gather enough resources to produce large seeds (Marino, 1980). The harsh conditions and lack of resources forces seedlings to quickly develop a large root system. Constant burial forces them to grow rapidly, thus their seeds need to contain a large energy reserve. They would reproduce only once, but may delay reproduction for a few years in order to build up sufficient resources. Plants with the characteristics of “stress tolerators” are found on the windward side of foredunes.

Species classified as “r” strategists are also density independent, but exist in less harsh conditions than “stress tolerators”. These species tend to be short lived and devote more of their resources to reproduction as compared to growth. They have few chances for spreading their progeny and so produce a large number of small-sized seeds. These plants are generally found on the leeward side of foredunes, where conditions are improved by the wind shadow, although there is still sand deposition and desiccating winds.

The longer lived “K” species live in stable mesic conditions, where mortality tends to be density dependent or as a result of competition for resources. These species invest in long-term strategies for survival and propagation. They devote more of their resources to internal structure before they start reproducing, producing fewer seeds per year but continuing to produce over many years. The seeds of “K” strategists tend to be large such that more resources are devoted per seed. They are most likely to occupy stable forested areas.

The broad patterns described by successional pioneer scientists such as Cowles (1899) and Olsen (1958) are readily discernible in Warren Dunes and Warren Woods. These natural areas lie about 50 km to the south of Ross Preserve and are good examples of a relatively intact dune ecosystem (Herman, personal communication, 1997) and are probably similar to the communities that used to be present at Ross Preserve. Close to the shore, marram grasses captured the sand and built up the dunes, so that they became elevated. Further back, the grasses are mixed with poplar trees and the occasional fire cherry, where all are subject to sand blasting on a windy day. In the lowland areas, there are thicker carpets of grasses, shrubs and trees, which are followed further away by oaks and some evergreens. These trees are quickly replaced by a maple-beech association, with ash, oak and tulip trees as associates in areas that are more stable and undisturbed. Swampy areas are occupied by blue beech, hophornbean, sugar maple, basswood, tamarack, and white pine.

Description of Ross Preserve

The preserve has been farmed in the past and remnants of its history remain – an old horse drawn plow, the remnants of an old building, an artificial pond that the former owners made for recreational purposes, the pine plantation and a high-graded woodland. Much of the pre-European forests have been high graded while other areas that were cleared for agriculture have been reforested in pine trees to stabilize the sand (Charles Nelson, personal communication, 1995).

The general terrain characteristics in Ross Preserve vary, from the flat, 0 to 4% slopes, to steep slopes, 2 to 60%. The wet or flooded low-lying areas have Oakville and Kingstone-Pipestone soils. The steep dunes tend to be Covert sand, which was deposited during the Lake Nipissing stage of Lake Michigan stage (Chuck Nelson, personal communication, 1995). The elevation in Ross is between 186 and 198 meters above sea level, and the water saturation zone tends to be close to 188 meters (TNC, 1995). The soils of Ross are Oakville fine sand, Covert sand and the Pipestone-Kingsville complex (Venner, 1991; Bowman, 1986).

Oakville fine sand soils are found on the upland dunes and as their name implies they are formed predominately from sand. They also are well drained, rapidly permeable, and have slopes of 2 to 60 percent. These dunes are commonly subject to blowouts if a disturbance is created on a once stable dune (Venner, 1991). I observed at least one small blowout in Ross within the pine plantation in 1995. When these soils are stabilized, they are capable of supporting hardwoods, conifers and herbaceous plants as

well as woodland wildlife. This soil is unsuitable for general agriculture (Venner, 1991; Bowman, 1986).

The Covert sand is found in relatively flat areas, 0 to 4% slope, on narrow ridge tops and in lake plains. Like the Oakville soils, these soils are a loose, rapidly permeable sand with low-water storage capacity and a high seasonal water table, 60 to 105 cm below surface level from November to April. These soils often support grassland or woodland and are unsuitable for agriculture.

The Pipestone-Kingsville complex consists of a mixture of both Pipestone and Kingsville soils in such close association that it is difficult to separate them geographically. This association is different than the other soil types in that it is found in the flat, low-lying, often water-saturated areas. Kingsville is made up of poorly drained to very poorly drained soils in depressions and waterways. The high water table of Kingsville soils is at or above the surface from January to April. Pipestone soil has a thick surface of fine sand about 125 mm thick, with substrata of very friable fine sand. The seasonal high water table of Pipestone is 15 to 45 cm below the soil surface from October to June. Kingsville and Pipestone experience droughtiness in the summer and an excess of water during the winter months.

Ross Preserve lies approximately within 0.8 and 1.2 km from the lake shore and is climatically influenced by the weather patterns caused by the prevailing westerly winds that cross Lake Michigan and modify year round temperatures (Roch, 1992; Venner, 1991; Carthey 1990). As Venner (1991) points out, the assemblages of plants are strongly influenced by the weather patterns. The 1990 USDA Plant Hardiness Zone Map classified the area along southwest Michigan by the lakeshore as having warmer

than expected winter minimum temperatures. In western Van Buren County the yearly average minimum temperature is -17.8°C to -20.5°C while most of the rest of the lower peninsula of Michigan has a yearly average minimum temperature of -23.4°C to -26.1°C (Carthey, 1990). The region summer temperatures are also cooler than the rest of the Lower Michigan peninsula and have on average 11 days that exceed 32°C (90°F) (Venner, 1991). As a result plant associations that are usually restricted to more southerly or northerly geographic distributions are found along the Michigan lake shore (Venner, 1991; Roch, 1992). For example, there are tamarack swamps south of their normal range, and hemlock in particular is found down almost the entire length of the western Lake Michigan shore, well beyond its southern limit for the rest of the state (personal observation, 1996; Burns and Honkala, 1990; Roch, 1992).

Pre-European Settlement Tree Cover

The area around Ross Preserve was originally surveyed in April 1827 and May 1830 by the General Land Office (GLO). These surveys show dominant trees and prominent features along points on a grid with lines spaced one mile apart. Samples were taken at every section corner and every half-mile, and were based on conspicuous “witness trees.” These trees tended to be easily marked long-lived species more than four inches in diameter. Albert *et al.* (1994) used these surveys along with U.S. Geological Topographical maps (1:24,000 scale) to delineate land cover types and wetland boundaries.

Using a combination of the GLO surveys, soil surveys, topographical maps, current vegetation maps, geographical information, and historical references, Roch (1992) and later Comer et al. (1995) assembled a map relating forest cover to soil, topography, and other features in southwestern Michigan. These data can be used to reconstruct the appearance of Ross in the late 1820's. Ross Preserve contained elevated wooded dune communities over which are juxtaposed ponds, marshes and a hardwood-conifer swamp. Roch (1992) identified five distinct forest communities: wooded dunes, hardwood-conifer forest, hemlock-hardwood swamp, mesic southern forest, and southern floodplain forest.

A mesic to dry northern forest, dominated by a hemlock-hardwood association, used to exist, in a roughly two mile north to south wedge-shaped strip along the coast on a system of steep coastal dunes. This forest occurred mainly on steep well-drained dunes of Oakville fine sand soils, occasionally in moderately drained sandy soils, and partially into the poorly to moderately drained sandy soils associated with the sandy lake plain. The dominant tree species of this area included eastern hemlock, American beech, sugar maple, white oak, red oak, and white pine. Associated species included hophornbean, black oak, sassafras and black cherry.

The tamarack swamps were confined to shallow depressions along the eastern edge of the wooded dunes and in isolated depressions to the northeast and southeast portions of the preserve. The soils in these swamps are a mixture of Houghton mucks and poorly drained Pipestone-Kingstone soils and were dominated by eastern hemlock and tamarack; associated species were white pine, red maple, black ash, speckled alder and American elm.

Most of the southeastern portion of the preserve consisted of a mesic southern forest community, except for the ponded areas and the wedge of hemlock-hardwood forest that tapers off in the southern portion of the preserve. This is a region of level to hilly terrain with typically moderate to well-drained sandy loams. The southwestern area of Ross where this last cover type is found is characteristic of a lake plain with moraines (Albert 1994). It was dominated by American beech and sugar maple, with associated species including oak, black ash, and poplar species.

The most frequently encountered species in Ross were American beech at 47%, maple species at 14%, eastern hemlock at 9% and other at 30%. Other consists of black ash, elm species, white oak, hickory species, poplar species, hophornbeam, American sycamore, birch species, ash species, basswood, white pine, black cherry, and tulip tree (Fig. 2.1). Fire probably wasn't a source of disturbance along the southwestern border of Michigan, based on the mesic nature of the forest composition (Roch, 1992; Venner, 1991). Dunes further south, receive fewer lake breezes, have less relief, and are far more likely to experience periodic fires (Venner, 1991). These more southern dunes are dominated by drought and fire resistant black oak. Ross Preserve is near the southern limit of the mesic forest community (Venner, 1991).

Study Questions

The dune ridge studied for this project does not have the same pre-European settlement forest cover. The native trees were either high-graded or removed and replaced with planted pine. Eventually the ridge in Ross Preserve will be managed in a

way that encourages indigenous plant communities to succeed the planted pine. This preliminary study was done to get base line data points for future vegetative studies and assess if or how natural succession is taking place on the ridge. This information will become valuable for further research in Ross Preserve.

Research question 1) Does the overstory tree composition affect the process of succession within Ross Preserve?

Justification

The species in a mature forest will have an influence on the types of trees that can survive in the understory and will therefore have an effect on succession. The process of succession in Ross could be predicted by looking at the presence and size classes of saplings in the understory of both hardwood stands and the pine plantation and comparing them to the presence of available seed sources. Canham *et al.* (1994) indicated that forest cover could influence succession through light extinction. They showed that the amount of light that is filtered through the canopy is highly correlated with the successional stage of the species in question and that all species have a higher survivorship in the shade cast by their conspecifics, relative to the shade of more shade tolerant species. Soil development is also affected by overstory species composition, and may potentially be another way by which trees could influence succession (Griffith *et al.* 1930, Wardenaar and Sevink 1992). This was demonstrated by

Wardenaar and Sevink (1992) who studied 80-year-old stands on sand dunes in the Netherlands and saw a divergence in soil development based on whether the soil was under a Scotch pine plantation or a Lombardy poplar volunteer forest.

Research question 2)

Does the overstory cause differences in characteristics of the ground cover between the pine and hardwood forests, including:

- a) species richness and distribution
- b) abundance of ground cover
- c) species diversity

Justification

Ovington (1950) has shown that as the pine forests stabilize dunes, the ground flora composition undergoes shifts in response to soil development and other changes in environmental conditions. Soil layer development is different under a hardwood forest compared to pine (Wardenaar and Sevink 1992, Griffith et al. 1930). The pine forest develop a larger undecomposed litter layer, clearly defined soil horizons and very little active soil fauna, whereas the hardwood forest would have a thinner layer of readily decomposable litter, a wavy or blurred transition between soil horizons, and more active soil fauna. The ground flora of Ross Preserve probably has been determined in part by whether the overstory is hardwood or pine. Since a goal of TNC is to preserve

native indigenous species, understanding the influence of dominant trees on the distribution of native species in the herbaceous layer is an important objective. The study will impact silviculturists and forest managers who need to prescribe management techniques to encourage desirable species, increase biodiversity, or understand how disturbances work to structure an ecosystem.

Chapter Two

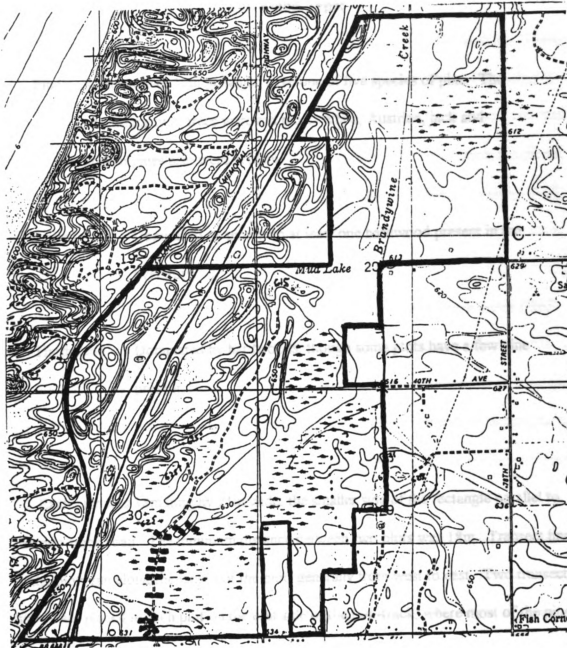
Methods

The first part of this chapter explains how the data were collected. The second part describes how the plots were divided into three categories based on overstory tree composition.

Data Collection

Data were collected along a north-south running dune ridge in Ross Preserve. The ridge was divided on the top by a two-track, a small dirt road. On the east side of the track was a pine plantation consisting mostly of red pine, while the west side of the track was a high-graded hardwood stand dominated by sassafras. According to the Government Land Office (GLO) (Comer *et al.*, 1995), the ridge contained a hemlock-hardwood forest before it was either cleared or highgraded by previous owners. Before European settlement the ridge was surrounded by and closely abutted a tamarack dominated wetland on one side (Comer *et al.*, 1995). Data were taken in both the hardwood stand and in the pine stand to characterize the vegetation dynamics in both regions.

A total of 24 plots were laid out along the ridge, within the pine plantation and hardwood forest (Figure 2.1). The overstory data indicated that the two forest types overlapped in some plots (see chapter four for data). For this reason, after the data were collected, the plots were separated into three stand types based on the tree census.



Scale 1 : 24,000

0 .5 1 Kilometer

Figure 2.1 Arrangement of plots in Ross Preserve. The thick line represents the boundary of Ross Preserve in 1996. The small rectangles represent 24, 25 m² plots. The stand types were: pine, mixed and hardwood forests using the criteria listed in table 3.1. (Source MNFI, 1997).

Table 2.1 description of the three stand types.

Stand Type:

Pine - All trees over 10m in height were one of five species of pine. The vast majority of trees were red pine. White, Austrian, jack and Scotch pines also were present.

Mixed - Dominated by pine with at least one hardwood present in the overstory.

Hardwood - Dominated by hardwoods, though some plots have a few pine present.

Each plot was 38m long by 21m wide, the smaller side of the rectangle parallel to the two-track road. The minimum distance between two plots was 18m. Transect lines in the plots ran along the length of the plot, generally from west to east. Two transect lines were placed in each plot on the east side of the two-track, where most of the pine stands were located. Only one transect line was placed in the plots on the west side of the two-track, where most of the hardwood stands were located. Each transect line had six data collection points, 5m apart. The first point was 5m away from the end bordering the two track to avoid edge effects.

Analyses

This section describes the analyses used to address the two study questions. There are four series of analyses described here. The first part explains the analyses used to describe the character of the entire research area and each of the three stand types, the next three describe the analyses needed to address each of the two research questions.

Four data sets were taken in each plot: (1) a stand density index; (2) census of all tree species in three height categories; (3) an inventory of all ground flora under 1m in height; and (4) tree core samples.

Stand density was calculated using an angle gauge with a basal area factor (BAF English) of 20. Three points were taken within each pine plot and two were taken in each hardwood plot. The heights of the two tallest trees were recorded for each sample point. These data were used to calculate: (1) the diameter distribution of all species, (2) the number of trees per ha, and (3) the volume of wood per ha. These three calculations were used to characterize Ross Preserve as a whole.

A *tree census* was taken at ten sample points per plot in the pine stands and five samples in the hardwood stands, each sample having an area of 25m². The trees were divided into three height categories: 1 to 5, 5 to 10, and above 10m. These data were used to describe the vertical structure in each plot by determining the number and species of trees in the understory, which predicts the future composition of the canopy.

Ground cover was sampled using a 1m² square frame, randomly placed on one of four quadrants at each transect sample point. All plants under 1m in height were considered. In each sample, the ground flora was estimated using the percent of ground

each species covered within the 1m² frame. These data were used to determine the number of understory species, the abundance of ground cover and the distribution of ground flora species among the three overstory categories.

Tree core samples were taken at breast height from the dominant hardwood, where present, and from a pine in each plot. Pine trees were all similar in diameter. These data were used to compare the ages of the dominant hardwoods to the pine plantation. Tree ages were calculated by counting the number of tree rings and adding five years. Five years was an estimate of how long the tree took to reach breast height.

Measurements for the entire research area were calculated, including the tree stand density, distribution of the dbh, and tree age. Stand density and the distribution of diameter were calculated from the tree expansion factor for a 20 BAF prism (Marty, 1984).

Species diversity

Diversity is a concept for which many different measures have been proposed (Magurran 1988). Diversity indices use a balance of species richness, total number of all individual plants present and the evenness of species distribution. Evenness refers to the balance of species populations; an even distribution means that all species present have roughly the same number of individuals. An uneven distribution means that only a few of the species present are commonly encountered and the majority of species are rarely encountered. Diversity was calculated with the Brillouin diversity index.

The Brillouin diversity index was calculated to determine differences in diversity between the stand types. The Brillouin diversity index was used because according to Pielou (Margurran, 1988), it has been shown to place a higher diversity score on areas which have more individuals present than the Shannon-Weaver index. In contrived data sets, the plots with higher numbers have had a greater diversity than plots that had very few members, but a lot of species richness within those members. A noticeable difference between the pine and hardwood plots was the number of individual plants in the understory. The diversity measure was meant to include this difference

The three stand types were not sampled evenly, which would bias the diversity results. In order to compensate, the diversity of each stand type was calculated using Brillouin's diversity measure with Pielou's pooled quadrant method (Margurran, 1988). Pielou's technique calculates the diversity of a sample, then sequentially adds the other samples in random order, recalculating the diversity after each addition until all samples are included. The pooled quadrant diversity was graphed with the number of samples as the independent variable. By using Pielou's pooled quadrant, the addition of additional plots drives the diversity level up. The point where the diversity value becomes asymptotic, is the estimate of total diversity. Since it is difficult to pinpoint the asymptote, the order of the samples was randomized 25 times in order to calculate an average value and standard deviation for all points along the graph. The Brillouin diversity index is calculated by:

$$HB = \frac{\ln(N!) - \sum \ln(n!)}{N}$$

Where N= total number of individuals and n= number of individuals within a single species

A species was assigned a “1” in a sample if it was encountered or a “0” if it was not encountered. Since evenness is part of the measure, using presence or absence of a plant, instead of percent coverage, minimized the effect of clumping or plant size, and put more emphasis on species richness.

Species richness

Species richness is the total number of species found in each stand type. The problem of quantifying species richness is that there were an uneven number of samples across the three stand types (Table 2.2). The stand type with the most samples is more likely to register uncommon species.

Table 2.2 Number of samples taken in each of the stand types

Pine	Mixed	Hardwood
68	112	42

To compensate and obtain a more accurate estimate, a jackknife method devised by Burnham & Overton (Colwell et al. 1994) was used to determine species richness. This method reduces the underestimation of the true number of species based on the number of individuals represented in a sample. The equation is:

$$S = S_{\text{obs}} + L\{(n-1)/n\}$$

Where S = the estimated species richness

S_{obs} = the observed species richness

L = the number of species that occur in only one sample

n = the number of samples

The variance is:

$$\text{var}(S) = \{(n-1)/n\}(\sum_{j=1}^{S_{\text{obs}}} j^2 f_j - L^2/n)$$

Where f_j = the number of samples containing exactly j of the L unique species

Abundance of ground cover

Ground cover, the percentage of ground area that particular species occupied within 1m² subplots, was recorded in each overstory type. Abundance is the percent coverage of all species added together. Some species overlapped in space, causing the abundance rating to be over 100% in a few plots. The abundance of ground flora was compared in the three stand types using nonparametric Kruskal-Wallis test (Sokal et al.1969), which addresses the uneven number of samples.

Chapter Three

Results

Description of trees at Ross Preserve

This chapter contains the results of the analyses described in chapter 3. The first section describes the entire stand and answers the study questions. The second section deals with factors other than those mentioned in the study questions that may affect the results.

Description of the study area

There were thirteen tree species present in the research area (Table 3.1): red pine, Austrian pine, jack pine, Scotch pine, black cherry, white pine, spruce, sassafras, bigtooth aspen, red oak, black gum, red maple and pin oak.

Analysis of the tree rings indicates that these trees were planted between 1957 and 1967. The ages of the pine trees were between 29 and 39 years old, the mean was 35 (Figure 3.1) in 1996. The mature hardwoods were older, especially sassafras, some of which were over 76 years. The mean age of the mature hardwoods was 57 years. The sassafras trees measured among the planted pines were older than the pines, signifying that they were there when the pines were planted.

The distribution of the diameter at breast height are represented in figures 3.2-3.5. Only a few of the species in the research area had a J-shaped diameter distribution curve typical of active regeneration and recruitment (Figures 3.2-3.5): sassafras, red maple, and black gum. The curves for all pine species were typical of plantations

Table 3.1 Basal areas of trees found in each stand types in m² / ha.

	Stand Type		
	Pine	Mixed	Hardwood
Red Pine	35.9	27.5	5.4
Austrian Pine	5.2	2.0	-
White Pine	5.4	-	0.8
Scotch Pine	0.4	1.5	1.1
Jack Pine	2.3	0.6	-
Sassafras	-	5.8	11.1
Black Cherry	0.2	1.1	4.2
Nyssa	-	0.3	2.7
Spruce	-	0.3	-
Red Maple	-	0.3	2.3
Pin Oak	-	0.3	0.4
Bigtooth aspen	-	0.2	0.4
Red Oak	0.2	0.2	-
total	49.7	40.4	31.4

with little variation in tree diameter, indicating that the trees were even-aged. The red pine curve gave the illusion that some red pines were regenerating because smaller diameter trees were present. However, the smaller diameter trees were stunted, probably due to competition with sassafras. Only a few hardwood species showed evidence of regeneration (Figures 3.2-3). Black cherry, cottonwood and the oaks had a limited diameter distribution, with no trees under 14 cm, suggesting that recruitment was interrupted at some point in the past.

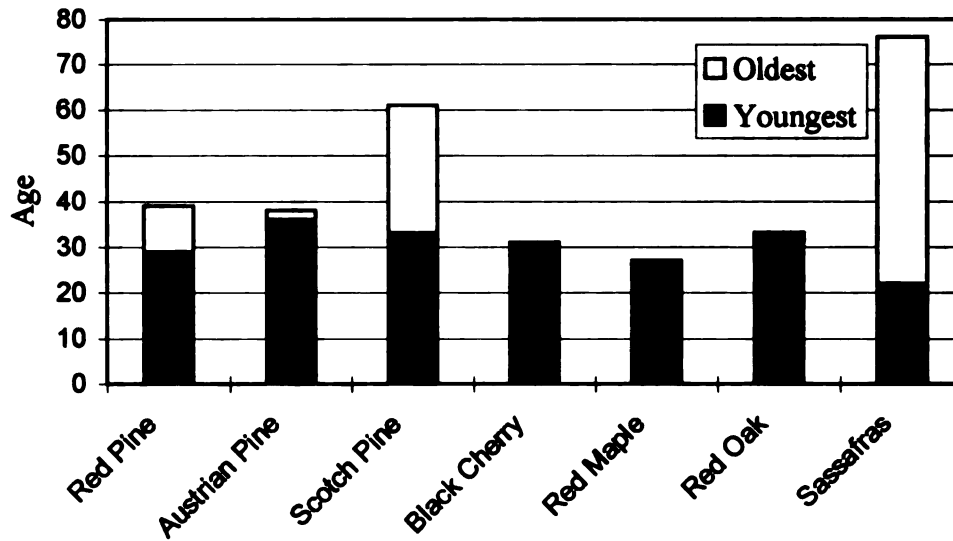


Figure 3.1 Tree ages as figured from core samples of the largest hardwood and/or pine in each plot.

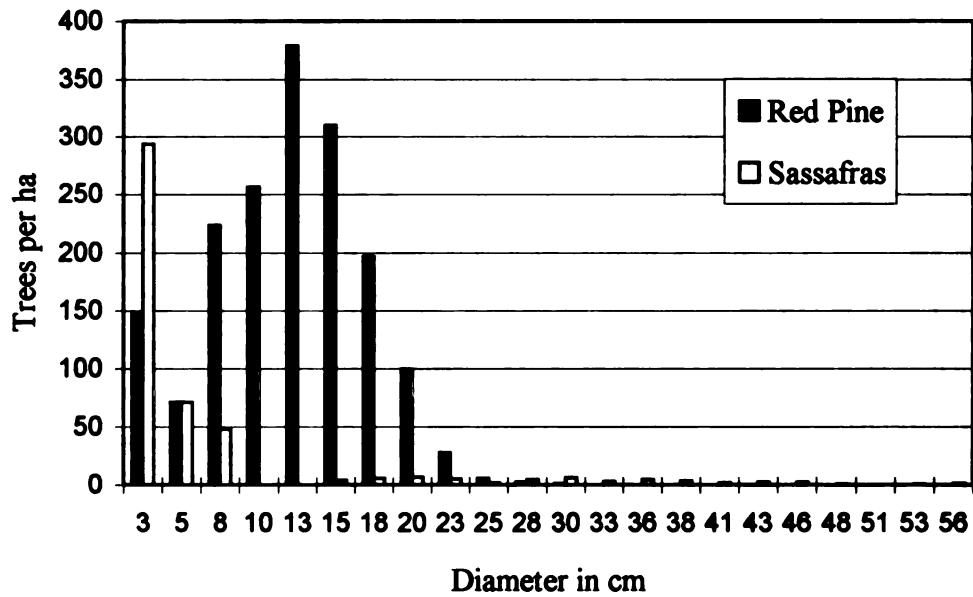


Figure 3.2 Distribution of diameter at breast height of the two major tree species for the entire research area

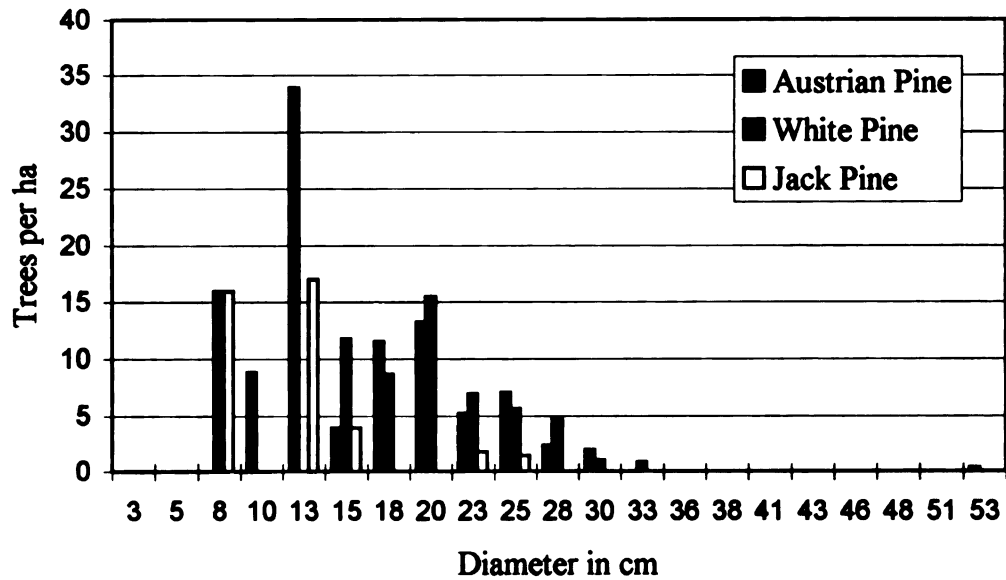


Figure 3.3 Distribution of diameter at breast height of minor conifer species for the entire research area

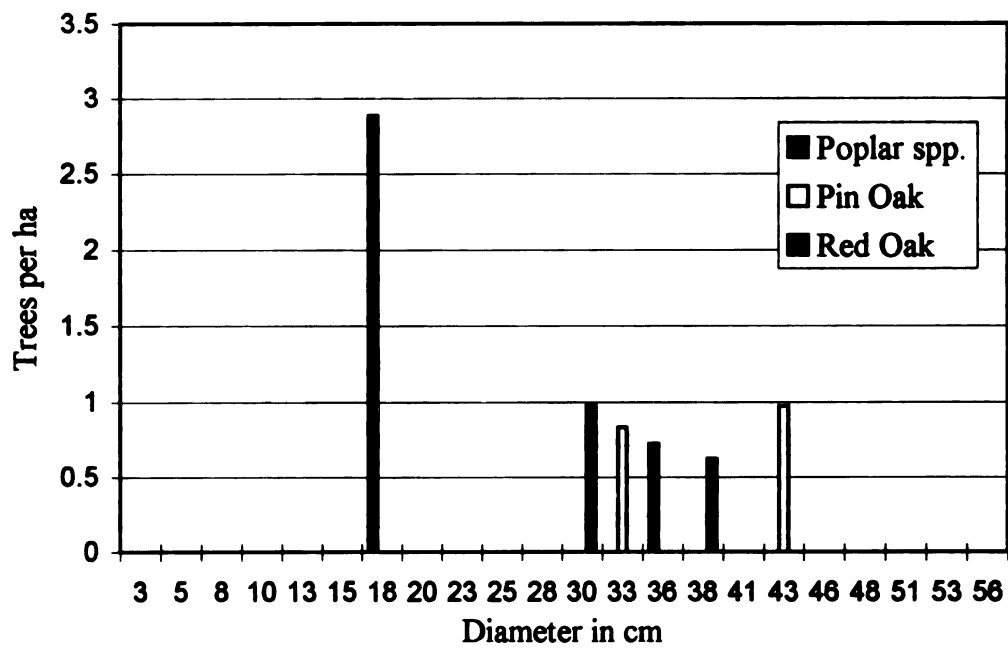


Figure 3.4 Distribution of diameter at breast height of three minor hardwood species for the entire research area

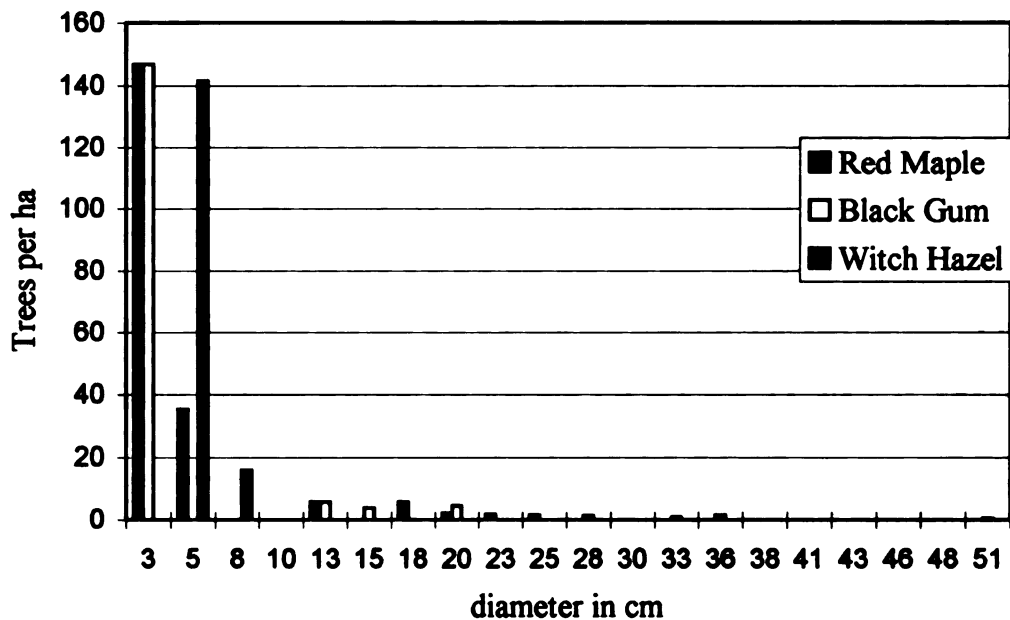


Figure 3.5 Distribution of diameter at breast height of two minor hardwood species and one large shrub for the entire research area

Description of the Stand Types:

The research area was divided into three stand types for comparison: pine, mixed and hardwood. The pine and the mixed stands were within the pine plantation, which consisted of red, white, Austrian, jack and Scotch pines. These pines were planted at a spacing that ranged from 1.5 x 1.5 to 3 x 3 meters apart. The hardwood stands consisted of a volunteer hardwood forest which had been high-graded in the past.

The **pine stands** had the greatest number of trees per hectare of all the stands (Table 3.1). The majority of the trees were red pines (Table 3.2), which is an exotic species to Ross, since their normal range ends mid-way down the coast of Lower Peninsula, just north of Ross Preserve.

Table 3.2 Basal area of pine and hardwood trees in each stand type in m² / ha.

	Stand type		
	Pine	Mixed	Hardwood
Pine	49	32	7
Hardwood	0	8	21

Red pines in Ross Preserve showed a lack of vitality and seemed unsuited to the area. There were a number of red pines under 5 m in height (Table 3.3). The red pines were in the process of self thinning; there were many dead trees. Live trees had a relatively thin bole and sparse foliage. White and Austrian pines, by contrast, showed vitality in Ross Preserve. White pines were part of the pre-European settlement community and seem to be well adapted to Ross Preserve, they had large healthy boles and showed almost no sign of self thinning. Austrian pines also seemed to be well adapted to the environment in Ross Preserve. There was only sparse evidence of regeneration of pine trees anywhere in the study area - only two pine seedlings were found; the most likely reason for this is that the pines were in a stressful environment or that they were still too young to reproduce.

Table 3.3 The number of trees encountered per ha in each of three height classes (in meters) in the pine stands.

	Height in m		
	>10	5-10	<5
Red pine	974	205	17
White pine	59	24	-
Jack pine	9	4	-
Austrian pine	9	1	-
Sassafras	-	5	56
Black cherry	-	-	4
total	1050	239	78

The **mixed stands** were less densely populated than the pine stands (Table 3.4). In these stands, the plantation was established around previously existing hardwoods. These hardwoods were at least 30 to 40 years older than the planted pines (Figure 3.2), and consisted mostly of sassafras, maples and black cherry.

The **hardwood stands** had the lowest density among the stand types (Table 3.5). They also had the greatest diversity of volunteer overstory species, with sassafras, maples, and black cherry as the predominant taxa.

Study Question I

Succession

To answer whether the tree cover type has been affecting succession, the understory species in all three stand types were compared to the overstory tree composition. The same five taxa were encountered among the ground flora in all three stand types: sassafras, cherry, maple, oak and ash (Table 3.6).

A comparison was made between these seedling taxa and the taxa that were present; between 1 - 5 m, between 5 - 10 m and greater than 10 m height categories on the basis that the seeds had been able to infiltrate and germinate all regions of the study area. Any absence of these taxa in the upper layers of the stand was assumed to mean that there was some restriction to their post germination growth. Of the five taxa (sassafras, cherry, maple, oak and ash) only sassafras and black cherry grew above 1 m in height in the pine stands. In both the mixed and hardwood stands all five taxa grew to at least 1 m in height (Tables 3.3-3.5). The seedlings that were present under the pines and

categorized as under one meter in height were seedlings. These results suggest that while the seeds of these five taxa are able to infiltrate and germinate in all parts of the research area, the growth of the seedlings is restricted under the pine overstory. The evidence suggests that the hardwood and pine overstories affect succession differently based on which seedlings are recruited into the understory. However, hardwood stands, were older, and thus had more time to recruit. Even if the survivorship of seedlings is low under the hardwoods, that stand was extant longer and therefore there were more growing seasons during which these species had an opportunity to be recruited.

Table 3.4 The number of trees encountered per ha in each of three height classes (in meters) in the mixed stands.

	Height in m		
	>10	5-10	<5
Red pine	734	145	42
Jack pine	19	4	-
Austrian pine	20	2	-
White pine	5	13	2
Scotch pine	9	-	-
Sassafras	29	46	230
Black cherry	11	6	35
Maple	-	-	110
Black gum	-	4	22
Oak	-	-	13
Alnus	-	-	11
Beech	-	-	9
Tulip tree	-	-	7
Ash	-	-	6
Cottonwood	-	-	2
total	828	218	488

Table 3.5 The number of trees encountered per ha in each of three height classes (in meters) in the hardwood stands.

	Height in m		
	>10	5-10	<5
Red pine	51	-	-
White pine	-	19	19
Sassafras	102	74	240
Black cherry	32	42	230
Maple	14	14	154
Oak	5	14	60
Spruce	9	37	9
Black gum	5	5	32
Ash	-	5	23
Beech	-	-	19
Cottonwood	5	-	9
Scotch pine	9	-	-
Tulip tree	-	-	9
total	231	208	804

Table 3.6 Frequency, percent of 1m² plots where tree seedlings were present

	Stand Type		
	Pine	Mixed	Hardwood
Pine	1	1	-
Sassafras	23	47	55
Cherry	27	39	55
Maple	33	31	40
Oak	18	29	14
Ash	3	3	2
Beech	-	2	-
Blackgum	-	1	7
Mulberry	-	-	2
Birch	-	-	2

Study Question II

Species diversity

The three stand types the initial diversity was greatest in the hardwood stands and lowest in the pine stands. The differences remained consistent as the diversity rose to distinctly different levels according to Pielou's pooled quadrant (Figure 3.8). The slopes approached an asymptote in a similar manner, especially after 11 plots were included. Thus, indicating that rare and uncommon species were assessed at the same rate. The diversity level was highest under the hardwood stand indicating that hardwoods promoted floristic richness relative to both the mixed and pine stands. Species richness and abundance of ground cover (see below) were two components of species diversity.

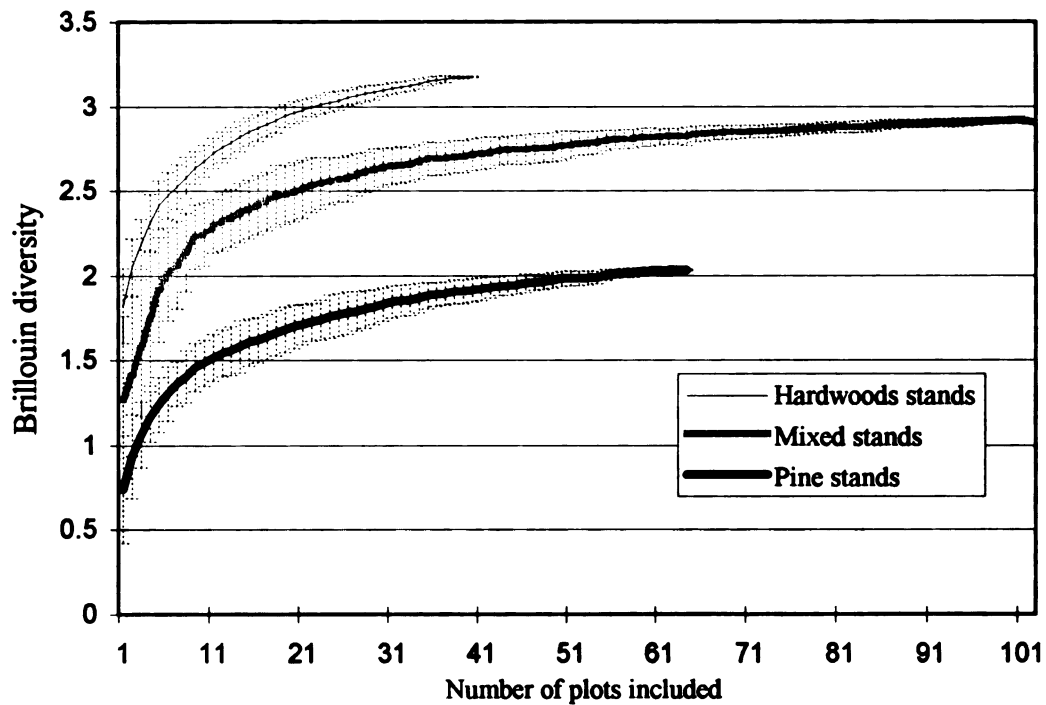


Figure 3.6 Pielou's Pooled Quadrant for three overstory types. The results are an average of 25 iterations, the error bars represent the standard error of the mean.

Species richness and distribution

Evaluating species richness based on the raw data would have underestimated richness in the hardwoods where fewer samples were taken. The bootstrap method used to compensate for the differences in sample sizes, shows that the hardwood understory had the highest species richness (figure 3.6). The pine understory had the lowest and the mixed forest was in the middle. Table 3.7 shows the distribution of species under the three cover types. While most

species favored the hardwood understory a few species seemed to favor the pine. Spotted pipsissewa was very common under the pines and relatively rare under the hardwoods. When encountered they tended to be near the few pines present within the hardwood.

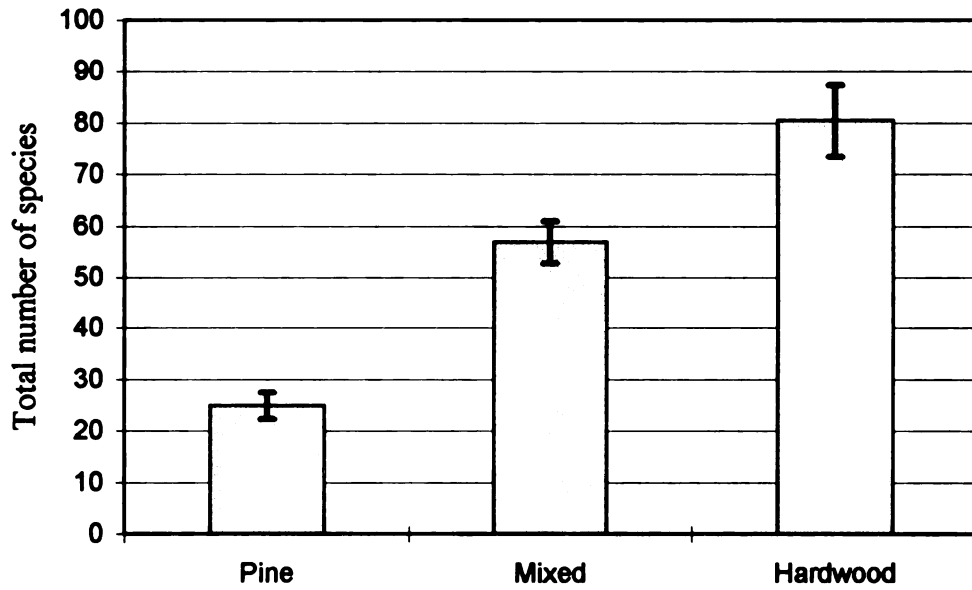


Figure 3.7 Species richness in the understory of all three stand types. Error bars represent the standard deviation.

Table 3.7 Relative frequency of plants in each of three stand types. The numbers represent the percentage of plots where each plant was found.

Plant	Stand Type		
	Pine	Mixed	Hardwood
Maple	33	31	40
Cherry	27	39	55
Spotted Pipsissewa	24	21	5
Sassafras	23	47	55
Oak	18	29	14
Bracken Fern	6	13	26
Lilly-of-the-valley	5	14	12
Posion Ivy	5	8	2
Ash	3	3	2
Unknown	2	16	40
Wild Gooseberry	2	5	10
Spice bush	2	3	7
lady slipper	2	2	-
Lady Fern	2	-	-
Pokeweed	2	-	-
Bittersweet nightshade	2	-	-
Pine	2	1	-
Virginia Creeper	-	27	40
Black Raspberry	-	12	19
Goldenrod	-	11	52
Wild Strawberry	-	8	60
Yellow Wild Licorice	-	6	2
Geranium	-	6	14
Dogwood spp.	-	3	10
Witch Hazel	-	3	19
Grass	-	3	19
False Spikenard	-	2	2
Wild Grape	-	2	2
Wild Rose	-	2	5
Common Speedwell	-	2	5
Starry False Solomon-Seal	-	2	7
Hophornbean	-	2	7
Common Dandelion	-	3	7
Sand Violet	-	2	10
Cinnamon Fern	-	2	10

Table 3.7 (cont'd)

<u>Plant</u>	<u>Pine</u>	<u>Mixed</u>	<u>Hardwood</u>
Sensitive Fern	-	2	21
Black Chokeberry	-	1	7
Shining Bedstraw	-	1	5
Black Gum	-	1	7
Juneberry	-	4	-
Beech	-	2	-
Violet	-	1	-
Night Shade	-	1	-
Sphagnum	-	1	-
Trumpet Vine	-	1	-
Elderberry	-	1	-
Viburnum	-	1	-
Arrow-leaved Tear-thumb	-	-	5
Spotted Touch Me Not	-	-	5
Horse Nettle	-	-	5
False Nettle	-	-	5
Rubus sp.	-	-	2
Blueberry	-	-	2
Birch	-	-	2
Swamp Candles	-	-	2
Aster sp.	-	-	2
Common Boneset	-	-	2
Partridge Berry	-	-	2
Meadowsweet	-	-	2
Hawthorn	-	-	2
Mulberry	-	-	2
Stagehorn Sumac	-	-	2
Red Sorrel	-	-	2
Lawn Prunella	-	-	2
White Avens	-	-	2
Tall lettuce	-	-	2
total number of species	17	45	54

Abundance of ground cover

The hardwood stands had the most area covered by understory herbaceous plants under one meter in height, while the pine stands had the least and the mixed stands were in the middle (Figure 3.7). The standard error of the mean was large due to clumping that is natural in plant communities. Three stand types were statistically different according to the Kruskal-Wallis test (Sokal et al. 1969).

Ground cover consistently became abruptly sparse under the pine canopy where it abutted with the hardwood area. In the mixed stands, wherever there was a lone hardwood tree among pine, there was a dramatic increase of vegetation under that hardwood tree. This increase in ground vegetation usually did not spread far beyond the canopy of the hardwood and occurred even when the soil below the hardwood tree had a layer of pine needles on it.

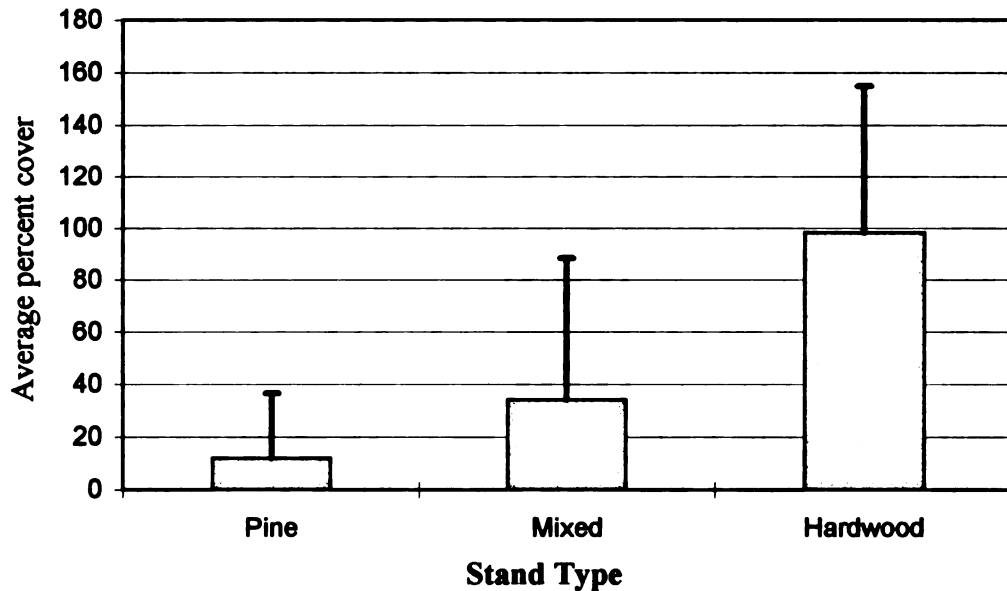


Figure 3.8 Average percent area covered by the ground flora.
Error bars are both positive and negative

Possible environmental factors

To confirm that the results of the study reflect differences in the stand types as opposed to independent environmental characteristics, soil type and soil wetness were compared among the stand types. Soil types in the study site were either the Pipestone-Kingville complex or the Oakville soil series (Bowman 1986). Neither the pine, mixed nor hardwood stands were associated with any one soil type.

The MNFI (Michigan Natural Features Inventory) developed an index with a corresponding computer application. The index assigns Michigan native species a coefficient of wetness (W) based on the probability that the species will naturally occur

in a wetland area (Herman et al. 1996). The coefficient of wetness was derived from the five main National Wetland Indicator Categories as recorded by Reed¹.

The wetness rating of each plot was calculated from the average coefficient of wetness of all species present regardless of relative abundances. Plants not assigned a rating by Reed were assigned values by the Michigan DNR (Herman et al. 1996).

The coefficient of wetness values range from 5 to -5. Plants assigned a value of 5 have less than a 1% probability of occurring in a wetland under natural conditions. The value 0 has an equal likelihood of occurring in wetland and upland areas, and a -5 has a 99% probability of occurring in a wetland. For the purposes of the Michigan DNR, an overall plot wetness rating of 0 or less indicates a predominance of wetland species. All the plots were inputted into this data base to yield a wetness rating based on category.

Figure 3.9 shows the average wetness of each category with the standard error of the mean. According to the nonparametric Kruskal-Wallis test there is a significant difference in soil wetness between the pine stand and the hardwood and mixed stand types.

¹ The vegetative analysis done by the MNFI relies heavily on the following manuscript: Reed, P. 1988. National list of plant species that occur in wetlands: Michigan. U.S. Fish and Wildlife Services, Department of Interior Biological Report: NERCC-88/18.22.23. 31pp.+ Appendices. In this manual Reed classified the vegetation using the same definitions as the MNFI. The MNFI has made some changes to the original work. For example, they took into account that some species may vary in wetness tolerance based on the region where the plant is located.

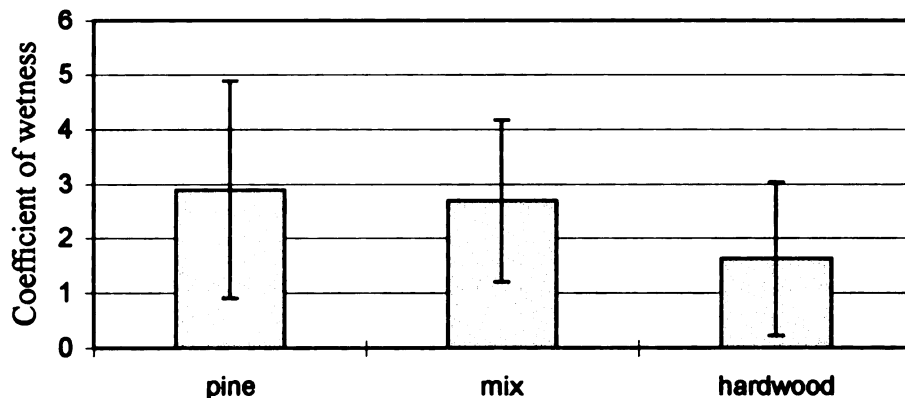


Figure 3.9 Average wetness of the three stand types. Error bars represent the standard error of the mean.

The inherent soil moisture differences between the stand types could be responsible for the differences found in the understories. On the other hand, overstory tree assemblages may be responsible for the relatively high soil moisture of the hardwood understory. A problem with this analysis is its use of herbaceous plants to define an environmental characteristic, when the goal is to use overstory differences to explain plant distribution. However I did not have data on soil moisture with which to directly assess stand differences.

Soil moisture on these dunes is not easily defined. Herman (1996), citing Will MacKinnon's (1994) report on the critical wetlands project, described areas located in coarsely sanded wooded dunes with well drained soils as "problematic wetlands" because they often support a mix of upland and wetland vegetation. In these areas the wetland and adjacent upland are often difficult to distinguish and may be non-contiguous to an inland body of water or stream. The result of this analysis is consistent with MacKinnon's description of a "problematic wetland" in that dry species and wet species were often recorded within the same plot. Species found under each stand type

are listed in Table 3.7. Certain high dunes have a mesophytic environment, for example there are sometimes found leatherleaf, red osier dogwood and blue beech growing in such places (Wells and Thompson, 1982; Olsen, 1958; Cowles, 1899).

In study question I, there was a response in the understory species composition to the overstory stand type. The pine overstory restricted maple, oak and ash seedlings from recruitment into the understory. No such restrictions were present in the mixed or hardwood stands. In response to study question II, the overstory stand type did affect the character of the understory flora in terms of species richness, abundance and diversity.

The alternative hypothesis was that soil type or moisture were responsible for the pattern of species distribution in the study area. While the soil map showed that there was no correlation between stand type and soil type, soil core samples should have been taken and compared for differences in soil structure and moisture. Since this information was not available, an attempt was made to determine differences in soil moisture based on the dependence of the understory species on soil moisture. The results were inconclusive since soil moisture can also be influenced by overstory trees. A future study that included soil analysis of the plots could resolve this issue. The ratio of sand to silt to clay would give a good indication to relative soil water availability.

Chapter 5

Conclusions and Recommendations

The Nature Conservancy (TNC) intended to manage Ross Preserve for the reestablishment of tree assemblages resembling what was present before European settlement in Western Michigan, while preserving native flora and fauna that are already dependent on the preserve. The goal was to do this in a way that would not disrupt other communities of native flora and fauna. The correct composition of the trees would also be more favorable to all species that were present before European settlement and depend on Ross Preserve during some point of their life cycle.

The dominant tree assemblages found in Ross during this study were very different from the ones recorded for the General Land Office surveys (GLO). Analysis of the GLO surveys by the MNFI depicts the study ridge covered with two types of associations. One was a tamarack swamp with white pine and black ash, and the other a highland association of hemlock, beech and maple with a small number of white oak (Figure 2.1). The sub-dominants were not determined. Future investigators might look at the assemblage of plants in nearby dune areas that have remained relatively unchanged since the European settlement era in order to make a wider assessment of what species used to be in Ross Preserve.

At some point in the 1800's, the ridge in Ross was both high-graded and cleared for agriculture. The high-grading left a forest dominated by sassafras with black cherry and maple as sub-dominants. In the 1940's, cleared areas were planted with pines to arrest wind erosion. The pines worked well, and wind erosion has been drastically diminished.

There is now a thick layer of pine litter over the soil and a continuous pine canopy.

White pine and Austrian pine have thrived in Ross Preserve. Red pines survive but do not look as healthy and were subject to at least two blowouts.

Conclusions for Study Question I

The purpose of study question I was to determine if overstory stands in Ross Preserve affect recruitment of tree species in the understory, to lend insight as to whether succession is taking place and what direction it might be going. The tree census itself can be used by managers of Ross Preserve to compare changes in the forest vegetation to determine the efficacy of their efforts to revert Ross Preserve to its pre-European settlement condition.

Results from the tree census demonstrate that the pine stands possibly discriminated against some species of saplings, thus affecting which species would be able to succeed the pines. Sassafras and cherry survived up to the sapling stage, maple, oak and ash did not. There was no evidence that the hardwoods selectively discouraged tree species between the seedling and sapling stages. The pines are probably affecting species survival by altering the environmental conditions of the understory. Measuring those differences was beyond the scope of this project. However, other research has shown that overstory pines affect soil development differently than hardwoods(Griffith et al. 1930, Wardenaar et al. 1992). Griffith et al. (1930) compared soil development under hardwoods and white pine trees in various stages of development between 10 and 80 years and found that the duff layer under the pines increased to an average of 5 cm.

Hardwood duff layer decreased to an average of 1.3 cm. The result is that seedling roots have to descend a longer distance under the pines before encountering mineral soil, which could reduce the success of trees sprouting from smaller seeds. Sassafras trees have avoided this challenge by using root suckers to create new individuals.

Mixed stands had the same number of species in the understory as the hardwoods stands. They have probably been able to recruit a wider number of species because hardwood litter decays faster than pine litter. Also, roots may be able to extract nutrients from the duff layer before reaching the mineral soil.

Although this study is a snapshot in time, inferences can be made regarding succession over the next few generations in the three stand types. The pine understory was sparse compared to the other stand types. The most common species encountered in the understory was sassafras, followed by black cherry (Table 4.3). These trees will most likely become part of the overstory. Pine tree reproduction was sparse, a total of two pine trees were encountered in the understory. This is a small number compared to the hardwoods present in the understory. Pines seem to be in danger of crowding by shade tolerant hardwoods such as sugar maple. However pines are hard to predict since most of them may not have reached reproductive age. Austrian pines were commonly planted in the mid 1900's to stabilize the sand dunes and while they showed no sign of reproduction in Ross, they have thrived on sand dunes in Saugatuck just over thirty kilometers to the north of Ross Preserve (Leege 1997). It is possible that the environment in Ross Preserve is stressful enough that neither the white pines nor the Austrian pines have reached reproductive age yet at age 35 (Figure 4.2). The future potential for the pine stands is to become pine-hardwood mixed stands with sassafras

being the dominant hardwood followed by black cherry, which is identical to the current mixed stands.

The mixed stands contain various pines in the overstory with a few sassafras and black cherry interspersed. The understory contained more diversity than the overstory, indicating that the mixed stands had potential to increase in hardwood diversity over the next few generations to include maple, black gum, oak, ash, beech, tulip tree and cottonwood (Table 4.4).

Most of the taxa in the understory of the hardwood stands were also represented in the overstory, demonstrating the relative stability of these stands. What did change was the ratio of the tree species to each other. A dominance value was calculated for the hardwood stands in the three height categories (Table 4.7). This value was calculated by adding the relative density (trees per hectare) and the relative frequency (number of plots where the species was encountered) for each species. In the overstory, sassafras had a dominance value more than double that of any other species, but the gap narrowed in the mid-story level and in the understory the ratio was almost one to one between sassafras and black cherry. Originally the study ridge was part of a highland covered by a hemlock, beech, maple and white oak association. Full-grown sassafras was occasionally encountered.

Conclusions for Study question II

Study question II addressed how the overstory was affecting the herbaceous understory. Most herbaceous plants favored the hardwood understory, while a minority

of plants favored the pine understory, demonstrating that having both cover types maximizes the overall diversity in Ross Preserve.

The most readily noticeable effect the overstory type had was the abundance of ground cover. There was less ground cover under the pine areas compared to the hardwood areas, suggesting that species recruitment under the pines is driven by the ability of the plant to survive in the pine modified environment

Recommendations

In order to make a stronger argument for the two research questions more data should be taken. The first research question addressed whether the pine, mixed and hardwood overstory affected the process of succession in the understory. This question was tested on the assumption that if survival of understory trees was different between the three stand types then the process of succession was being effected. Since the two stand types were different ages, the results are inconclusive. However the argument would be strengthened if the stands were resampled to show changes in the forest composition over time. The soil moisture was confounded with the distribution of species in the stand understories. The overstory species were also probably influencing soil moisture. In order to make soil moisture an independent variable, soils samples should be taken from each of the stand types. The soil particle size should be measured to determine the likely available soil moisture under each stand type.

The Nature Conservancy is interested in replacing the exotic pines in Ross Preserve with trees that were present before European settlement (McGowan-Stintsky 1993). To

achieve this goal, red, Austrian and Scotch pines should be removed before they start reproducing. Since pines increase the overall diversity of native species white pines should be preserved, spruce and hemlock be planted to replace the removed exotics. Removal should be done gradually to avoid exposing the soil to wind erosion, and to minimize the disturbance to other communities. Ross contains loose soils; once denuded they are subject to erosion which makes surrounding areas more susceptible to blowouts. Another concern is that Ross Preserve is on a migration route for Neotropical birds. Care should be taken to sustain the characteristics that migrating birds depend on.

The exotic trees can be removed gradually by girdling; this would minimize exposing the ground to wind erosion. The understories of the exotic plantation should be controlled burned to reduce ground litter into mineral, ash and increase usable nitrogen, which would encourage plant growth and herbs and expose any seeds that may have been lying dormant in the soil (Neumann and Dickmann 1999). Burning once or twice can result in doubling the amount of herbaceous plant cover (Neumann and Dickmann 1999). The disadvantage to burning is that fires would initially kill the herbaceous ground cover, could expose the soil to wind erosion, discourage beech, maple and hemlock seedlings which were part of the pre-European settlement tree composition, and encourage sassafras (Neumann and Dickmann 1999).

Appendix

Table A.1 Species list, both common and Latin names

American elm	<i>Ulmus americana</i>
American Sycamore	<i>Platanus occidentalis</i>
Arrow-leaved Tear-thumb	<i>Polygonum sagittatum</i>
Ash	<i>Fraxinus spp.</i>
Aster sp.	<i>Aster spp.</i>
Austrian Pine	<i>Pinus nigra</i>
Basswood	<i>Tilia americana</i>
Beech	<i>Fagus grandifolia</i>
Bigtooth aspen	<i>Populus grandidentata</i>
Birch	<i>Betula spp.</i>
Bittersweet nightshade	<i>Solanum dulcamara</i>
Black Ash	<i>Fraxinus nigra</i>
Black Cherry	<i>Prunus serotina</i>
Black Chokeberry	<i>Aronia melanocarpa</i>
Black Gum	<i>Nyssa sylvatica</i>
Black Oak	<i>Quercus velantina</i>
Black Raspberry	<i>Rubus occidentalis</i>
Blue Beech	<i>Carpinus carolina</i>
Blueberry	<i>Vaccinium spp.</i>
Box elder	<i>Acer negundo</i>
Bracken Fern	<i>Pteridium aquilinum</i>
Cherry	<i>Prunus spp.</i>
Cinnamon Fern	<i>Osmunda cinnamomea</i>
Common Boneset	<i>Eupatorium perfoliatum</i>
Common Speedwell	<i>Veronica officinalis</i>
Dandelion	<i>Taraxacum officinale</i>
Dogwood spp.	<i>Cornus spp.</i>
Eastern Hemlock	<i>Tsuga canadensis</i>
Elderberry	<i>Sambucus canadensis</i>
Elm	<i>Ulmus spp.</i>
False Nettle	<i>Boehmeria cylindrica</i>
False Spikenard	<i>Smilacina racemosa</i>
Flowering Dogwood	<i>Cornus florida</i>
Geranium	<i>Geranium spp.</i>
Globe-fruited Seedbox	<i>Ludwigia sphaerocarpa</i>
Goldenrod	<i>Solidago spp.</i>
Grass	—
Greenbriar	<i>Smilax rotundifolia</i>

Table A.1 (cont'd)

Hawthorn	<i>Crataegus spp.</i>
Hickory	<i>Carya spp.</i>
Hophornbean	<i>Ostrya virginiana</i>
Horse Nettle	<i>Solanum carolinense</i>
Ironwood	<i>Carpinus caroliniana</i>
Jack Pine	<i>Pinus banksiana</i>
Juneberry	<i>Amelanchier spp.</i>
Lady Fern	<i>Athyrium filix-femina</i>
Ladyslipper	<i>Cypripedium reginae</i>
Common Trillium	<i>Trillium grandiflorum</i>
Lawn Prunella	<i>Prunella vulgaris</i>
Leatherleaf	<i>Dirca palustris</i>
Lilly-of-the-valley	<i>Maianthemum canadense interius</i>
Lombardy poplar	<i>Populus nigra</i>
Loosestrife	<i>Lysimachia spp.</i>
Maple	<i>Acer spp.</i>
Maple-leaved Arrow-wood	<i>Viburnum</i>
Marram Grasses	<i>Ammophila breviligulata</i>
Meadowsweet	<i>Spiraea alba</i>
Milkweed	<i>Asclepias spp</i>
Mulberry	<i>Morus alba</i>
Night Shade	<i>Solanum nigrum</i>
Oak	<i>Quercus spp.</i>
Partridgeberry	<i>Mitchella repens</i>
Pin Oak	<i>Quercus palustris</i>
Pine	<i>Pinus spp.</i>
Poison Ivy	<i>Toxicodendron radicans</i>
Pokeweed	<i>Phytolacca americana</i>
Poplar	<i>Populus spp.</i>
Red Oak	<i>Quercus rubra</i>
Red Osier Dogwood	<i>Cornus stolonifera</i>
Red Pine	<i>Pinus resinosa</i>
Red Sorrel	<i>Rumex acetosella</i>
Redbud	<i>Cercis canadensis</i>
Red Maple	<i>Acer rubrum</i>
Sand Violet	<i>Viola spp.</i>
Sassafras	<i>Sassafras albidum</i>
Scotch Pine	<i>Pinus sylvestris</i>

Table A.1 (cont'd)

Sedge	<i>Carex spp.</i>
Sensitive Fern	<i>Onoclea sensibilis</i>
Shining Bedstraw	<i>Galium concinnum</i>
Shrubby Cinquefoil	<i>Potentilla fruticosa</i>
Silver Maple	<i>Acer saccharinum</i>
Speckled Alder	<i>Alnus rugosa</i>
Spice Bush	<i>Lindera benzoin</i>
Spotted Pipsissewa	<i>Chimaphila maculata</i>
Spotted Touch Me Not	<i>Impatiens capensis</i>
Spruce	<i>Picea spp.</i>
Stagehorn Sumac	<i>Rhus typhanea</i>
Starry False Solomon-Seal	<i>Smilacina stellata</i>
Sugar Maple	<i>Acer saccharum</i>
Sumac	<i>Rhus spp.</i>
Swamp White Oak	<i>Quercus bicolor</i>
Tall Lettuce	<i>Lactuca canadensis</i>
Tamarack	<i>Larix laricina</i>
Trumpet Vine	<i>Campsis radicans</i>
Tulip Tree	<i>Liriodendron tuliperifera</i>
Virginia Creeper	<i>Parthenocissus quinquefolia</i>
Virginia Meadow Beauty	<i>Rhexia virginica</i>
White Avens	<i>Geum canadensis</i>
White Oak	<i>Quercus alba</i>
White Pine	<i>Pinus strobus</i>
Wild Gooseberry	<i>Ribes cynosbati</i>
Wild Grape	<i>Vitus spp.</i>
Wild Rose	<i>Rosa spp.</i>
Wild Strawberry	<i>Fragaria virginiana</i>
Willow	<i>Salix spp.</i>
Wintergreen	<i>Galium lanceolatum</i>
Witch Hazel	<i>Hamamelis virginiana</i>

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