

FOREST VEGETATION:
INVENTORY AND MANAGEMENT RECOMMENDATIONS,
OUTER ISLAND, APOSTLE ISLANDS NATIONAL LAKESHORE,
WISCONSIN

By

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A Thesis

submitted in partial fulfillment of the
requirements for the degree
MASTER OF SCIENCE

College of Natural Resources

UNIVERSITY OF WISCONSIN

Stevens Point, Wisconsin

September 1984

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Abstract

The Apostle Islands National Lakeshore (AINL), Wisconsin, was established as a unit of the National Park System on 26 September 1970 (PL 91-424). Since the establishment of the AINL, the development of resource management policies has been the focus of concern.

Existing AINL natural resource management policies (PL 91-424, AINL Master Plan of 1971, AINL Statement for Management of 1977, AINL Environmental Assessment of 1981, AINL Selected Management Alternatives of 1982) are conceptual in nature and are in reference to the Park as a whole.

The major goal of AINL natural resource management policy is the re-establishment of the original (ca. 1880) conditions of the Lakeshores resources for the purpose of visitor exposure to the same. The next step to be taken toward the attainment of the above goal is the development "of detailed working plans for the key (major) natural resources of the AINL" (Brander 1981).

The objective of this thesis was to inventory, and develop "detailed working plans" (management recommendations) for, the forest vegetation of Outer Island.

Eight major vegetation-types were identified on Outer

Island. The forest vegetation-types were quantitatively sampled and comparisons were made with original forest vegetation conditions to determine which forest species needed to be actively managed in the attempt to re-establish original forest conditions on Outer Island. Original and current forest vegetation comparisons identified hemlock (Tsuga canadensis), yellow birch (Betula alleghaniensis), white pine (Pinus strobus) and red pine (Pinus resinosa) as the "target species" of management activities facilitating re-establishment of original forest conditions.

The eight vegetation-types previously identified were mapped in greater detail for the purpose of identifying areas on Outer Island believed to be environmentally suitable to the regeneration of the target species listed above.

Management recommendations to facilitate the reproduction of hemlock and yellow birch involve increasing the availability of seedbeds within environmentally appropriate conditions.

Management recommendations to facilitate the reproduction of white pine and red pine include the removal of competing vegetation, seedbed preparation and planting.

ACKNOWLEDGEMENTS

I wish to begin by expressing my appreciation and love to my parents, brothers, sister and their spouses for their unending support and encouragement throughout this research project.

I am grateful to my graduate committee of Drs. Richard Geesey, Richard Wilke and Michael Gross for their guidance during this project. Acknowledgement is particularly due to my graduate committee chairman, Dr. Richard Geesey for the extra efforts put forth toward the completion of this thesis.

A special thanks is given to Mr. Merryll Bailey, Park Ecologist, Apostle Islands National Lakeshore for his reviews of drafts of this thesis. Mr. Baileys comments and suggestions have been most valuable and ensure the applicability of the concepts and recommendations presented herein to forest vegetation management at the Apostle Islands National Lakeshore.

I further extend my appreciation to Dr. David Hillier for his thorough examination of my draft manuscript. His expertise in plant ecology has been a contribution to the quality of this final product.

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INTRODUCTION

Outer Island (Fig.1), and the remainder of the Apostle Islands National Lakeshore (AINL), Wisconsin, became a unit of the National Park System on 26 September 1970 (PL 91-424). This action was the culmination of nearly 80 years of public interest in the establishment of the area as a National Park (Bielenberg 1976).

The development of AINL management policies have been the focus of concern since its establishment. Legislation published to date, regarding the management of the natural resources of the AINL, includes: 1) Public Law 91-424, establishing the AINL, 2) AINL Master Plan (USDI 1971), 3) AINL Statement for Management (USDI 1977), 4) AINL Environmental Assessment (Brander 1981), and 5) AINL Selected Management Alternatives (USDI 1982). These documents represent a continuing development of management policy, from general concepts and intents (PL 91-424) to specific selected management alternatives (USDI 1982) for the AINL. USDI (1982) outlines managerial parameters for each major natural resource type of the AINL. The major natural resource types considered as amenable to management of the AINL are: 1) Forest Vegetation, 2) Sand-spits and Beaches, 3) Clearings (forest openings), 4) Wildlife, 5) Extirpated species, 6) Water resources, 7) Fire and 8) Fisheries (USDI 1982).

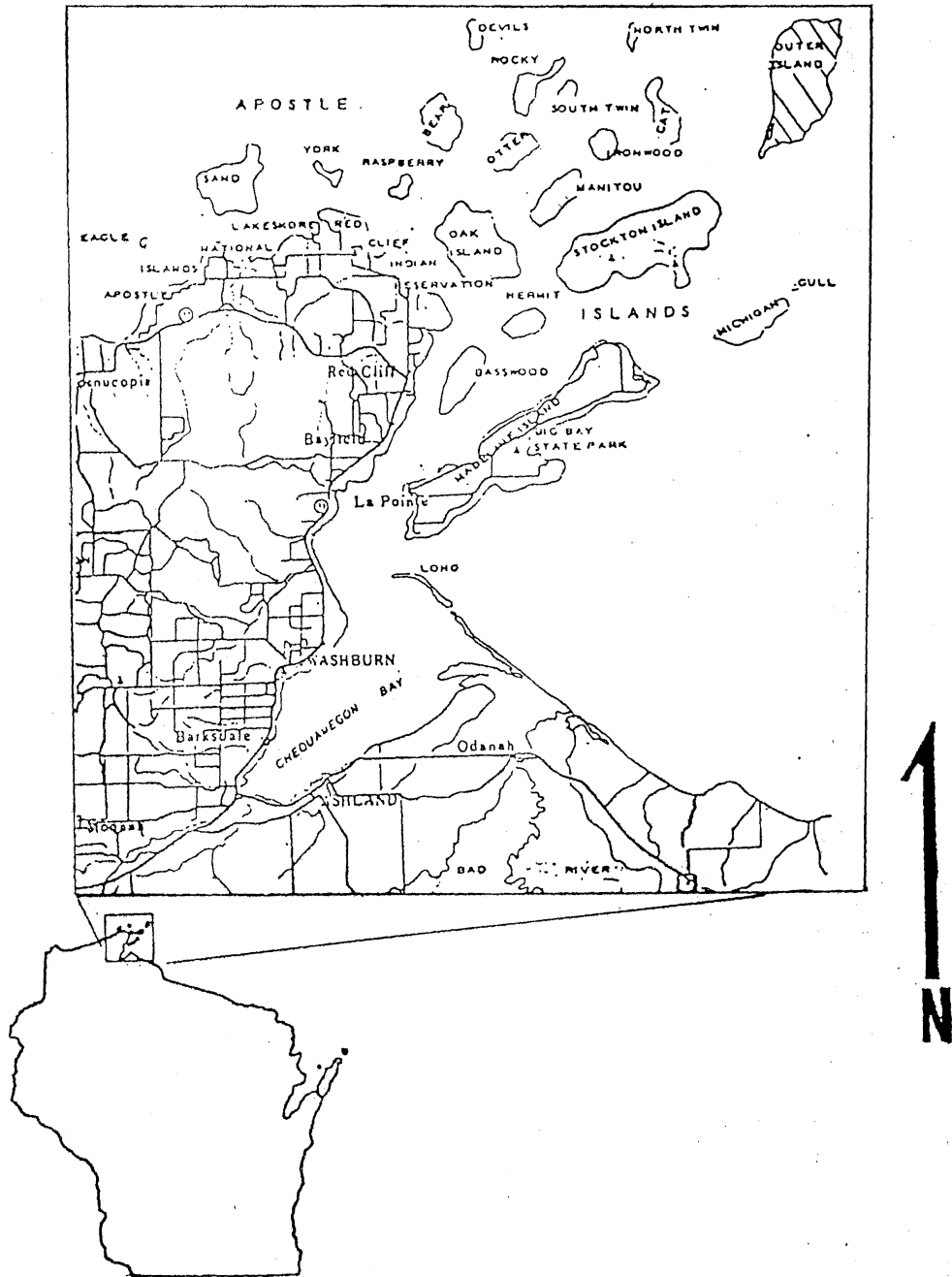


Fig. 1. The location of the Apostle Islands in Wisconsin. Outer is the most northeastern island.

The major goal of AINL natural resource management policy is the re-establishment of the original (ca. 1880) conditions of the Lakeshores resources for the purpose of visitor exposure to the same. The next step to be taken toward the attainment of the above goal is the development "of detailed working plans for the key (major) natural resources of the AINL" (Brander 1981).

The objective of this thesis was to inventory, and develop "detailed working plans" (management recommendations) for, the forest vegetation of Outer Island.

Management recommendations were developed in close consultation with AINL personnel and within the confines of existing AINL natural resource management policy. National Park Service (NPS) support of the management recommendations presented herein is included as Appendix A.

The information presented in this thesis should assist Park managers in bridging the gap between conceptual and applied forest vegetation management on Outer Island.

STUDY AREA

Outer Island, AINL, is located in Lake Superior off the Bayfield, Wisconsin peninsula. Outer Island (3,238 ha) is the northeast most of the Apostle Islands (Fig. 1). Bedrock of the Apostle Islands area was deposited during

the Precambrian era (Coffin 1977) and is classified as a quartzose unfossiliferous Bayfield sandstone (Thwaites 1912). Subsequent glacial activities during the Quaternary period cut out and formed the present day Apostle Island archipelago (Engstrom 1972).

The climate of the Apostle Islands area is similar to that of the northern Wisconsin mainland. Differences between the two are attributed to the buffering effects of Lake Superior. The thermo-dynamic properties of Lake Superior result in a later spring and fall, cooler summer temperatures and somewhat milder winter temperatures on the islands, as compared to adjacent (inland) mainland areas. Consequently, spring emergence of vegetation begins later on the Apostle Islands than on those adjacent mainland areas not affected by Lake Superior (Harris 1977).

Summers on the Apostle Islands are cool and damp with a mean July temperature of 18.3 degrees C (65 F). Mean January temperature is -11.1 degrees C (12 F). Average annual precipitation is 70 cm. (27.6 inches; USDC 1974), most of which is received in July (Beals et al. 1960).

The original forest vegetation of the Apostle Islands area was what Curtis (1959) describes as the Northern-Mesic forest. Elements of the Boreal forest (Curtis 1959) are also present. Hemlock (Tsuga canadensis), yellow birch

(Betula alleghaniensis), sugar maple (Acer saccharum), white cedar (Thuja occidentalis) and white pine (Pinus strobus) dominated the original vegetation of the AINL. Original forest dominants of Outer Island were hemlock, yellow birch and sugar maple (Finley 1976, Frederick et al. 1976, Anderson et al. 1979, 1980, Brander 1981).

Historical, human-related disturbances of the vegetation of Outer Island include logging and fire. Commercial logging was of importance during the period from (ca.) 1880 to 1960 (Frederick et al. 1976, Rakestraw 1976). Logging activities created slash buildups which fueled extensive fires during 1930 (Frederick et al. 1976, Anderson et al. 1980, Brander 1981).

Existing forest vegetation of Outer Island is reflective of previous human disturbance, and includes early successional species such as white birch (Betula papyrifera), trembling aspen (Populus tremuloides) and pin cherry (Prunus pensylvanica).

NPS forest vegetation management policy states that manipulation of the forest vegetation of the AINL will be conducted in an attempt to hasten the re-establishment of original forest conditions (Brander 1981, USDI 1982). The intent of this thesis is to suggest methods towards the actualization of this policy.

METHODS

Forest Vegetation Inventory

Vegetation-type (VT) boundaries were tentatively determined from vertical aerial photographs (1973 1:15,840 black and white) and were refined following field investigations and study of 35 mm aerial slides (1977, 1978 color and infrared oblique), soils and topographic maps of Outer Island.

Forest vegetation types were sampled using the technique of Ohmann (1973). Sample plots were spaced at equal intervals along line transects within a given vegetation-type.

Additional sample data were obtained by reviewing the work of Brander et al. (1978) who also employed the technique of Ohmann (1973). Sample plot locations were mapped by Brander et al. (1978) and were superimposed upon the vegetation-type map of Outer Island produced by the present author. Sample data were assigned to their respective vegetation-type and were analyzed following the technique of Ohmann (1973).

Selective harvesting of the original forest vegetation of the northern portion of Outer Island occurred between 1948-1960 (Frederick et al. 1976). The forest vegetation conditions that existed prior to this logging were estimated with a modification of the point-centered quarter technique of Cottam and Curtis (1956). Sample plots were equally

spaced in a grid fashion within the area logged between 1948-1960. Sample data were obtained from trees judged to be old enough to have been present prior to the logging of the area (mean elapsed time of 24 years) and from stumps of harvested trees. Estimates of tree age were facilitated by cross-sectioning and increment coring of select trees to obtain diameter-age relationships. Additional data on tree diameter-age relationships was obtained from Fowells (1965). Stumps of harvested trees were undecayed enough to allow for reasonable measurements of the original tree diameter. Average annual diameter increments of all tree species sampled were estimated from study of tree cross-sections, increment corings and from data presented by Fowells (1965). Estimated annual diameter increments were multiplied by 24 to approximate tree species diameter increases occurring since the time of harvesting. To more accurately appraise the original forest conditions the estimated 24-year tree species diameter increment was subtracted from the existing diameter of each tree sampled.

Forest Vegetation Management Recommendations

The existing forest vegetation management policy of the AINL (Brander 1981, USDI 1982) largely predetermined the focus of the forest vegetation management recommendations presented herein. This thesis will hopefully be of value to forest vegetation management of the AINL by further

defining specific management actions to be taken to obtain the goals stated within existing AINL forest vegetation management policy. This increased definity in management recommendations are the product of an extensive analysis and synthesis of literature pertaining to the silviculture of forest vegetation.

Acknowledgement

Data presented in the Fig.s and Tables of this thesis were collected (1 June- 16 October 1978) and prepared by the present author, unless cited otherwise. Publication of these data first appeared in Anderson et al. (1979).

RESULTS

Outer Island: Vegetation-Types

The vegetation of Outer Island was delineated into eight vegetation-type categories (Fig. 2). The objective of vegetation-type designations was the identification of reasonable working units of vegetative homogeneity for the purpose of quantitative sampling.

Vegetation-types were distinguished primarily by dominant species composition of the tallest vertical stratum and by gross variations within dominant species densities as resultant of previous human disturbances.

Vegetation-type-1 are upland open areas characterized by

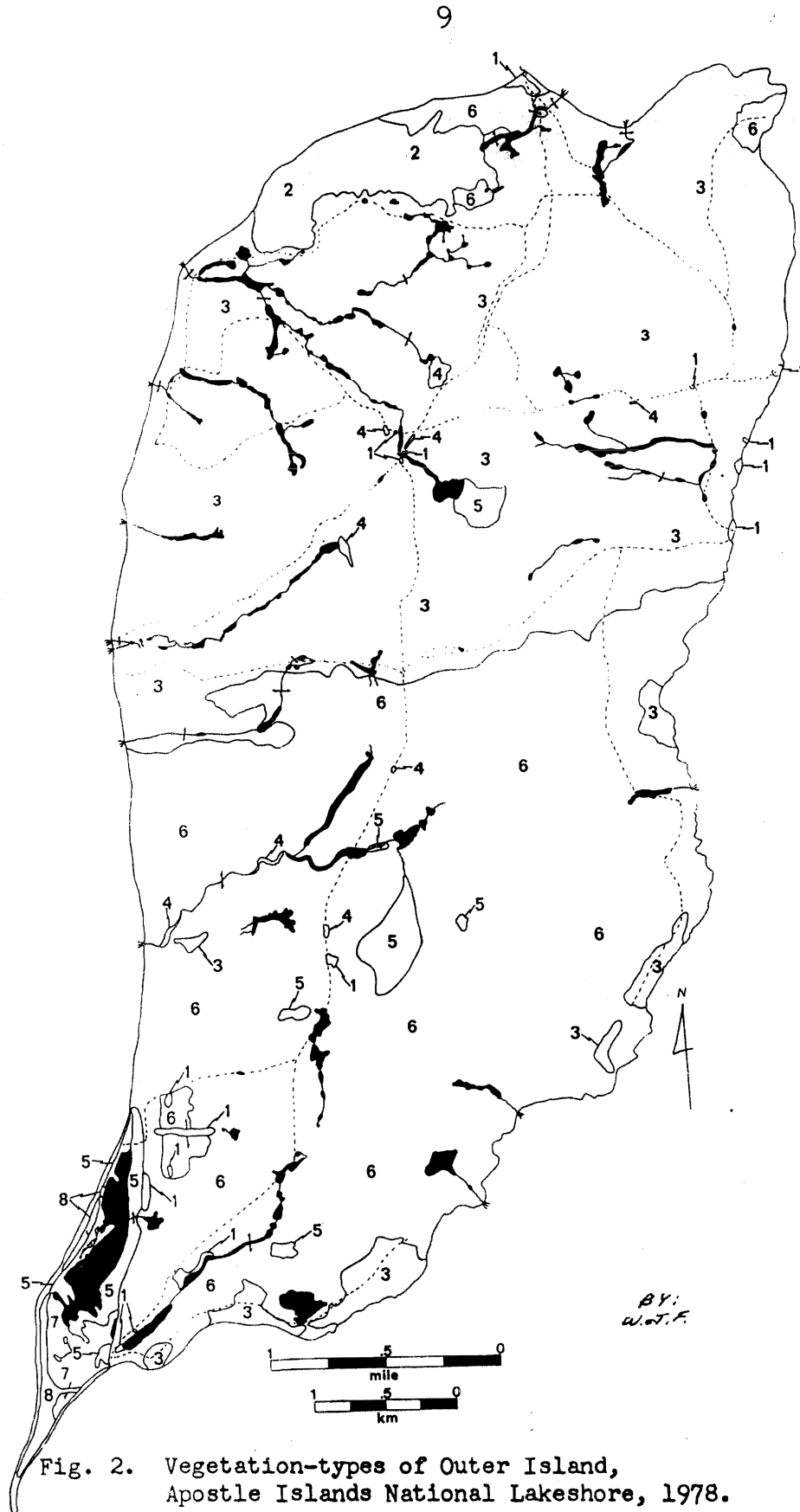


Fig. 2. Vegetation-types of Outer Island, Apostle Islands National Lakeshore, 1978.

Key to Fig. 2.

| <u>Vegetation-Type</u> | <u>Area (ha)</u> | <u>Description^a</u> |
|---|----------------------|---|
| 1 (Upland Openings) | 8.7 | <u>0</u> <u>Ta' 1.3-5.1</u> Fo ⁻ , Gs ⁻ , Sh ⁻ |
| 2 (Undisturbed Northern- Mesic Forest) | 78.0 | <u>Hm'⁺, Yb'⁺, Wc' 10.2-101.7</u> <u>Hm', Sm', Wc', Mm' 2.5-7.6</u> As ⁻ , Wc ⁻ , Ay ⁻ , Cl ⁻ |
| 3 (Selectively harvested Northern-Mesic Forest) | 1,482.0 | <u>Hm', Yb', Sm' 10.2-50.9</u> <u>Sm', Yb', Mm' 2.5-7.6</u> Sm ⁻ , Ay ⁻ , Ff ⁻ , Cl ⁻ |
| 4 (Lowland Openings) | 15.0 | <u>0</u> <u>Mm', Rd' 1.3-3.8</u> Bs ⁻ , As ⁻ , Ss ⁻ , Gs ⁻ |
| 5 (Bog Areas) | 60.6 | <u>Wp', Bp', Tm' 10.2-50.9</u> <u>Bp' 2.5-7.6</u> Ms ⁼ , Ss ⁼ |
| 6 (Birch-Maple Forest) | 1,460.0 | <u>Wb', Yb', Sm' 10.2-25.4</u> <u>Sm', Yb', Mm' 2.5-7.6</u> As ⁻ , Ay ⁻ , Ws ⁻ , Cl ⁻ |
| 7 (Sand-Spit: Forested) | 21.1 | <u>Wp', Rp' 10.2-30.5</u> <u>Bf', Jb' 2.5-7.6</u> Bf ⁻ , Rm ⁻ , Bb ⁻ , Gs ⁻ |
| 8 (Sand-Spit: Shrub-Grass) | 17.2 | <u>0</u> <u>Pj' 0.6-3.8</u> Ww ⁻ , Sc ⁻ , Bg ⁻ |

About 95.0 ha of water (darkened areas) is present on Outer Island.

----- are logging trails.

Key to Fig. 2: footnote ^a

| | | | |
|---------|---|----------|--|
| Strata: | <u>tree stratum</u> <u>shrub stratum</u> herbaceous stratum | Density: | ' or ~ Sparsely stocked (10-40% stratum closure) '' or = Moderately stocked (41-70% stratum closure) ''' or ≥ Densely stocked (71-100% stratum closure) |
|---------|---|----------|--|

Numbers in each stratum are diameters at breast height in centimeters.

Symbols:

| | |
|--|---|
| As Maple (<i>Acer</i> spp.) | Jb Juneberry (<i>Amelanchier</i> spp.) |
| Ay American yew (<i>Taxus canadensis</i>) | Mm Mountain maple (<i>Acer spicatum</i>) |
| Bb Velvet-leaved blueberry (<i>Vaccinium myrtilloides</i>) | Ms Mosses |
| Bf Balsam fir (<i>Abies balsamea</i>) | O Stratum closure less than 10% |
| Bg Beach grass (<i>Ammophila breviligulata</i>) | Pj Prostrate juniper (<i>Juniperus communis</i>) |
| Bp Black spruce (<i>Picea mariana</i>) | Rd Red-osier dogwood (<i>Cornus stolonifera</i>) |
| Bs White and Yellow birch <i>Betula papyrifera</i> and <i>alleghaniensis</i>) | Rm Red maple (<i>Acer rubrum</i>) |
| Cl Corn lily (<i>Clintonia borealis</i>) | Rp Red pine (<i>Pinus resinosa</i>) |
| Ff Florists fern (<i>Dryopteris spinulosa</i>) | Rs Raspberry and blackberry (<i>Rubus</i> spp.) |
| Fo Forbs | Sc Sand cherry (<i>Prunus pumila</i>) |
| Gs Grasses | |
| Hm Hemlock (<i>Tsuga canadensis</i>) | Sg Sweet gale (<i>Myrica gale</i>) |

Key to Fig. 2: footnote^a continued.

Symbols:

Sh Shrubs

Sm Sugar maple
(*Acer saccharum*)

Ss Sedges

Ta Trembling aspen
(*Populus tremuloides*)

Wb White birch
(*Betula papyrifera*)

Wc White cedar
(*Thuja occidentalis*)

Wp White pine
(*Pinus strobus*)

Ws Wild sarsaparilla
(*Aralia nudicaulis*)

Ww Wormwood
(*Artemisia campestris*)

Yb Yellow birch
(*Betula alleghaniensis*)

a variety of species of grasses and forbs. Encroachment of these open areas by trees and shrubs is occurring. All upland openings are believed products of previous logging operations as evidenced by the abundance of logging artifacts within many of them.

Vegetation-type-2 is a mesic forest dominated by large (61-91 cm. diameter at breast height (dbh)) hemlock and yellow birch. No indication of human-related disturbance was found within this vegetation-type. The area encompassing vegetation-type-2 was under federal ownership, and therefore its timber not harvested during the 1948-1960 logging of the northern one-half of Outer Island.

Vegetation-type-3 is that portion of Outer Island which has been selectively harvested for hemlock, hardwoods and white pine (original forest vegetation) and is presently characterized by a broken forest canopy of residual hemlock, yellow birch and sugar maple. Sugar maple and yellow birch are the most common tree saplings present.

Vegetation-type-4 are lowland open areas characterized by a variety of species of sedges and grasses. Lowland, open areas were found to contain a greater diversity of flora than any other vegetation-type on Outer Island (Anderson et al. 1979) and include wet areas along existing trails and the edges of beaver flowages.

Vegetation-type-5 are the bog areas of Outer Island. Bog areas vary in floristic composition from floating mats dominated by needle-leaved sedge (Carex lasiocarpa) to more successional advanced areas which support scattered stockings of black spruce (Picea mariana), tamarack (Larix laricina) and white pine upon bog mats of mosses and sedges.

Vegetation-type-6 is that portion of Outer Island which has been selectively harvested for hemlock, hardwoods and white pine (original forest vegetation) with the residual timber subsequently destroyed by extensive forest fires. VT-6 is characterized by a forest canopy of white birch, yellow birch and sugar maple. Hemlock is virtually absent.

Vegetation-type-7 is the forested portion of the Outer Island sand-spit and is characterized by a broken forest canopy of white pine and red pine (Pinus resinosa).

Vegetation-type-8 is the unforested portion of the Outer Island sand-spit. Shrubs characterize this vegetation-type; dominants are prostrate juniper (Juniperus communis), wormwood (Artemisia campestris) and sand cherry (Prunus pumila). Beach grass (Ammophila breviligulata) dominates the herbaceous flora.

The forested vegetation-types (2, 3, 6 and 7) of Outer Island are the specific interest of this thesis; following are discussions of AINL forest vegetation management policy,

original/existing forest vegetation-types of Outer Island and silviculture and management recommendations for select forest species of Outer Island.

Forest Vegetation: National Park Service Perspective
and Policy

The NPS perspective regarding the forest vegetation of the AINL is as follows:

"The Apostle Islands are the continental northwestern limits of the hemlock-white pine-hardwood forest. They also contain strong elements of the boreal forest. Thus, the islands and their forests comprise an ecosystem which is unique in North America. However, the islands have retained only fragments of their former continental significance.

Some vegetative species on 15 of the islands (North Twin, Devils, Raspberry, Eagle and Gull are the exceptions) and on the mainland have greatly reduced in relative importance through logging and fires that followed logging; white pine, hemlock and white cedar are notable examples. Logging and fires created habitats attractive to deer and beaver. During the period 1940-1960, deer overbrowsed 12 of the islands (Eagle, Sand, York, Raspberry, Devils, North Twin, Gull and Outer are the exceptions) and the mainland and caused a decline in the relative importance of several vegetative species; yew and white cedar are notable examples. Since 1940, beaver have caused inundation and large-scale mortality of forest stands on Stockton and Outer Islands.

Today, the majority of the islands and all of the mainland support a forest ecosystem quite unlike that which would have prevailed had not Man intervened in the 19th and 20th centuries" (Brander 1981).

This perspective is reflected within existing AINL forest vegetation management policy in stating:

"Practically all of the forest vegetation in Apostle Islands National Lakeshore has been altered due to logging activities, and there remains only a few small pockets of original vegetation. Reforestation, if left to natural succession, would take a very long time and some species, such as hemlock, may never regenerate.

The National Park Service believes that it is important for the Park visitor to have some insight as to how the islands looked prior to the logging era. At the same time, it is recognized that it would be prohibitively expensive to attempt to reforest large areas within the Lakeshore. Therefore, certain islands will be selected and attempts will be made to restore original vegetative types in an accelerated program to allow Park visitors an opportunity to see pre-logging vegetative conditions" (USDI 1982).

"The great majority of visitors to the Apostle Islands National Lakeshore do not view the forest beyond its coastal fringe. The most striking and characteristic aspect of the coastal fringe are stands of old-growth white pine and, to a lesser extent, red pine. Other species such as hemlock, cedar and several hardwoods were historically important on sections of coast.

Selected coastal stands, especially white and red pines, will be mechanically treated so that they regenerate. Where logging has totally removed pines from a segment of coast, plantations may be established.

Selected areas of the islands interiors will be manipulated to produce vignettes of the forest prior to European Mans arrival on the Apostle Islands.

Culturally important vegetation such as sap trees (sugar maple) and blueberry may be managed for human use in some areas.

Selected areas of white cedar on the

mainland may be managed as deer habitat.

The remainder (most) of the Lakeshores forest will be left to natural successional processes.

Fire will be used as a management tool in some places and natural fires will be allowed to burn in other areas" (Brander 1981).

Forest Vegetation: Target Species

AINL forest vegetation management policy is intended to facilitate the re-establishment of forest conditions which prevailed prior to the logging of the original forest vegetation (ca. 1880) and to expose Park visitors to these original cover types.

The intent of this thesis is to assist in the realization of AINL forest vegetation management goals by the formulation of specific forest vegetation management recommendations for Outer Island. Essential to the formulation of forest vegetation management recommendations are comparisons of original and existing forest conditions to assess which forest species need to be actively managed. These species are herein referred to as "target species". Once identified, the silvicultural characteristics of the target species need to be understood; management recommendations facilitating the "regeneration and maintenance" (USDI 1982) of target species can then be proposed. Discussion identifying target species is undertaken by vegetation-type (Fig. 2).

Vegetation-type-2 (Undisturbed Northern-Mesic Forest)

The sampled composition of VT-2 is presented as Table 1. The canopy of VT-2 is dominated by hemlock and yellow birch with white cedar being of secondary importance.

Hemlock blowdowns were frequently observed; hemlocks shallow rooting habit and susceptibility to being windthrown has been described by Fowells (1965).

Evidence of human-related disturbance of VT-2 was not observed. Hemlock and yellow birch 61-91 cm. dbh were commonly found within VT-2. Data presented within Fowells (1965) suggests these individuals to be 200, or more, years of age. Reproduction of hemlock, white cedar, red maple (Acer rubrum), sugar maple, and to a lesser extent, yellow birch dominates the shrub and herbaceous strata. Hemlock trees grade in size from seedlings to those approaching canopy size. Large areas of even-sized (possibly even-aged) hemlock were not observed, with the exception of seedlings on decaying logs.

Had VT-2 been extensively disturbed (logging and subsequent fire) old-age hemlock would be less common and hemlocks, if present at all, would be expected to be more even-aged. The same has been noted by Stearns (1951), Brown (1960), Fowells (1965), USDA (1973), Rogers (1978), Nicholson et

Table 1. Vegetation-Type-2 (Undisturbed Northern-Mesic forest): tree species importance values, Outer Island, Apostle Islands National Lakeshore, 1978.

| Species | No. of Plots | No. of Stems | Basal area (ft. ²) | Plot Frequency (%) | Stems/hectare | Basal area (ft. ²)/hectare | Relative Frequency | Relative Density | Relative Dominance | Import. Value |
|--|--------------|--------------|--------------------------------|--------------------|---------------|--|--------------------|------------------|--------------------|---------------|
| Trees (≥10.16 cm.d.b.h.) | | | | | | | | | | |
| <i>Tsuga canadensis</i> | 11 | 28 | 43.68 | 68.8 | 173.0 | 269.8 | 26.8 | 35.0 | 49.8 | 111.6 |
| <i>Betula alleghaniensis</i> | 14 | 30 | 30.39 | 87.5 | 185.3 | 187.7 | 34.1 | 37.5 | 34.6 | 106.2 |
| <i>Thuja occidentalis</i> | 8 | 11 | 6.86 | 50.0 | 68.0 | 42.4 | 19.5 | 13.8 | 7.8 | 41.1 |
| <i>Acer saccharum</i> | 4 | 4 | 0.65 | 25.0 | 24.7 | 4.0 | 9.7 | 5.0 | 0.7 | 15.4 |
| <i>Pinus strobus</i> | 1 | 1 | 3.77 | 6.3 | 6.2 | 23.3 | 2.5 | 1.3 | 4.3 | 8.1 |
| <i>Acer rubrum</i> | 1 | 3 | 1.14 | 6.3 | 18.6 | 7.0 | 2.5 | 3.8 | 1.3 | 7.6 |
| <i>Sorbus americana</i> | 1 | 2 | 0.76 | 6.3 | 12.4 | 4.7 | 2.5 | 2.5 | 0.9 | 5.9 |
| <i>Betula papyrifera</i> | 1 | 1 | 0.47 | 6.3 | 6.2 | 2.9 | 2.5 | 1.3 | 0.6 | 4.4 |
| | | 80 | 87.72 | 256.5 | 494.4 | 541.8 | 100.1 | 100.2 | 100.0 | 300.3 |
| Tree Saplings (≥2.54 cm. but <10.16 cm.d.b.h.) | | | | | | | | | | |
| <i>Tsuga canadensis</i> | 10 | 50 | 1.13 | 62.5 | 308.9 | 7.0 | 34.5 | 53.8 | 45.2 | 135.5 |
| <i>Thuja occidentalis</i> | 6 | 17 | 0.45 | 37.5 | 105.0 | 2.8 | 20.7 | 18.3 | 17.7 | 56.7 |
| <i>Acer saccharum</i> | 4 | 11 | 0.29 | 25.0 | 68.0 | 1.8 | 13.8 | 11.8 | 11.3 | 36.9 |
| <i>Abies balsamea</i> | 4 | 8 | 0.31 | 25.0 | 49.4 | 1.9 | 13.8 | 8.6 | 12.9 | 35.3 |
| <i>Acer rubrum</i> | 3 | 3 | 0.19 | 18.8 | 18.5 | 1.2 | 10.4 | 3.2 | 8.1 | 21.7 |
| <i>Betula alleghaniensis</i> | 2 | 4 | 0.10 | 12.5 | 24.7 | 0.6 | 6.9 | 4.3 | 4.8 | 16.0 |
| Tree Seedlings (<2.54 cm.d.b.h.) | | | | | | | | | | |
| | | 93 | 2.47 | 181.3 | 574.5 | 15.3 | 100.1 | 100.0 | 100.0 | 300.1 |
| <i>Acer rubrum</i> | 3 | 63 | .0038 | 18.8 | 9729.6 | 0.6 | 9.7 | 27.2 | 26.9 | 63.8 |
| <i>Acer spp.</i> | 10 | 69 | 0 | 62.5 | 10656.2 | 0 | 32.2 | 29.7 | 0 | 61.9 |
| <i>Thuja occidentalis</i> | 6 | 34 | .0042 | 37.5 | 5250.9 | 0.6 | 19.3 | 14.7 | 26.9 | 60.9 |
| <i>Tsuga canadensis</i> | 4 | 25 | .0019 | 25.0 | 3860.9 | 0.3 | 12.9 | 10.8 | 13.5 | 37.2 |
| <i>Acer saccharum</i> | 1 | 9 | .0019 | 6.3 | 1390.0 | 0.3 | 3.2 | 3.9 | 13.5 | 20.6 |
| <i>Betula alleghaniensis</i> | 2 | 19 | .0006 | 12.5 | 2934.3 | 0.1 | 6.4 | 8.2 | 4.5 | 19.1 |
| <i>Abies balsamea</i> | 1 | 1 | .0019 | 6.3 | 154.4 | 0.3 | 3.2 | 0.4 | 13.5 | 17.1 |
| <i>Sorbus americana</i> | 3 | 4 | .0002 | 18.8 | 617.8 | 0.03 | 9.7 | 1.7 | 1.3 | 12.7 |
| <i>Betula spp.</i> | 1 | 8 | 0 | 6.3 | 1235.5 | 0 | 3.2 | 3.4 | 0 | 6.6 |
| | | 232 | .0145 | 194.0 | 35829.6 | 2.23 | 99.8 | 100.0 | 100.1 | 299.9 |

al. (1979) and Lorimer (1980).

VT-2 appears to be an undisturbed remnant of what Curtis (1959) describes as the Northern-Mesic Forest and of what other ecologists describe as the Hemlock-Northern Hardwoods Forest. Hemlock, yellow birch and sugar maple were the original dominants of the Northern-Mesic Forest (Stearns 1947, 1949, 1951, Curtis 1959, Barnes 1968, USDA 1973, Eickmeier 1975, Frederick et al. 1976, Rakestraw 1976, Anderson et al. 1979, 1980) and still remain today as the canopy dominants of VT-2.

Existing levels of reproduction appear adequate for the regeneration and maintenance of the vegetative composition of VT-2. Rogers (1981) studied this same area of Outer Island and presented similar conclusions. Stearns (1949), in writing of undisturbed Northern-Mesic forests, states that "it seems probable that natural disturbances (mainly windthrow) occur with sufficient frequency as to permit the mixed forest to perpetuate itself, assuming that climatic conditions do not change drastically." Gleason (1924), Stearns (1951) and Rogers (1978) state that a hemlock dominated forest can maintain itself even if sapling densities are relatively low. Rogers (1978) goes on to say that regeneration as low as 260 stems/ha. is sufficient to restock the canopy of hemlock dominated stands. The density of hemlock saplings within VT-2 is in excess of 260 stems/ha. (Table 1, also Rogers 1981).

Conditions favoring the reproduction of hemlock will also favor the reproduction of the other species it is naturally associated with (Stearns 1949, Fowells 1965, USDA 1973).

Management to facilitate the regeneration already occurring within VT-2 is believed to be unnecessary. Management may, however, become necessary regarding the overall preservation of VT-2 should it ever be threatened by fire or an establishing deer (Odocoileus virginianus) population. The impact of fire and deer on Northern-Mesic forests is discussed later in this paper.

Vegetation-Type-3 (Selectively Harvested Northern-Mesic Forest)

The original forest vegetation conditions of the area denoted as VT-3 were estimated, with a modification of the point-centered quarter technique of Cottam and Curtis (1956), and are presented as Table 2.

Yellow birch and hemlock are believed to have been of major importance within the original forest vegetation of the area denoted as VT-3. Sugar maple, white cedar and red maple were of secondary importance. Other species determined as components of the original forest vegetation are listed within Table 2. White pine does not appear within Table 2 but is considered to be a component of original forest conditions. Old-age white pine as well as stumps of

Table 2. Species importance values for the original forest vegetation of the area presently denoted as Vegetation-Type-3 (1978).

| | No. of Individuals ^a | No. of Points | Average Basal area (ft ²)/ individual | Trees/ hectare | Relative Density | Basal area (ft ²)/ hectare | Relative Dominance | % Frequency of Occurrence | Relative Frequency | Import. Value |
|------------------------------|------------------------------------|------------------|--|-------------------|---------------------|--|-----------------------|------------------------------------|-----------------------|------------------|
| <i>Betula alleghaniensis</i> | 36 | 22 | 1.08 | 114.9 | 45.5 | 124.1 | 42.7 | 75.9 | 42.3 | 130.5 |
| <i>Tsuga canadensis</i> | 29 | 18 | 1.53 | 92.6 | 36.7 | 141.6 | 48.8 | 62.1 | 34.6 | 120.1 |
| <i>Acer saccharum</i> | 5 | 4 | 0.62 | 16.0 | 6.3 | 9.9 | 3.4 | 13.8 | 7.7 | 17.4 |
| <i>Thuja occidentalis</i> | 3 | 2 | 0.44 | 9.6 | 3.8 | 4.2 | 1.4 | 6.9 | 3.8 | 9.0 |
| <i>Acer rubrum</i> | 2 | 2 | 1.05 | 6.4 | 2.5 | 6.7 | 2.3 | 6.9 | 3.8 | 8.6 |
| <i>Abies balsamea</i> | 2 | 2 | 0.13 | 6.4 | 2.5 | 0.8 | 0.3 | 6.9 | 3.8 | 6.6 |
| <i>Quercus rubra</i> | 1 | 1 | 0.58 | 3.2 | 1.3 | 1.9 | 0.7 | 3.5 | 1.9 | 3.9 |
| <i>Sorbus americana</i> | 1 | 1 | 0.36 | 3.2 | 1.3 | 1.2 | 0.4 | 3.5 | 1.9 | 3.6 |
| | 79 | 52 | 5.79 | 252.3 | 99.9 | 290.4 | 100.0 | 179.5 | 99.8 | 299.7 |

^aIncludes stumps of harvested trees and trees judged to be 24 years old or older.

previously harvested white pine were occasionally found throughout the area denoted as VT-3. Frederick et al. (1976), from study of the original general land office survey records, substantiates the above by saying that "the original vegetation of Outer Island was almost entirely hemlock-yellow birch --- white pine-red pine was found along the shoreline ---."

The only red pine found during the present study was within VT-7 (Sand-spit: forested), discussed later in this paper.

The first disturbance of the original forest vegetation of Outer Island occurred in the late 1800s to 1908 with the selective removal of white pine. Hemlock, yellow birch, sugar maple and red maple were harvested from the southern portion of Outer Island between 1922-1926; from the northern portion of Outer Island between 1948-1960 (Frederick et al. 1976). This selective removal of canopy trees created ideal conditions for hardwood (birch, maple) regeneration (Fowells 1965, USDA 1973, Frederick et al. 1976, Brander et al. 1978, Anderson et al. 1979). It is this abundant hardwood regeneration and residual forest canopy (not having been destroyed by fire) of hemlock, yellow birch and sugar maple which defines VT-3. Those portions of Outer Island which were extensively burned following logging (residual, original forest vegetation destroyed) are discussed below as VT-6.

The existing conditions of VT-3 are presented as Table 3.

Table 3. Vegetation-Type-3 (Selectively harvested Northern-Mesic forest): tree species importance values, Outer Island, Apostle Islands National Lakeshore.^a

| Species | No. of Plots | No. of Stems | Basal Area (ft. ²) | Plot Frequency % | Stems/hectare | Basal area (ft. ²)/hectare | Relative Frequency | Relative Density | Relative Dominance | Import. Value |
|--|--------------|--------------|--------------------------------|------------------|---------------|--|--------------------|------------------|--------------------|---------------|
| Trees (>10.16 cm.d.b.h.) | | | | | | | | | | |
| Acer saccharum | 18 | 42 | 18.71 | 37.5 | 86.5 | 38.5 | 17.6 | 19.2 | 20.1 | 56.9 |
| Betula alleghaniensis | 16 | 32 | 18.90 | 33.3 | 65.9 | 38.9 | 15.7 | 14.6 | 20.3 | 50.6 |
| Tsuga canadensis | 14 | 24 | 16.42 | 29.2 | 49.4 | 33.8 | 13.7 | 11.0 | 17.7 | 42.4 |
| Acer rubrum | 12 | 29 | 10.95 | 25.0 | 59.7 | 22.5 | 11.8 | 13.2 | 11.8 | 36.8 |
| Populus tremuloides | 9 | 27 | 10.31 | 18.8 | 55.6 | 21.2 | 8.8 | 12.3 | 11.1 | 32.2 |
| Prunus pensylvanica | 7 | 24 | 2.96 | 14.6 | 49.4 | 6.1 | 6.9 | 11.0 | 3.2 | 21.1 |
| Betula papyrifera | 8 | 12 | 6.09 | 16.7 | 24.7 | 12.5 | 7.9 | 5.5 | 6.5 | 19.9 |
| Thuja occidentalis | 9 | 11 | 2.21 | 18.8 | 22.6 | 4.5 | 8.8 | 5.0 | 2.4 | 16.2 |
| Abies balsamea | 4 | 12 | 5.04 | 8.3 | 24.7 | 10.4 | 3.9 | 5.5 | 5.4 | 14.8 |
| Sorbus americana | 2 | 3 | 1.01 | 4.2 | 6.2 | 2.1 | 2.0 | 1.4 | 1.1 | 4.5 |
| Unknown species | 2 | 2 | 0.24 | 4.2 | 4.1 | 0.5 | 2.0 | 0.9 | 0.3 | 3.2 |
| Tilia americana | 1 | 1 | 0.14 | 2.1 | 2.1 | 0.3 | 1.0 | 0.5 | 0.2 | 1.7 |
| | | 219 | 92.98 | 212.7 | 450.9 | 191.3 | 100.1 | 100.1 | 100.1 | 300.3 |
| Tree Saplings (>2.54 but <10.16 cm.d.b.h.) | | | | | | | | | | |
| Betula alleghaniensis | 27 | 247 | 5.96 | 56.3 | 508.6 | 12.3 | 21.8 | 37.1 | 31.8 | 90.7 |
| Acer saccharum | 22 | 129 | 3.28 | 45.8 | 265.6 | 6.7 | 17.7 | 19.4 | 17.3 | 54.4 |
| Acer rubrum | 20 | 65 | 2.12 | 41.7 | 133.9 | 4.4 | 16.1 | 9.8 | 11.4 | 37.3 |
| Populus tremuloides | 9 | 57 | 2.00 | 18.8 | 117.4 | 4.1 | 7.3 | 8.6 | 10.6 | 26.5 |
| Prunus pensylvanica | 9 | 51 | 2.00 | 18.8 | 105.0 | 4.1 | 7.3 | 7.7 | 10.6 | 25.6 |
| Sorbus americana | 7 | 26 | 0.62 | 14.6 | 53.5 | 1.3 | 5.6 | 3.9 | 3.4 | 12.9 |
| Abies balsamea | 7 | 13 | 0.52 | 14.6 | 26.8 | 1.1 | 5.6 | 2.0 | 2.8 | 10.4 |
| Unknown species | 5 | 21 | 0.60 | 10.4 | 43.2 | 1.2 | 4.0 | 3.2 | 3.1 | 10.3 |
| Betula papyrifera | 5 | 20 | 0.52 | 10.4 | 41.2 | 1.1 | 4.0 | 3.0 | 2.8 | 9.8 |
| Tsuga canadensis | 5 | 12 | 0.42 | 10.4 | 24.7 | 0.9 | 4.0 | 1.8 | 2.3 | 8.1 |
| Thuja occidentalis | 3 | 13 | 0.43 | 6.3 | 26.8 | 0.9 | 2.4 | 2.0 | 2.3 | 6.7 |
| Fraxinus sp. | 1 | 6 | 0.15 | 2.1 | 12.4 | 0.3 | 0.8 | 0.9 | 0.8 | 2.5 |
| Quercus rubra | 2 | 2 | 0.06 | 4.2 | 4.1 | 0.1 | 1.6 | 0.3 | 0.3 | 2.2 |
| Fraxinus nigra | 1 | 2 | 0.07 | 2.1 | 4.1 | 0.1 | 0.8 | 0.3 | 0.3 | 1.4 |
| Ostrya virginiana | 1 | 1 | 0.05 | 2.1 | 2.1 | 0.1 | 0.8 | 0.2 | 0.3 | 1.3 |
| | | 665 | 18.80 | 258.6 | 1369.4 | 38.7 | 99.8 | 100.2 | 100.1 | 300.1 |

Table 3 continued.

| Species | No. of Plots | No. of Stems | Basal area (ft. ²) | Plot Frequency % | Stems/hectare | Basal area (ft. ²)/hectare | Relative Frequency | Relative Density | Relative Dominance | Import. Value |
|----------------------------------|--------------|--------------|--------------------------------|------------------|---------------|--|--------------------|------------------|--------------------|---------------|
| Tree seedlings (<2.54 cm.d.b.h.) | | | | | | | | | | |
| <i>Acer saccharum</i> | 23 | 290 | 0.0534 | 47.9 | 14928.9 | 2.74 | 32.4 | 53.7 | 31.9 | 118.0 |
| <i>Betula alleghaniensis</i> | 12 | 54 | 0.0703 | 25.0 | 2779.9 | 3.61 | 16.9 | 10.0 | 42.1 | 69.0 |
| <i>Acer rubrum</i> | 16 | 158 | 0.0147 | 33.3 | 8133.7 | 0.76 | 22.5 | 29.3 | 8.9 | 60.7 |
| <i>Thuja occidentalis</i> | 3 | 13 | 0.0123 | 6.3 | 669.2 | 0.64 | 4.3 | 2.4 | 7.5 | 14.2 |
| <i>Sorbus americana</i> | 7 | 10 | 0.0010 | 14.6 | 514.8 | 0.05 | 9.9 | 1.9 | 0.6 | 12.4 |
| <i>Betula papyrifera</i> | 4 | 4 | 0.0074 | 8.3 | 205.9 | 0.37 | 5.6 | 0.7 | 4.3 | 10.6 |
| <i>Tsuga canadensis</i> | 1 | 4 | 0.0058 | 2.1 | 205.9 | 0.30 | 1.4 | 0.7 | 3.5 | 5.6 |
| <i>Prunus pensylvanica</i> | 1 | 1 | 0.0019 | 2.1 | 51.5 | 0.10 | 1.4 | 0.2 | 1.2 | 2.8 |
| Unknown species | 1 | 3 | 0 | 2.1 | 154.4 | 0 | 1.4 | 0.6 | 0 | 2.0 |
| <i>Ostrya virginiana</i> | 1 | 1 | 0.0002 | 2.1 | 51.5 | 0.01 | 1.4 | 0.2 | 0.1 | 1.7 |
| <i>Abies balsamea</i> | 1 | 1 | 0 | 2.1 | 51.5 | 0 | 1.4 | 0.2 | 0 | 1.6 |
| <i>Quercus rubra</i> | 1 | 1 | 0 | 2.1 | 51.5 | 0 | 1.4 | 0.2 | 0 | 1.6 |
| | | 540 | 0.1670 | 148.0 | 27798.7 | 8.58 | 100.0 | 100.1 | 100.1 | 300.2 |

^aCalculated from data obtained by Brander et al. (1978).

Data were calculated from information collected by Brander et al. (1978). Sugar maple, yellow birch and hemlock dominate the canopy of VT-3. Species characteristic of disturbed forest conditions are of secondary importance and include red maple, trembling aspen, pin cherry and white birch. Remaining species include white cedar, balsam fir (Abies balsamea), mountain ash (Sorbus americana) and basswood (Tilia americana).

Shrub stratum tree species composition is dominated by yellow birch, sugar maple, red maple, trembling aspen and pin cherry.

Sugar maple is the dominant tree species within the herbaceous stratum with yellow birch and red maple being of secondary importance.

The relative importance of species characteristic of disturbed forest conditions (white birch, trembling aspen, pin cherry) is expected to decrease over time due to natural succession.

Of the species present within the original forest conditions of VT-3, yellow birch, red maple and white cedar reproduction appears adequate to restock the tree stratum. These species will likely form climax communities in wetter areas, but are expected to decrease in relative importance in areas where

growing in competition with sugar maple. The relative importance of sugar maple is expected to increase over time. Conversely, the relative importance of hemlock appears to be decreasing. The importance value for hemlock seedlings (5.60) is low when compared to its importance within the residual canopy of VT-3 (42.35). This difference becomes even more dramatic when comparison is made to the relative importance of hemlock within the original forest-type (Table 2). The hemlock reproduction that is occurring is within localized areas of suitable habitat as opposed to sparse reproduction over large areas.

The relative importance of white pine is suspected as having decreased since the late 1800s due to harvesting and to increasingly unfavorable reproductive conditions as a result of a policy of fire suppression.

It is clear that efforts to hasten the re-establishment of original forest conditions within VT-3 must focus on facilitating the reproduction of hemlock and possibly that of white pine as well.

Vegetation-Type-6 (Birch-Maple Forest)

The original forest vegetation of VT-6 is believed to have been similar to that described above for VT-3.

Frederick et al. (1976), from study of the original general

land office survey records, substantiates this by stating that "the original vegetation of Outer Island was almost entirely hemlock-yellow birch ---." He goes on to say that the southern portion of Outer Island (primarily denoted as VT-6) was logged for "hemlock and hardwoods" between 1922-1926.

Charles Sheridan, a life-long resident of the Apostle Islands area, described the original forest vegetation of the southern portion of Outer Island by saying; " --- it had a stand of hemlock and hardwood that was just beautiful --- some of the stuff ran five feet in diameter at the butt" (Rakestraw 1976).

Pockets of residual, original forest vegetation (presumably having escaped the extensive fires of 1930) were found within the southern portion of Outer Island (areas denoted as VT-3, Fig. 2) during the present study. The composition of these areas (canopy dominants are sugar maple, yellow birch, white cedar, white pine and hemlock) gives further support for the original dominance of the majority of Outer Island by hemlock and hardwoods.

The existing conditions of VT-6 are presented as Table 4. Data were calculated from information collected by Brander et al. (1978). VT-6 could be described as a northern mesic hardwood forest of an intermediate successional stage. The canopy dominant is white birch, with yellow birch, sugar maple and trembling aspen being of secondary importance.

Table 4. Vegetation-Type-6 (Birch-Maple Forest): tree species importance values, Outer Island, Apostle Islands National Lakeshore.^a

| Species | No of Plots | No. of Stems | Basal area (ft. ²) | Plot Frequency % | Stems/hectare | Basal area (ft. ²)/hectare | Relative Frequency | Relative Density | Relative Dominance | Import. Value |
|--|-------------|--------------|--------------------------------|------------------|---------------|--|--------------------|------------------|--------------------|---------------|
| Trees (≥10.16 cm, d.b.h.) | | | | | | | | | | |
| <i>Betula papyrifera</i> | 65 | 310 | 90.08 | 81.3 | 383.0 | 111.3 | 27.8 | 41.1 | 42.5 | 111.4 |
| <i>Betula alleghaniensis</i> | 45 | 169 | 33.29 | 56.3 | 208.8 | 41.1 | 19.2 | 22.4 | 15.7 | 57.3 |
| <i>Acer saccharum</i> | 38 | 116 | 35.38 | 47.5 | 143.3 | 43.7 | 16.2 | 15.4 | 16.7 | 48.3 |
| <i>Populus tremuloides</i> | 20 | 36 | 18.63 | 25.0 | 44.5 | 23.0 | 8.5 | 4.8 | 8.8 | 22.1 |
| <i>Abies balsamea</i> | 12 | 27 | 3.96 | 15.0 | 33.4 | 4.9 | 5.1 | 3.6 | 1.9 | 10.6 |
| <i>Populus grandidentata</i> | 8 | 15 | 9.20 | 10.0 | 18.5 | 11.4 | 3.4 | 2.0 | 4.3 | 9.7 |
| <i>Quercus rubra</i> | 9 | 15 | 7.25 | 11.3 | 18.5 | 9.0 | 3.9 | 2.0 | 3.4 | 9.3 |
| <i>Acer rubrum</i> | 10 | 20 | 4.46 | 12.5 | 24.7 | 5.5 | 4.3 | 2.6 | 2.1 | 9.0 |
| <i>Sorbus americana</i> | 9 | 15 | 2.38 | 11.3 | 18.5 | 2.9 | 3.9 | 2.0 | 1.1 | 7.0 |
| <i>Thuja occidentalis</i> | 9 | 14 | 2.07 | 11.3 | 17.3 | 2.6 | 3.9 | 1.9 | 1.0 | 6.8 |
| <i>Tilia americana</i> | 2 | 8 | 3.15 | 2.5 | 9.9 | 3.9 | 0.9 | 1.1 | 1.5 | 3.5 |
| <i>Tsuga canadensis</i> | 4 | 5 | 1.40 | 5.0 | 6.2 | 1.7 | 1.7 | 0.7 | 0.6 | 3.0 |
| <i>Ostrya virginiana</i> | 1 | 3 | 0.76 | 1.3 | 3.7 | 0.9 | 0.4 | 0.4 | 0.3 | 1.1 |
| <i>Betula sp.</i> | 1 | 1 | 0.11 | 1.3 | 1.2 | 0.1 | 0.4 | 0.1 | 0.0 | 0.5 |
| <i>Fraxinus nigra</i> | 1 | 1 | 0.11 | 1.3 | 1.2 | 0.1 | 0.4 | 0.1 | 0.0 | 0.5 |
| | | 755 | 212.23 | 292.9 | 932.7 | 262.1 | 100.0 | 100.2 | 99.9 | 300.1 |
| Tree saplings (≥2.54 cm, but <10.16 cm, d.b.h.) | | | | | | | | | | |
| <i>Acer saccharum</i> | 54 | 546 | 12.09 | 67.5 | 674.6 | 14.9 | 24.9 | 40.9 | 28.3 | 94.1 |
| <i>Betula alleghaniensis</i> | 57 | 380 | 14.12 | 71.3 | 469.5 | 17.4 | 26.3 | 28.5 | 33.0 | 87.8 |
| <i>Betula papyrifera</i> | 44 | 202 | 9.23 | 55.0 | 249.6 | 11.4 | 20.3 | 15.1 | 21.6 | 57.0 |
| <i>Abies balsamea</i> | 16 | 108 | 3.02 | 20.0 | 133.4 | 3.7 | 7.4 | 8.1 | 7.0 | 22.5 |
| <i>Acer rubrum</i> | 13 | 31 | 1.12 | 16.3 | 38.3 | 1.4 | 6.0 | 2.3 | 2.7 | 11.0 |
| <i>Thuja occidentalis</i> | 11 | 35 | 1.14 | 13.8 | 43.2 | 1.4 | 5.1 | 2.6 | 2.7 | 10.4 |
| <i>Populus tremuloides</i> | 6 | 9 | 0.98 | 7.5 | 11.1 | 1.2 | 2.8 | 0.7 | 2.3 | 5.8 |
| <i>Sorbus americana</i> | 7 | 10 | 0.46 | 8.8 | 12.4 | 0.6 | 3.2 | 0.8 | 1.1 | 5.1 |
| <i>Prunus pensylvanica</i> | 4 | 7 | 0.26 | 5.0 | 8.6 | 0.3 | 1.8 | 0.5 | 0.6 | 2.9 |
| <i>Ostrya virginiana</i> | 4 | 4 | 0.22 | 5.0 | 4.9 | 0.3 | 1.8 | 0.3 | 0.6 | 2.7 |
| <i>Tilia americana</i> | 1 | 3 | 0.11 | 1.3 | 3.7 | 0.1 | 0.5 | 0.2 | 0.2 | 0.9 |
| | | 1335 | 42.75 | 271.5 | 1649.3 | 52.7 | 100.1 | 100.0 | 100.1 | 300.2 |

Table 4 continued.

| Species | No. of Plots | No. of Stems | Basal area (ft. ²) | Plot Frequency % | Stems/hectare | Basal area (ft. ²)/hectare | Relative Frequency | Relative Density | Relative Dominance | Import. Value |
|----------------------------------|--------------|--------------|--------------------------------|------------------|---------------|--|--------------------|------------------|--------------------|---------------|
| Tree seedlings (<2.54 cm d.b.h.) | | | | | | | | | | |
| <i>Acer saccharum</i> | 55 | 1005 | 0.1573 | 68.8 | 31041.9 | 4.858 | 44.3 | 77.8 | 75.2 | 197.3 |
| <i>Acer rubrum</i> | 26 | 202 | 0.0344 | 32.5 | 6239.3 | 1.063 | 20.9 | 15.6 | 16.5 | 53.0 |
| <i>Quercus rubra</i> | 13 | 19 | 0.0008 | 16.3 | 586.9 | 0.025 | 10.5 | 1.5 | 0.4 | 12.4 |
| <i>Betula papyrifera</i> | 11 | 30 | 0.0012 | 13.8 | 926.6 | 0.037 | 8.9 | 2.3 | 0.6 | 11.8 |
| <i>Betula alleghaniensis</i> | 6 | 10 | 0.0068 | 7.5 | 308.9 | 0.210 | 4.8 | 0.8 | 3.3 | 8.9 |
| <i>Abies balsamea</i> | 5 | 7 | 0.0059 | 6.3 | 216.2 | 0.183 | 4.1 | 0.5 | 2.8 | 7.4 |
| <i>Sorbus americana</i> | 6 | 7 | 0.0004 | 7.5 | 216.2 | 0.012 | 4.8 | 0.5 | 0.2 | 5.5 |
| <i>Thuja occidentalis</i> | 1 | 8 | 0.0015 | 1.3 | 247.1 | 0.046 | 0.8 | 0.6 | 0.7 | 2.1 |
| <i>Populus tremuloides</i> | 1 | 4 | 0.0008 | 1.3 | 123.6 | 0.025 | 0.8 | 0.3 | 0.4 | 1.5 |
| | | 1292 | 0.2091 | 155.3 | 39905.7 | 6.459 | 99.9 | 99.9 | 100.1 | 299.9 |

^aCalculated from data obtained by Brander et al. (1978).

Shrub stratum species importance values indicate that understory conditions have changed to favor the more shade tolerant sugar maple and yellow birch. Importance values of the shade intolerant white birch and trembling aspen have dropped markedly.

Herb stratum species importance values indicate that conditions are more shaded than in the upper strata with sugar maple being the dominant tree seedling present. Red maple is also important. White birch, yellow birch and trembling aspen reproduction exists, but is almost negligible.

All species believed to have been components of original forest conditions still exist within the canopy of VT-6 except for white pine. Decayed stumps of harvested white pine were occasionally found within VT-6, but white pine was not recorded in Table 4 and it was not observed within VT-6.

Reproduction of sugar maple and red maple appears adequate to restock the tree stratum of VT-6. Yellow birch reproduction is occurring but at an apparently declining rate. Yellow birch occupied a position of major importance within the original forest vegetation (Table 2; also Frederick et al. 1976), but is of low relative importance within the herb stratum of VT-6.

Hemlock reproduction is not occurring in VT-6. The importance value of hemlock within the tree stratum of VT-6 (3.03) is low, relative to its importance within original

forest conditions. Hemlock importance values are likely to continue to decrease over time.

Reproductive levels of other species of original forest conditions (white cedar, balsam fir, mountain ash, red oak (Quercus rubra)) appear to be adequate to restock the tree stratum.

Efforts to hasten the re-establishment of original forest conditions within VT-6 need to focus on facilitating the reproduction of hemlock, yellow birch and possibly that of white pine as well.

Vegetation-Type-7 (Sand-spit: Forested portion)

The forested portion of the Outer Island sand-spit composes VT-7 (Fig. 2). The existing conditions of the tree stratum of VT-7 have been summarized; white pine and red pine are dominant with white birch and balsam fir being of secondary importance.

The existing conditions of the shrub and herb strata of VT-7 are presented as Table 5. Shrub stratum tree species reproduction is sparse and is predominantly composed of balsam fir and white pine. Balsam fir, red maple and white pine reproduction are present within the herb stratum.

Frederick et al. (1976-b), from study of the original general land office survey records, composed a map of the

Table 5. Vegetation-Type-7 (Sand-Spit:Forested): tree species importance values, Outer Island, Apostle Islands National Lakeshore, 1978.

| Species | No. of Plots | No. of Stems | Basal area (ft. ²) | Plot Frequency % | Stems/ hectare | Basal area (ft. ²)/ hectare | Relative Frequency | Relative Density | Relative Dominance | Import. Value |
|---|--------------|--------------|--------------------------------|------------------|----------------|---|--------------------|------------------|--------------------|---------------|
| Tree saplings (>2.54 cm, but <10.16 cm, d.b.h.) | | | | | | | | | | |
| Abies balsamea | 2 | 2 | 0.0156 | 6.9 | 170.4 | 1.3 | 67.0 | 66.7 | 72.2 | 205.9 |
| Pinus strobus | 1 | 1 | 0.0053 | 3.4 | 85.2 | 0.5 | 33.0 | 33.3 | 27.8 | 94.1 |
| | | 3 | 0.0209 | 10.3 | 255.6 | 1.8 | 100.0 | 100.0 | 100.0 | 300.0 |
| Tree seedlings (<2.54 cm, d.b.h.) | | | | | | | | | | |
| Abies balsamea | 11 | 76 | 0.0104 | 37.9 | 6475.6 | 0.88 | 52.4 | 55.1 | 71.5 | 179.0 |
| Acer rubrum | 3 | 51 | 0.0033 | 10.3 | 4345.5 | 0.28 | 14.2 | 37.0 | 22.8 | 74.0 |
| Pinus strobus | 7 | 11 | 0.0008 | 24.1 | 937.3 | 0.07 | 33.3 | 8.0 | 5.7 | 47.0 |
| | | 138 | 0.0145 | 72.3 | 11758.4 | 1.23 | 99.9 | 100.1 | 100.0 | 300.0 |

original forest vegetation of Outer Island. White pine and red pine are denoted as dominating the original forest vegetation of the sand-spit.

The present study identified a stand of large white pine (individuals up to 51 cm. dbh) within VT-7. Increment corings of two comparatively sized (47 and 55 cm. dbh) white pine on Stockton Island, AINL (Unpublished data, Fraundorf 1979) yielded tree ages of 99 and 108 years. These diameter-age relationships are supported by data presented within Fowells (1965). This substantiates that white pine was a member of the original forest-type of VT-7.

Balsam fir and red maple reproduction seems to indicate that relatively mesic conditions exist in the shrub and herb strata (despite the sandy substrate), which suggests that mesic forest species such as balsam fir, red maple, sugar maple, yellow birch or even hemlock may have also been components of the original forest vegetation of VT-7.

Sediment studies of the bog areas adjacent to VT-7 may be of value in the reconstruction of the original forest composition. Charcoal and pollen deposits within sediment samples would be of particular value in reconstructing the fire periodicity and subsequently the species composition of the original forest conditions of VT-7.

Efforts to hasten the re-establishment of original forest conditions within VT-7 should focus on facilitating the

reproduction of white pine and red pine. Even if mesic area species (balsam fir, birches, maples, hemlock) are determined to have been components of original forest conditions, active management to aid their reproduction would be more efficiently applied within the previously discussed VT-3 and VT-6. The sandy soils of VT-7 are better suited to the regeneration of pines, original forest components which would be much more difficult to re-establish within other areas of Outer Island where hardwood competition would be greater.

In summary, the above discussions of original and existing vegetation-types have identified hemlock, yellow birch, white pine and red pine as the target species of management efforts to assist in re-establishing an approximation of the original forest conditions of Outer Island.

Forest Vegetation: Hemlock Silviculture

Climatic and Edaphic Requirements

The range of eastern hemlock (Curtis 1959, Goder 1962, Fowells 1965) includes much of the eastern portion of the United States and extends northward into Canada and westward to the Great Lakes States.

Hemlock forests in Wisconsin most commonly occurred in the northern portion of the state. Bayfield County is noted as the western edge of hemlocks range (Curtis 1959, Goder

1962), although hemlock has also been noted to occur in the more western county of Douglas (Davidson et al. 1973, Personal observation 1984).

The climate in which eastern hemlock is most productive "is predominantly humid and cool, with adequate moisture in all seasons" (Fowells 1965). Toumey et al. (1928), Daubenmire (1930), Potzger et al. (1937), Bard (1967), Hodges et al. (1968), Davidson et al. (1973), Eickmeier et al. (1975), Lewin (1975), Coffman (1978), Rogers (1978), Kessel (1979), Nicholson et al. (1979), Charney (1980), Hardin et al. (1980), Huenneke (1982) and Pastor et al. (1982) have all shown eastern hemlock to prefer relatively mesic conditions. The preference of hemlock for cool climatic conditions has been demonstrated by Stearns et al. (1958), Olson et al. (1959), Buell et al. (1966), Adams et al. (1971) and Kessell (1979).

Hemlock "is found in localities with annual precipitation as low as 28 inches --- hemlock is most productive where the annual precipitation is from 32 to over 56 inches ---" (Fowells 1965). The average annual precipitation of the Apostle Islands area is 70 cm. (27.6 inches; USDC 1974). Factors acting to reduce evaporative losses (increase net precipitation available) would then, seem to be of great significance to the occurrence of hemlock on the Apostle Islands: included are the cool and moist climatic conditions created by Lake Superior and by the dense canopies of existing hemlock stands.

Proximity to Lake Superior has been suggested as a favorable factor to the occurrence of hemlock on the Porcupine Mountains of the Upper Peninsula of Michigan (Fowells 1965). Stearns (1949, 1951) describes the effects the dense canopies of hemlock stands have on maintaining cool and moist microclimatic conditions. Fowells (1965) reiterates the same:

" --- the microclimate beneath hemlock differs from the regional climate and from that of adjacent hardwood stands, especially during the growing season. Beneath a hemlock canopy the microclimate is cooler and there is less evaporation during the growing season than in adjacent hardwood stands of similar age on similar topography."

The original forest vegetation was harvested from the Apostle Islands during the 19th and 20th centuries. The effects of this logging on the survival and regeneration of hemlock on Outer Island are discussed later in this section.

Hemlock grows in a wide range of edaphic conditions (Fowells 1965, Rogers 1978, Charney 1980). Soil texture varies from coarse sands and gravels (Rogers 1978, Nicholson et al. 1979) to loams (Rogers 1978, Hardin et al. 1980) and clays (Fowells 1965). Soil pH (Fowells 1965) and nutritive status of areas hemlock will occupy is also quite variable. Hemlock is most commonly found on nutrient-poor soils, but grows best on the more fertile loamy soils (Rogers 1978). Organic acids and aluminum liberated from decomposing hemlock needles tend to acidify the soils hemlock grows upon

(Messenger 1975). Daubenmire (1931), Rogers (1978), Hardin et al. (1980) and Huenneke (1982) have all found the soils under hemlock stands to be acidic.

Hemlock flowers from April to early June, depending upon location. The small, winged seeds are shed during the fall and winter following cone maturity. Good seed crops may occur every two or three years in mature stands (Fowells 1965). Hemlock seed production is considered by many (Merrill et al. 1924, Hough et al. 1943, Stearns 1949, 1951, Borman et al. 1958, Olson et al. 1959) to be "highly periodic." An explanation for the periodic production of hemlock seed may lie within the fact that hemlock is a long lived species and often grows on nutrient-poor sites. Frothingham (1915) and Jenkins (1946) regard potential hemlock longevity to be "at least 600 years" and "at least 800 years", respectively. Rogers (1978) states that the generation time of hemlock may normally exceed 300 years. Due to such a long life expectancy, the regular production of seed would seem to be both unnecessary and an inefficient use of available nutrients. Dominant hemlock may produce seed for up to 450 years or more (Fowells 1965).

The stratification of hemlock seed is considered necessary to postpone germination of the fall-shed seed, and to maintain seed viability, until spring. In addition, overwinter stratification hastens the germination of seed in the spring (Toumey et al. 1928, Stearns et al. 1958).

The successful germination of hemlock seed is dependent upon a continuous supply of moisture. Coffman (1978) states that ideal conditions for hemlock seed germination are present in an atmosphere of 100% relative humidity. He further states that occasional spring drying will not only delay seed germination but will also lessen the total percentage of seed that will germinate. Stearns et al. (1958) and Olson et al. (1959) state that germination of hemlock seed is better on cool sites. This is more likely due to the lowered evaporation rates and moisture stress of cool sites, than it is due to the direct effects of injury by heat. Coffman (1978) says that even moderate levels of light in areas of marginal moisture can be enough to set hemlock germination back.

Once germinated, the survival of hemlock seedlings is dependent upon a continuous availability of moisture (Daubenmire 1930, Potzger et al. 1937) and upon adequate levels of light (Stearns 1949, 1951, Brown et al. 1952, Olson 1954, Olson et al. 1959). Seedling vigor is reduced if overly shaded; conversely, too much light may cause heat lesions or direct seedling mortality (Brown et al. 1952, Olson 1954). Rogers (1978) feels the major problem with excessive insolation is moisture stress rather than direct heat damage. Fowells (1965) agrees that moisture stress is the more critical factor and suggests that 20% of full sunlight will allow for adequate seedling vigor

without causing soil desiccation. The study cited by Fowells was that of Lutz (1928). Data were collected on the east coast where annual precipitation levels may be greater than those of the Apostle Islands area. Acceptable levels of insolation for hemlock seedlings on Outer Island may therefore be lower than the 20% of full sunlight suggested by Fowells (1965).

In summary, the requirements discussed above for the successful regeneration of hemlock are:

- 1) moist and cool conditions for overwinter seed stratification,
- 2) conditions of 100% relative atmospheric humidity and a continuous moisture supply for seed germination,
- 3) continuous moisture availability and some sunlight for early seedling survival. Hemlock of all ages needs a continuous supply of moisture; older hemlock seedlings can, however, survive under deep shade.

Seedbed Requirements

In regard to the previous discussion of climatic conditions, it is apparent that the moisture conditions required for successful hemlock regeneration are optimal under existing hemlock canopies. However, without disturbance of any kind that favorable moist reproductive climate is generally not available to hemlock seed due to the accumulation of one to three inches of duff (Stearns 1951). Seed landing on duff is subject to desiccation. Even if germination occurs,

the hemlock hypocotyl cannot successfully penetrate the duff to reach the moist underlying substrate (Grant et al. 1961, USDA 1973).

Conditions favoring the reproduction of hemlock (moist seedbed accessibility) are created by the windthrow of canopy trees. Hemlock is shallow rooted and is highly susceptible to being blown over (Stearns 1949, 1951, Nicholson et al. 1979). Windthrown trees within the pre-settlement Northern-Mesic forest are noted by Stearns (1949) as being "neither a rare nor an isolated and local occurrence." He further states that "windfall is a common agent of mortality in the mature stand where it operates in conjunction with disease."

Windthrown trees result in dead and rotting wood on the forest floor; mineral soil is exposed (scarification) by the uplifted root system. These mediums (rotting wood and mineral soil) are normally continuously moist and therefore, serve as seedbeds for hemlock reproduction (Fowells 1965).

Many investigators (Harlow 1900, Lutz 1930, 1930-b, Friesner et al. 1932, Hough 1936, 1943, Potzger 1946, Stearns 1951, Niering 1953, Goder 1955, Maycock et al. 1960, McFee et al. 1966, Keever 1973, Coffman 1978, Ward et al. 1982) have found hemlock seedlings to be most numerous upon rotting wood and associate the success of hemlock reproduction with the amount of rotting wood on the forest floor. Rotting wood is continuously moistened because of its "organic nature" and "abundant moss covering" (Stearns 1951).

Ward et al. (1982) studied the intraspecific relationships of hemlock reproduction and found that decomposing hemlock leaf litter released chemicals into the soil which prohibited hemlock reproduction. This toxin was experimentally found to be lethal to hemlock seedlings up to six days of age. Hemlock reproduction then, is actually inhibited under its own canopy. The importance of rotting wood to hemlock reproduction then, is not only in that it serves as a moist seedbed, but also as a seedbed elevated above the toxic environment of the forest floor. Stearns (1951) description of how the root systems of hemlock tree seedlings develop on rotting logs seems to substantiate this theory:

"The seedling growing on an old log sends out an extensive root system. In the case of hemlock, these roots, instead of passing into the adjoining soil or leaf mold, restrict themselves almost entirely to the rotten wood and may extend several feet in each direction within its limits. The main roots are extensively branched with numerous mycorrhizae and are frequently covered with a yellowish mycelium. The limitation in root habitat seems to persist at least until the seedling has developed into a sapling several feet in height."

A "sapling several feet in height" would therefore be able to go on and root into the soil without being vulnerable to the toxic environment of the forest floor. This allelopathic effect of hemlock on its own reproduction and on the reproduction of other species has also been noted by Lutz (1930), Stearns (1951), Buell et al. (1966) and Messenger (1975).

Besides providing appropriate seedbeds, windthrown trees also allow light to penetrate to the forest floor and in doing so fulfill the light requirement for active growth of young, establishing hemlock seedlings.

The importance of windthrow to the perpetuation of original Northern-Mesic forest conditions is stressed by Stearns (1949) in saying:

"It seems probable that natural disturbances (primarily windthrow) occur with sufficient frequency as to permit the mixed forest to perpetuate itself, assuming that climatic conditions do not change drastically."

Effects of Logging and Fire

White pine was harvested from the Apostle Islands by 1908. The southern portion of Outer Island was logged for hemlock and hardwoods between 1922-1926; the northern portion between 1948-1960. Extensive, slash-fueled fires burned the southern half of Outer Island in 1930. The effects of logging and fire on reducing stocking levels of hemlock on Outer Island have been both immediate and long-term.

Immediate effects include the direct reduction of hemlock by harvesting and the destruction of residual hemlock by post-logging fires. The susceptibility of hemlock to damage by fire is attested to by VanDersal (1938), Brown (1960)

and Davidson et al. (1973). Rogers (1978) describes hemlock as "possibly the most fire-sensitive mesophytic tree in its range." Fowells (1965) reiterates:

"young hemlocks are highly vulnerable to damage by fire; older tree may survive the lighter surface fires by virtue of their thick bark, but the roots are easily injured by any fire that burns deeper than the loose surface litter."

Fowells (1965), Kozlowski et al. (1974) and Coffman (1978) note that logging and fire result in increased insolation and subsequently in elevated soil temperatures and surface soil moisture loss.

"Maximum daytime temperatures of the soil under a complete plant cover may be 30 degrees F or more below that at the surface of a bare soil under otherwise similar conditions." Surface soil moisture loss increases proportionally with surface soil temperature (Hausenbuiller 1972).

The logging and burning of the original forest vegetation of Outer Island is believed to have resulted in warmer and drier microclimatic conditions than within undisturbed forest conditions (ca. 1880). Long-term effects of these altered climatic conditions are believed to include increased rates of hemlock mortality, and decreases in hemlock productivity and reproductive potential.

The sudden exposure (as by logging) of mature hemlock may result in sunscald, root damage due to increased soil temperatures and possibly insect infestation (Fowells 1965).

Kessell (1979), in studying the relationship of soil moisture availability to hemlock productivity, noted that "a one standard deviation increase in May-July precipitation and relative humidity" will increase the radial growth of Massachusetts hemlock by up to 71%.

Eickmeier et al. (1975) found that photosynthetic rates of northern Wisconsin hemlock were only 29% of their potential when exposed to conditions of "moderate water stress" (osmotic potential of -4 bars). He further notes that reductions in photosynthetic rates were "more pronounced" at tissue temperatures of 25 degrees C (77 F) as compared to tissue temperatures of 15 degrees C (59 F).

Adams et al. (1971) and Kessel (1979) found optimal hemlock photosynthetic temperatures to be 12 degrees C (54 F) and 14-19 degrees C (57-66 F), respectively. Adams et al. (1971) states that "slight differences in field air temperature are critical to net carbon dioxide fixation" and possibly to the survival of hemlock.

Coffman (1978) describes the effect of logging on reducing the reproductive potential of hemlock in stating:

" --- good germination of eastern hemlock occurs only when the seedbed is kept very moist. Any condition of drying, in frequency or severity, will substantially reduce germination percentages. Increased exposure following heavy cutting of hemlock, as frequently practiced in the Upper Peninsula of Michigan and elsewhere in the Northern Hardwood Region, normally results in increased drying of the soil surface, in frequency and severity. This fact may provide a partial explanation of why eastern hemlock is

rarely found in second-growth stands following cutting or other major disturbances of virgin hemlock forests."

Coffman (1978) feels this (moisture deficits) to be the case "even in lightly cut stands."

From the previous discussion of climatic requirements, it is apparent that drying of the soil surface following logging is also detrimental to the regeneration of hemlock in that appropriate conditions for hemlock seed stratification and seedling development are not available.

The relative importance of sugar maple on Outer Island has increased in conjunction with the decline of hemlock (Tables 3 and 4). Messenger (1975) found that the organic acids and aluminum liberated from decomposing hemlock litter enhances the rate of depletion of basic cations from the surface soils. Thus, hemlock stands serve to enhance soil infertility. Sugar maple, a common associate and competitor of hemlock, "thrives only on fertile, moist and well drained soils" (Fowells 1965). Therefore, the decline of hemlock, due to both the immediate and long-term effects of logging activities, is believed to have in turn resulted in an increased reproductive potential for sugar maple on Outer Island.

Other factors favoring the occurrence of sugar maple over hemlock are its resprouting habit following cutting, a higher rate of seed production, the ability to regenerate on forest floor duff and its faster rate of growth,

especially as a seedling (Fowells 1965, USDA 1973). Coffman (1978), Rogers (1978) and Nicholson et al. (1979) have all noted corresponding decreases in hemlock and increases in hardwoods (commonly sugar maple) following logging.

Once established, these even-aged and relatively windfirm hardwood stands serve to further inhibit hemlock reproduction by; 1) covering the forest floor with a leaf layer which the developing hemlock hypocotyl cannot penetrate, 2) preventing light, needed by young establishing hemlock seedlings, from penetrating to the forest floor and 3) limiting the amount of rotting wood available on the forest floor. "Windthrows and other events that expose mineral soil and deposit dead wood are clearly infrequent in the uniform pole forests that result after clearcutting" (Rogers 1978).

Forest Vegetation: Yellow Birch Silviculture

The geographical range of yellow birch generally coincides with that of eastern hemlock, though yellow birch extends somewhat further north and west (Fowells 1965).

Yellow birch and hemlock are believed to have dominated the original forest vegetation of Outer Island; sugar maple was of secondary importance (Table 2). The concurrence of yellow birch, hemlock and sugar maple and their dominance of original Northern-Mesic forest conditions has been documented by Stearns (1951), Barnes (1968), USDA (1973),

Eickmeier et al. (1975) and Rogers (1978).

Yellow birch begins to produce seed at about 40 years of age. Seed production is best from trees 70 years or older. Male catkins form in late summer to fall and elongate in the spring. Female flowers appear in May as the tree begins to leaf out. Seeds mature in late July to August and are shed with the onset of cold weather in October. Good seed crops occur every one to two years. Stratification of yellow birch seed aids in maintaining seed dormancy and viability until spring, when germination occurs. Germination of yellow birch seed is best under conditions of low to moderate insolation, presumably due to the effects of desiccation which may result from higher levels of exposure. Successful seedling establishment requires a moderately well-lit seedbed which also allows the yellow birch hypocotyl access to a dependably moist, humus or mineral soil substrate (Fowells 1965).

Conditions favorable to the regeneration of yellow birch are created by disturbances such as logging, windthrow or fire (Graham 1941, Stearns 1951, Fowells 1965, USDA 1973). Without such disturbances, the forest floor is normally covered with a layer of duff one to three inches in depth (Stearns 1951). Yellow birch does not regenerate well on forest floor duff (Stearns 1951, Fowells 1965, USDA 1973). Periodic desiccation of the duff layer (Fowells 1965)

provides unsuitable conditions for yellow birch seed stratification, germination or for seedling development. Even if desiccation does not occur, the weak yellow birch hypocotyl cannot penetrate the duff layer to become established within the underlying medium (Graham 1941, Zillgitt et al. 1945, Fowells 1965).

Logging, fire and windthrow create appropriate seedbed conditions by opening up of the forest canopy (light penetration to the forest floor), scarification of the duff layer and by depositing dead and rotting wood on the forest floor. Scarification provides access to moist humus or mineral soils; rotting wood is also normally moistened and accessible (no duff buildup) for yellow birch regeneration (Stearns 1951, Fowells 1965, USDA 1973).

By definition, logging was not a factor serving to create appropriate seedbed conditions for yellow birch regeneration within original forest conditions.

Fire was rarely of importance as the original agent of disturbance, but did occur within the original forests as a result of fuel accumulations due to windthrown trees.

"Windfalls in the pre-settlement forest were neither a rare nor an isolated and local occurrence. Windfall is a common agent of mortality in the mature stand where it operates in conjunction with disease" (Stearns 1949).

It therefore seems apparent that the creation and continual rejuvenation of yellow birch seedbeds within original

forest conditions was most frequently the product of windthrow. This is substantiated by Harlow (1900), Lutz (1930), Hough (1943), Potzger (1946), Stearns (1951) and Fraundorf (1983), who have all found yellow birch reproduction within undisturbed (re. human-related disturbances) areas to occur most frequently upon seedbeds composed of rotting wood.

The concurrence of yellow birch, hemlock and sugar maple within original Northern-Mesic forest conditions, in concert with the susceptibility of hemlock to being windthrown (Stearns 1949, 1951, USDA 1973, Nicholson et al. 1979) invites the present conclusion that yellow birch reproduction within original forest conditions was largely dependent upon the windthrow and subsequent contribution of hemlock as seedbeds. In a recent study within the undisturbed area (VT-2, Fig. 2) on Outer Island, all yellow birch reproduction observed was noted as occurring on rotting, moss-covered hemlock logs (Fraundorf 1983).

The silvicultural relationships of hemlock and yellow birch suggests that management to assist in re-establishing original forest conditions be conducted on an ecosystemic level.

Forest Vegetation: Hemlock-Yellow Birch Management
Recommendations

The destruction of the virgin forest canopy of Outer

Island is believed the principal reason for the reduction of the relative importance of hemlock since original forest conditions (ca. 1880). Canopy destruction has created moisture and seedbed deficits, resulting in increased mortality, reduced productivity and reproductive potential for hemlock and increases in the relative importance of sugar maple.

Decreases in the relative importance of hemlock are likely to result in a decreased reproductive potential for yellow birch. Existing log seedbeds will decay and will not be adequately replenished due to a relative decrease of mature hemlock in the forest canopy. The current, high importance values of yellow birch in the shrub and herb strata of VT-3 (Table 3) and in the tree and shrub strata of VT-6 (Table 4) are, resultant of the appropriate seedbed conditions which were created by previous logging and subsequent fire activities and are therefore, not representative of original forest conditions.

National Park Service forest vegetation management policy states that:

"practically all of the forest vegetation in Apostle Islands National Lakeshore has been altered due to logging activities, and there remains only a few small pockets of original vegetation. The National Park Service believes that it is important for the Park visitor to have some insight as to how the islands looked prior to the logging era. Reforestation, if left to natural succession, would take a very long time and some species, such as hemlock, may never regenerate.

--- attempts will be made to restore original vegetative types in an accelerated program to allow Park visitors an opportunity to see prelogging vegetative conditions (USDI 1982). Selected areas of the islands interiors will be manipulated to produce vignettes of the forest prior to European Mans arrival on the Apostle Islands (Brander 1981)."

Management recommendations, to enhance the above policy by, facilitating the reproduction of hemlock and yellow birch on Outer Island follow. Yellow birch management is viewed herein as a byproduct of hemlock management.

The initial phase of management should be the identification of those areas on Outer Island believed to be climatically suitable to the growth and reproduction of hemlock. The following, conceptual priority ranking of hemlock management areas is proposed:

Priority-1 areas; areas composed of a moderate (41-70% canopy closure) to dense (71-100% canopy closure) canopy of hemlock and located on soils with a high and stable ground water table,

Priority-2 areas; remaining areas composed of a moderate to dense canopy of hemlock,

Priority-3 areas; areas composed of a moderate to dense canopy of any species (or combination of species), and containing some hemlock, which are located on soils with a high and stable ground water table,

Priority-4 areas; remaining forested areas located on soils with a high and stable ground water table.

A high and stable ground water table would be one which is near the soil surface throughout the growing season. Soils with potentially high water tables would include; 1) those having little topographic relief and underlain by water impervious materials and, 2) those lands bordering bogs or beaver flowages. Water table stability needs to be site-determined prior to implementation of the specific management recommendations discussed below.

For purposes of identifying specific hemlock-yellow birch management areas on Outer Island, the vegetation-types presented in Fig. 2 have been further detailed as Fig. 3. Vegetation-types composed of a moderately to densely stocked hemlock canopy (Priority-1 and -2 management areas) are; 1, 13, 27, 28, 39 and 56 (Fig. 3). These vegetation types all occur on poorly to very poorly drained soils with little topographic relief (Anderson et al. 1979) and as such are all Priority-1 management areas. Vegetation-types 27, 28, 39 and 56 are also located adjacent to bogs or beaver flowages.

Priority-3 management areas include vegetation-types 2, 5, 6, 30, 36, 40, 55, 57, 58 and 80 (Fig. 3).

Priority-4 management areas are many and can be identified from Fig. 3 in concert with the soils maps of Outer Island presented in Anderson et al. (1979).

Within each management priority-class, other factors to consider include area accessibility and aesthetic values. Consideration of these factors will facilitate management

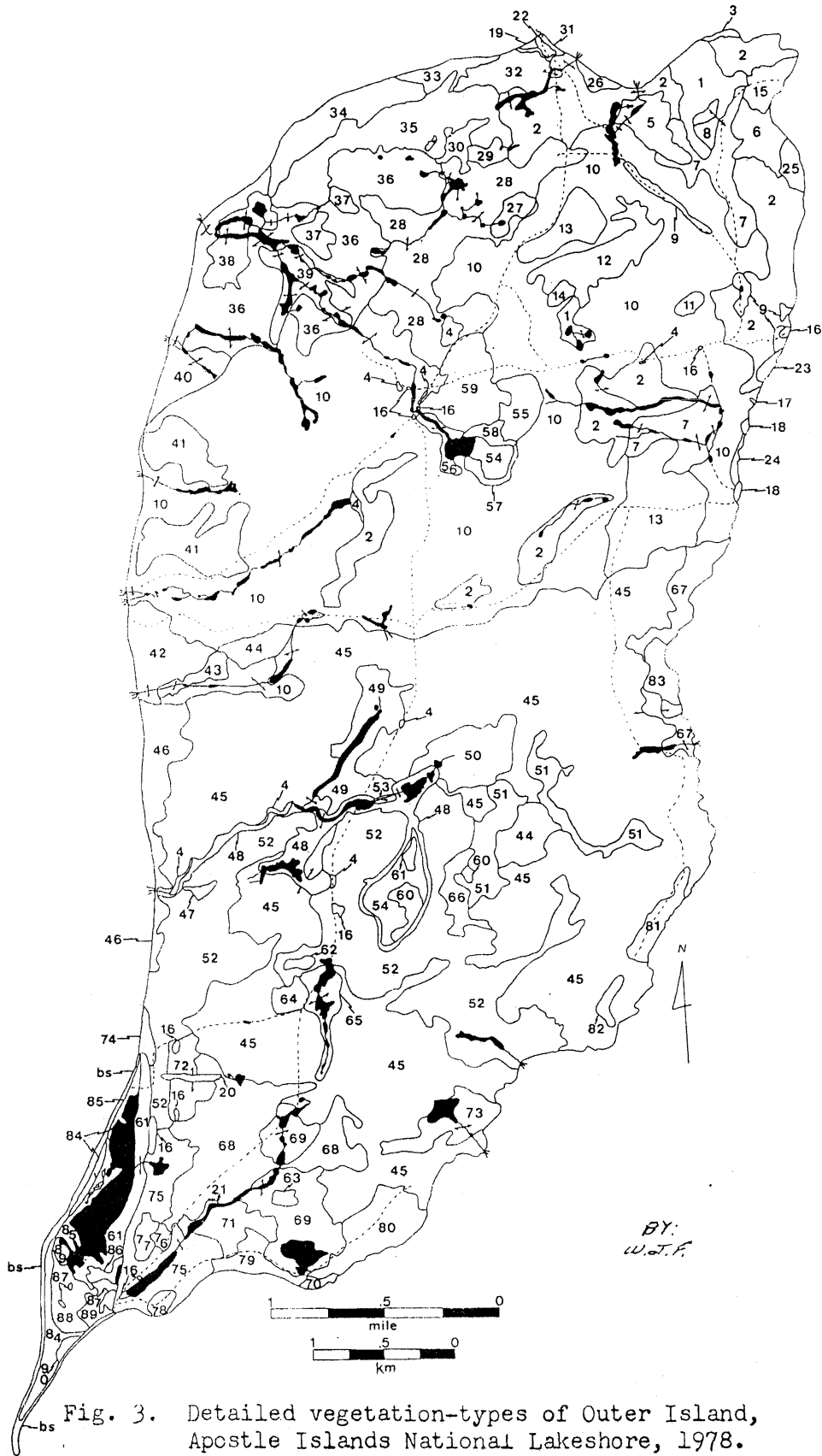


Fig. 3. Detailed vegetation-types of Outer Island, Apostle Islands National Lakeshore, 1978.

Key to Fig. 3.

| <u>Detailed Vegetation-Type</u> | <u>Area (ha)</u> | <u>Description^a</u> |
|-------------------------------------|----------------------|---|
| 1 | 26.5 | <u>Hm'', Yb' 10.2-50.8</u> <u>Yb', Rm and Mm' 2.5-7.6</u> N |
| 2 | 163.2 | <u>Hm', Yb' 10.2-50.8</u> <u>Yb'', As', Pc and Ta' 2.5-7.6</u> N |
| 3 | 0.8 | <u>Mm'', Ma', $\frac{O}{Bl'}$ 2.5-5.1, Wc' 5.1-10.2</u> N |
| 4 | 15.0 | <u>$\frac{O}{Mm', Rd' 1.3-3.8}$</u> Bs ⁻ , As ⁻ , Ss ⁻ , Gs ⁻ |
| 5 | 11.5 | <u>Yb'', Hm' 10.2-50.8</u> <u>Yb', As' 2.5-7.6</u> N |
| 6 | 12.6 | <u>Yb'', Hm', Rm' 10.2-50.8</u> <u>Rm and Mm', Wc' 2.5-7.6</u> N |
| 7 | 42.6 | <u>$\frac{O}{Yb'', As', Pc and Ta' 2.5-7.6}$</u> N |
| 8 | 2.5 | <u>Sm'', Yb' 10.2-50.8</u> <u>Yb', As' 2.5-7.6</u> N |
| 9 | 8.2 | <u>$\frac{O}{Yb'', Pc', Ta' 2.5-7.6}$</u> N |
| 10 | 694.9 | <u>Hm', Yb', Sm' 10.2-50.8</u> <u>Yb'', As', Pc and Ta' 2.5-7.6</u> N |

| <u>Detailed Vegetation-Type</u> | <u>Area (ha)</u> | <u>Description^a</u> |
|-------------------------------------|----------------------|---|
| 11 | 2.7 | $\frac{\text{Hm}', \text{Yb}' 10.2-50.8}{\text{Yb}', \text{As}' 2.5-7.6}$ N |
| 12 | 24.9 | $\frac{\text{Sm}' 10.2-50.8}{\text{Yb}'', \text{As}', \text{Pc} \text{ and } \text{Ta}' 2.5-7.6}$ N |
| 13 | 59.0 | $\frac{\text{Hm}'', \text{Yb}', \text{Sm}' 10.2-50.8}{\text{Yb}'', \text{As}', \text{Pc} \text{ and } \text{Ta}' 2.5-7.6}$ N |
| 14 | 2.5 | $\frac{\text{Yb}'', \text{Hm}', \text{Sm}' 10.2-50.8}{\text{Yb}'', \text{As}', \text{Pc} \text{ and } \text{Ta}' 2.5-7.6}$ N |
| 15 | 8.5 | $\frac{\text{Yb}', \text{Wb}', \text{Bf}' 7.6-15.2}{\text{Rm}', \text{Yb}', \text{Bf}' 2.5-7.6}$ N |
| 16 | 2.2 | $\frac{0}{\text{Fo}^=, \text{Gs}^-}$ |
| 17 | 0.3 | $\frac{0}{\text{Wb}', \text{Wc}' 2.5-7.6}$ $\text{Ms}^=, \text{Gs}^-$ |
| 18 | 1.4 | $\frac{0}{\text{Ta}' 1.3-3.8}$ $\text{Fo}^-, \text{Gs}^-, \text{Ms}^-$ |
| 19 | 0.8 | $\frac{0}{\text{Pc}' 1.3-2.5}$ $\text{Fo}^=, \text{Gs}^-, \text{Sh}^-$ |
| 20 | 1.7 | $\frac{0}{\text{Ta}' 1.3-3.8}$ $\text{Fo}^=, \text{Gs}^-$ |
| 21 | 1.4 | $\frac{0}{\text{Fo}^=, \text{Gs}^-, \text{Sh}^-}$ |
| 22 | 1.1 | $\frac{0}{\text{Gs}^=}$ |

| <u>Detailed Vegetation-Type</u> | <u>Area (ha)</u> | <u>Description^a</u> |
|-------------------------------------|----------------------|--|
| 23 | 1.7 | <u>Wp', Hm' 10.2-50.8</u> <u>As' 2.5-7.6</u> N |
| 24 | 1.7 | <u>Wp'' 10.2-50.8</u> <u>As' 2.5-7.6</u> N |
| 25 | 4.7 | <u>O</u> <u>Rm and Mm'', Yb' 2.5-7.6</u> N |
| 26 | 4.1 | <u>As' 10.2-50.8</u> <u>Yb'', As', Pc and Ta' 2.5-7.6</u> N |
| 27 | 4.9 | <u>Hm'' 10.2-50.8</u> <u>Yb', Rm and Mm' 2.5-7.6</u> N |
| 28 | 74.3 | <u>Hm'', Yb' 10.2-50.8</u> <u>Yb'', Rm and Mm', Pc and Ta' 2.5-7.6</u> N |
| 29 | 4.1 | <u>O</u> <u>Pc' Wb', Yb', Ta' 2.5-10.2</u> N |
| 30 | 5.5 | <u>Wc'' 10.2-25.4, Hm and Yb' 10.2-50.8</u> <u>Wc', Bf' 2.5-7.6</u> N |
| 31 | 0.8 | <u>Ta' 10.2-20.3, Wb' 10.2-15.2</u> <u>Rm', Rd' 1.3-2.5</u> N |
| 32 | 14.2 | <u>Yb', Wb', Ta' 15.2-40.6</u> <u>Rm', Mm' 1.3-2.5</u> N |
| 33 | 7.7 | <u>Yb', Rm' 15.2-30.5</u> <u>Rm', Mm' 1.3-2.5</u> N |
| 34 | 22.8 | <u>Yb'', Hm' 10.2-101.6, Wc' 10.2-63.5</u> <u>As'' 2.5-7.6</u> N |

| <u>Detailed Vegetation-Type</u> | <u>Area (ha)</u> | <u>Description</u> ^a |
|-------------------------------------|----------------------|---|
| 35 | 49.7 | <u>Hm'', Yb' 10.2-101.6</u> <u>Hm', Wc' 2.5-7.6</u> N |
| 36 | 117.0 | <u>Hm', Yb', Rm and Wc' 10.2-50.8</u> <u>Yb'', Pc', Ta', Rm and Mm' 2.5-7.6</u> N |
| 37 | 7.7 | <u>Yb'', Hm', Rm and Wc' 10.2-50.8</u> <u>Rm and Mm' 2.5-7.6</u> N |
| 38 | 15.8 | <u>Yb'', Hm', Rm and Wc' 10.2-50.8</u> <u>Yb', Rm and Mm' 2.5-7.6</u> N |
| 39 | 13.6 | <u>Hm and Rm'', Yb' 10.2-50.8</u> <u>Yb and Wc', Rm and Mm' 2.5-7.6</u> N |
| 40 | 15.3 | <u>Hm', Yb' 10.2-50.8</u> <u>Yb'', Pc', Ta', Rm and Mm' 2.5-7.6</u> N |
| 41 | 40.5 | <u>Sm' 10.2-50.8</u> <u>Sm and Mm'', Yb', Pc and Ta' 2.5-12.7</u> N |
| 42 | 25.4 | <u>Sm' 10.2-50.8</u> <u>As'', Yb', Pc and Ta' 2.5-7.6</u> N |
| 43 | 5.2 | <u>Yb'', Hm', Sm' 10.2-50.8</u> <u>Yb', As' 2.5-7.6</u> N |
| 44 | 23.8 | <u>Sm'' 10.2-20.3, Bs' 10.2-25.4</u> <u>As', Bs' 2.5-7.6</u> N |
| 45 | 771.8 | <u>Sm'' 10.2-20.3, Bs'' 10.2-25.4, Ta' 15.2-45.7</u> <u>Yb', As' 2.5-7.6</u> N |
| 46 | 30.6 | <u>As''' 10.2-20.3, Ps' 15.2-45.7</u> <u>As' 2.5-7.6</u> N |

| <u>Detailed Vegetation-Type</u> | <u>Area (ha)</u> | <u>Description^a</u> |
|-------------------------------------|----------------------|---|
| 47 | 1.7 | <u>Yb', Hm', Sm' 10.2-50.8</u> <u>As' 2.5-7.6</u> N |
| 48 | 28.1 | <u>Wb'' 10.2-15.2</u> <u>Bf'' 2.5-15.2</u> N |
| 49 | 26.2 | <u>Bs''' 10.2-25.4, As' 10.2-20.3</u> <u>Yb', As', Bf' 2.5-7.6</u> N |
| 50 | 24.9 | <u>Bs''' 10.2-25.4, Sm(10.2-20.3) and Ta(15.2-45.7)'</u> <u>Yb', As', Bf' 2.5-7.6</u> N |
| 51 | 32.5 | <u>Bs''' 10.2-25.4, As' 10.2-20.3</u> <u>Yb', As' 2.5-7.6</u> N |
| 52 | 236.1 | <u>Bs'' 10.2-25.4, Sm' 10.2-20.3, Ro and Ta' 15.2-45.7</u> <u>Yb', As' 2.5-7.6</u> N |
| 53 | 0.6 | <u>Tm' 10.2-20.3</u> O N |
| 54 | 21.3 | <u>Bp' 5.1-15.2</u> <u>Bp' 1.3-5.1</u> N |
| 55 | 10.9 | <u>Yb'', Hm' 10.2-50.8</u> <u>Yb', Hm', Rm and Mm' 2.5-7.6</u> N |
| 56 | 4.4 | <u>Hm'' 15.2-35.6</u> <u>Hm', Rm and Mm' 2.5-7.6</u> N |
| 57 | 3.3 | <u>Wp'' 20.3-50.8, Bp' 5.1-15.2</u> <u>Hm', Wc', Bp' 2.5-5.1</u> N |
| 58 | 2.8 | <u>Wp' 20.3-50.8, Hm' 10.2-50.8</u> <u>Hm', Wc', Rm and Mm' 2.5-7.6</u> N |

| <u>Detailed Vegetation-Type</u> | <u>Area (ha)</u> | <u>Description^a</u> |
|-------------------------------------|----------------------|--|
| 59 | 27.6 | <u>Sm' 15.2-40.6, Ta' 7.6-20.3</u> <u>Yb', Sm', Pc' 2.5-7.6</u> N |
| 60 | 5.2 | <u>Wp'' 10.2-50.8, Tm(15.2-30.5) and Bp(5.1-15.2)'</u> <u>Bp' 1.3-5.1</u> N |
| 61 | 17.2 | <u>0</u> <u>0</u> Ss ⁻ , Ms ⁻ |
| 62 | 2.2 | <u>Wp' 10.2-38.1</u> <u>Hm', Bp' 2.5-5.1</u> N |
| 63 | 1.9 | <u>Wp' 25.4-45.7, Bp', Bf' 10.2-15.2</u> <u>Wc' 2.5-15.2</u> N |
| 64 | 4.9 | <u>Bs'' 10.2-25.4, Sm' 10.2-20.3, Ta' 15.2-45.7</u> <u>As'', Yb' 2.5-7.6</u> N |
| 65 | 8.5 | <u>Bs'' 10.2-25.4, Sm' 10.2-20.3</u> <u>As' 2.5-7.6</u> N |
| 66 | 9.6 | <u>Sm'', Ro' 12.7-50.8, Bs' 10.2-25.4</u> <u>As'', Yb' 2.5-7.6</u> N |
| 67 | 23.5 | <u>Sm''' 10.2-20.3, Ta' 15.2-45.7</u> <u>Yb', As' 2.5-7.6</u> N |
| 68 | 71.3 | <u>Bs'' 10.2-25.4, As' 10.2-20.3, Ta' 15.2-45.7</u> <u>Yb', As' 2.5-5.1</u> N |
| 69 | 39.4 | <u>Bs''' 10.2-25.4</u> <u>As', Bf' 2.5-5.1</u> N |
| 70 | 1.9 | <u>Bs''' 10.2-25.4</u> <u>Yb', Wc' 2.5-5.1</u> N |

| <u>Detailed Vegetation-Type</u> | <u>Area (ha)</u> | <u>Description^a</u> |
|-------------------------------------|----------------------|---|
| 71 | 12.0 | <u>Bs" 10.2-25.4, As" 10.2-20.3, Ta' 15.2-45.7</u> <u>Yb', As' 2.5-5.1</u> N |
| 72 | 13.1 | <u>O</u> <u>Ta" 1.3-3.8</u> Wb-, Ta- |
| 73 | 15.0 | <u>Bs"' 10.2-25.4</u> <u>Yb', As' 2.5-7.6</u> N |
| 74 | 2.8 | <u>Bs" 10.2-25.4, Sm' 10.2-20.3</u> <u>Yb', As' 2.5-7.6</u> N |
| 75 | 41.0 | <u>Bs"' 10.2-25.4</u> <u>Yb', As', Bf' 2.5-7.6</u> N |
| 76 | 1.9 | <u>As" 10.2-20.3, Bs' 10.2-25.4, Ta' 15.2-45.7</u> <u>Yb', As' 2.5-7.6</u> N |
| 77 | 3.8 | <u>Sm"' 10.2-30.5</u> <u>Sm" 2.5-7.6</u> N |
| 78 | 2.5 | <u>Sm" 10.2-63.5</u> <u>As' 2.5-5.1</u> N |
| 79 | 9.6 | <u>Sm" 10.2-63.5, Yb' 10.2-30.5</u> <u>Yb', As' 2.5-5.1</u> N |
| 80 | 24.1 | <u>Yb" 10.2-45.7, Sm' 10.2-50.8, Wc, Wp and Hm' 10.2-</u> <u>As' 2.5-5.1</u> 50.8 N |
| 81 | 8.7 | <u>Yb", Sm', Wp', Wc' 20.3-50.8</u> <u>As", Yb' 2.5-7.6</u> N |
| 82 | 2.8 | <u>Yb', Sm' 20.3-50.8</u> <u>Yb', As' 2.5-7.6</u> N |

| <u>Detailed Vegetation-Type</u> | <u>Area (ha)</u> | <u>Description^a</u> |
|-------------------------------------|---------------------------------------|---|
| 83 | 7.7 | <u>Sm'' 15.2-55.9, Yb' 20.3-45.7</u> <u>As' 2.5-7.6</u> N |
| 84 | 17.2 (area includes beach sand) | <u>0</u> <u>Pj' 0.6-3.8</u> Ww ⁻ , Sc ⁻ , Bg ⁻ |
| 85 | 7.1 | <u>0</u> <u>Sg', Rd' 1.3-3.8</u> Gs ⁻ , Rs ⁻ |
| 86 | 2.4 | <u>Wp'' 15.2-50.8</u> <u>0</u> N |
| 87 | 1.9 | <u>0</u> <u>0</u> <u>Ll⁻, Ss⁻, Sh⁻</u> |
| 88 | 11.9 | <u>Wp', Rp' 10.2-30.5</u> <u>0</u> N |
| 89 | 5.3 | <u>Wb' 10.2-15.2, Rp' 10.2-25.4</u> <u>0</u> N |
| 90 | 1.6 | <u>Wp', Rp' 10.2-30.5, Bf' 10.2-20.3</u> <u>0</u> N |

About 95 ha of water (darkened areas) is present on Outer Island.

bs is beach sand.

----- are logging trails.

Key to Fig. 3: footnote^a.

| | | | | |
|---------|----------------------|----------|----------|---|
| Strata: | <u>tree stratum</u> | Density: | ' or - | Sparsely stocked (10-40% stratum closure) |
| | <u>shrub stratum</u> | | " or = | Moderately stocked (41-70% stratum closure) |
| | herbaceous stratum | | ''' or ≡ | Densely stocked (71-100% stratum closure) |

Numbers in each stratum are diameters at breast height in centimeters.

Symbols:

| | | | |
|----|---|----|--|
| As | Maple (<i>Acer</i> spp.) | Jb | Juneberry (<i>Amelanchier</i> spp.) |
| Bf | Balsam fir (<i>Abies balsamea</i>) | Ll | Leather-leaf (<i>Chamaedaphne calyculata</i>) |
| Bg | Beach-grass (<i>Ammophila breviligulata</i>) | Ma | Mountain ash (<i>Sorbus americana</i>) |
| Bl | Balmagiliad (<i>Populus balsamifera</i>) | Mm | Mountain maple (<i>Acer spicatum</i>) |
| Bp | Black spruce (<i>Picea mariana</i>) | Ms | Mosses |
| Bs | Birch (<i>Betula</i> spp.) | N | Stratum composition not recorded |
| Fo | Forbs | O | Stratum closure less than 10% |
| Gs | Grasses | Pc | Pin cherry (<i>Prunus pensylvanica</i>) |
| Hm | Hemlock (<i>Tsuga canadensis</i>) | Pj | Prostrate juniper (<i>Juniperus communis</i>) |
| | | Ps | Aspen (<i>Populus</i> spp.) |

Key to Fig. 3: footnote ^a continued.

| | | | |
|----|--|-----------|---|
| Rd | Red-osier dogwood (<i>Cornus stolonifera</i>) | Ss | Sedges |
| Rm | Red maple (<i>Acer rubrum</i>) | Ta | Trembling aspen (<i>Populus tremuloides</i>) |
| Ro | Red oak (<i>Quercus rubra</i>) | Tm | Tamarack (<i>Larix laricina</i>) |
| Rp | Red pine (<i>Pinus resinosa</i>) | Wb | White birch (<i>Betula papyrifera</i>) |
| Rs | Raspberry and blackberry (<i>Rubus</i> spp.) | Wc | White cedar (<i>Thuja occidentalis</i>) |
| Sc | Sand cherry (<i>Prunus pumila</i>) | Wp | White pine (<i>Pinus strobus</i>) |
| Sg | Sweet gale (<i>Myrica gale</i>) | Ww | Wormwood (<i>Artemisia campestris</i>) |
| Sh | Shrubs | Yb | Yellow birch (<i>Betula alleghaniensis</i>) |
| Sm | Sugar maple (<i>Acer saccharum</i>) | | |

activities and will enhance visitor appreciation of the resource.

It is recommended that National Park Service actions to facilitate the reproduction of hemlock and yellow birch on Outer Island begin within vegetation-types 1, 13, 28 and 56 (encircled; Fig. 4). Vegetation-types 13, 28 and 56 are presently accessible by existing trails. Grown-over trails could be cleared of vegetation to give access to vegetation-type-1. Austad Bay would serve as a scenic trail-head and is accessible with small craft when seas are calm.

Management beyond the limits of vegetation-types 1, 13, 28 and 56 should include the adjacent vegetation-types of 2, 5, 6, 27, 55, 57 and 58 (remaining portions of encircled areas of Fig. 4).

The second phase of this management proposal addresses the problem of hemlock seedbed deficits. As previously discussed, rotting wood on the forest floor beneath a hemlock canopy appears to create optimal habitat conditions for hemlock reproduction and seedling survival. The availability of rotting wood, within these climatically suitable conditions, has been greatly reduced as a result of the destruction of the virgin forests of Outer Island. It therefore seems apparent, that management aimed at providing appropriate seedbed conditions would likely

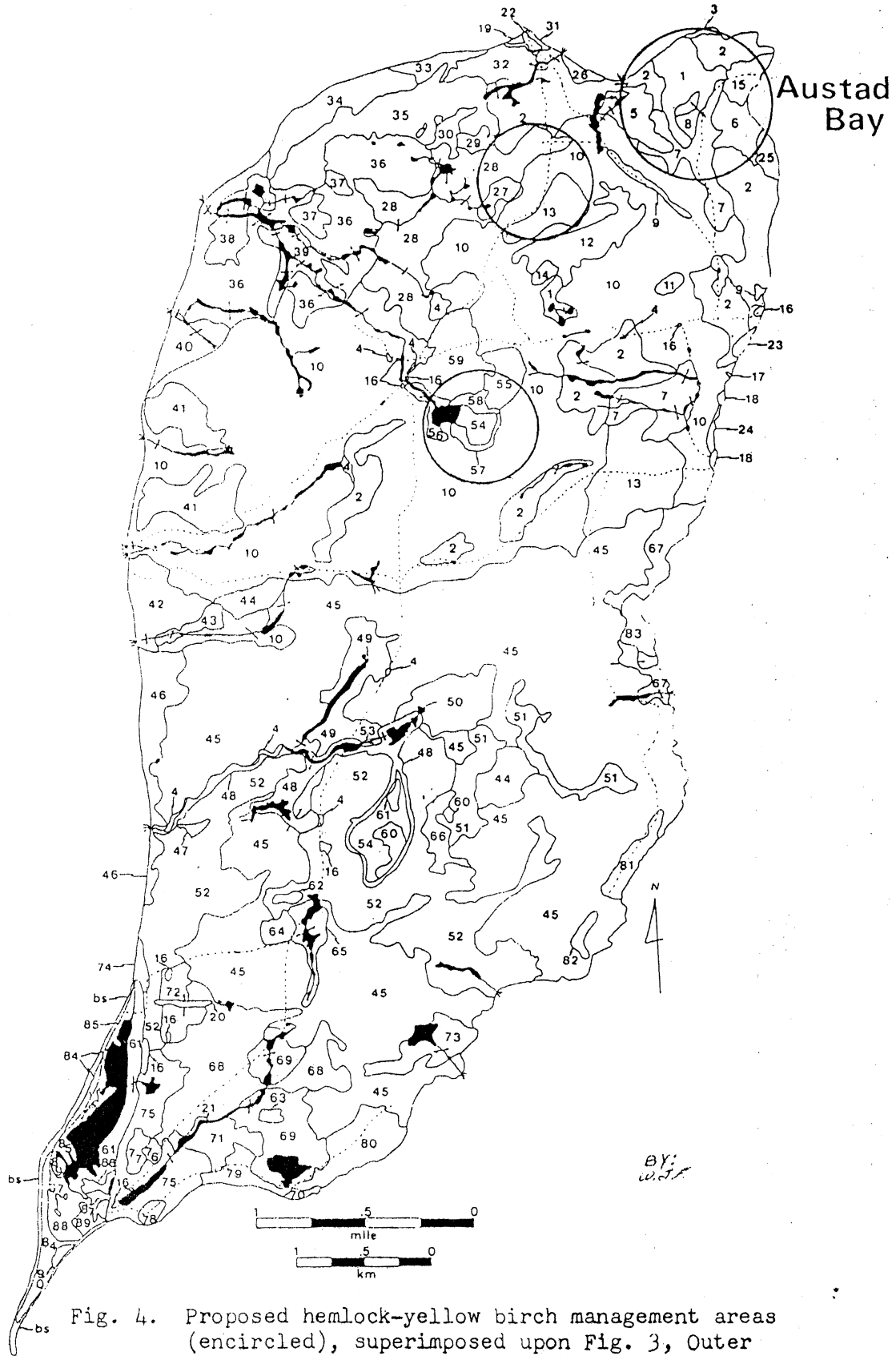


Fig. 4. Proposed hemlock-yellow birch management areas (encircled), superimposed upon Fig. 3, Outer Island, Apostle Islands National Lakeshore.

result in increased hemlock reproduction.

Because of the recentness of logging on the northern portion of Outer Island (1948-1960) much dead and rotting wood still remains today. This rotting wood resource is believed to have potential as hemlock seedbeds if placed in appropriate environmental conditions. The following procedure (now termed log-stocking) is suggested:

- 1) Obtain portions of rotting wood. Larger bole sections of hemlock should be selected when available, although rotting yellow birch and sugar maple may also serve as hemlock seedbeds (Coffman 1978 and Guttay 1982, respectively). To minimize transport distance, collection should be done in areas adjacent to the management areas discussed above. Transport will be difficult at best but may be facilitated with the use of wheelbarrows on existing trails. During a recent study of Outer Island (Fraundorf 1983), rotting bole sections of hemlock were observed along an existing trail adjacent to vegetation-types 13 and 28 (Fig. 4). Care should be taken in the handling of bole sections so as to not extensively disturb their moss covering. Stearns (1951) feels that moss growing on rotting wood serves to preserve the moist condition of the substrate. Conversely, the removal of excessive accumulations of leaf litter and maple seedlings should be done, and would tend to promote hemlock establishment.

- 2) Rotting bole sections should be placed on the forest floor within the management areas previously discussed (Fig. 4). Optimal placement location would be within small openings under dense hemlock canopies. Hibbs (1982) noted that for successful hemlock reproduction to occur, the diameter of the forest opening should be about one-half the height of the adjacent canopy trees. To simultaneously manage for yellow birch reproduction, the specific sites selected for log placement should also contain some mature yellow birch. These individuals will serve as a seed source; the stocked logs will provide appropriate seedbeds upon which yellow birch can reproduce alongside hemlock. Log-stocking may need to be continued until canopy hemlock mature and die, serving to once again begin the natural and sustained process of seedbed rejuvenation. Care should be taken to minimize trampling of the forest floor moss covering while working in the proposed hemlock-yellow birch management areas.

In areas where the hemlock seed source proves to be inadequate to stock the logs furnished as seedbeds, or if managerial decisions are to re-establish hemlock in areas where none presently exists, then the following procedure (now termed seedling/log transplanting) is suggested:

- 1) Obtain portions of rotting wood which contain established hemlock seedlings. Transplant these into areas, presently dominated by a canopy of yellow birch (and hemlock, if

available), as described in 2) above. Logs transplanted into these areas would also serve as seedbeds for yellow birch reproduction. The process of seedling/log transplanting may need to be continued until the originally transplanted hemlock reach seed-bearing age (30-50 years; Fowells 1965). Log-stocking will then need to be done to provide seedbeds for hemlock and yellow birch reproduction until the originally transplanted hemlock mature and die, serving to once again begin the natural and sustained process of seedbed rejuvenation. Initial seedling/log transplanting attempts would be least labor intensive if conducted within vegetation-types 33 or 34 (Fig. 3); these vegetation-types are adjacent to vegetation-type-2 (Fig. 2), the most logical source of seeded logs. Logs removed from vegetation-type-2 for the purpose of seedling/log transplanting should be replaced with unseeded logs (log stocking) as described above so as to not devoid the parent area of seedbeds. If the method proves successful and managerial decisions are to expand the seedling/log transplanting program, then it is suggested that such continuing efforts occur within vegetation-type 80 (Fig. 3). VT-80 is dominated by yellow birch up to 51 cm. (20 inches) dbh; a representative array of other old-age individuals of a variety of original forest species are also present. Access to this impressive area of original forest remnants would be made possible by clearing of an old logging trail (shown as a broken

line within Fig. 3).

Log-stocking activities are considered to be of more immediate value regarding the exposure of Park visitors to original forest conditions (AINL forest vegetation management goal; USDI 1982) than are efforts involving seedling/log transplanting. Log-stocking is to be conducted within areas presently containing a forest canopy fairly representative of original forest conditions. Conversely, the canopies of areas where seedling/log transplanting is to be conducted are low or void of hemlock. Priority in management should therefore be placed upon log-stocking.

Existing stocking levels and the reproductive status of remaining species (ex. sugar maple) of original Northern Mesic forest conditions are adequate (Tables 3 and 4) to ensure their presence within the management areas discussed above.

The susceptibility of hemlock to fire has been previously discussed. Yellow birch is also easily injured by fire; butt rot may result (Fowells 1965). If fire should ever threaten vegetation-type-2 (Fig. 2) or areas of hemlock-yellow birch management, it should be suppressed. Deer and snowshoe hare (Lepus americanus) browsing has been noted to reduce stocking levels of hemlock (Secret et al. 1941, Graham 1954, Stoeckeler et al. 1957, Fowells 1965,

Hough 1965, Rogers 1978, 1981) and yellow birch (Fowells 1965, USDA 1973). Deer do not presently occupy Outer Island; if they ever do, their population should be eradicated. Snowshoe hare sign was abundant on Outer Island in 1978 (Anderson et al. 1979). The effects of their population on Outer Island, hemlock or yellow birch reproduction are unknown and may require future study. The girdling of 7.6-12.7 cm. (3-5 inch) diameter yellow birch, by red squirrel (Tamiasciurus hudsonicus) has been observed on Outer Island (Personal observation 1978). The extent of this girdling and the effect it has on stocking levels of yellow birch is unknown.

Interpretive trail construction within vegetation-type-2 (Fig. 2), or in hemlock-yellow birch management areas should be done carefully to avoid moss compaction, damage to the shallow roots of hemlock, and to minimize potential tree wounding from carving or other human-related activities. An elevated interpretive trail may be one method allowing for resource use and preservation.

Forest Vegetation: White Pine-Red Pine Silviculture

The range of eastern white pine includes the northeastern United States, adjacent southeastern Canada and Newfoundland. It is found as far west as Minnesota and northeastern Iowa and grows in the south along the Appalachian Mountains into

northern Georgia (Fowells 1965).

The range of red pine (Fowells 1965) is generally coincident with that of white pine but is more restricted to the south, extending only to northern Pennsylvania; in Newfoundland, where white pine is abundant, red pine is found to be only locally common.

White pine and red pine will thrive on loamy, nutrient-rich sites but are found most commonly growing upon well-drained sandy soils. Soils supporting vigorous growths of white pine usually contain a moisture surplus throughout the growing season. Conversely, red pine will grow in areas which commonly experience periods of summer drought. Red pine will grow on less nutrient-rich soils than will white pine and is commonly found as a successional predecessor to white pine on xeric, nutrient-poor sandy sites (Fowells 1965, USDA 1973, Coffin 1977).

White pine and red pine of about five years of age or older are capable of producing female cones. Staminate cones may be produced by red pine as early as nine years of age, however white pine produces few staminate cones until about 50 years or older. Good seed crops occur every 3-5 years and 3-7 years for white pine and red pine, respectively. Some seed is produced in the intervening years. The successful germination and establishment of both white pine and red pine is dependent upon access to a continuously

moistened seedbed (Fowells 1965, USDA 1973).

Seedbed accessibility is a result of tree blowdown, logging, fire or wind (Nichols 1935, Hough 1943, Stearns 1951, Brown 1960, Fowells 1965, USDA 1973, Coffin 1977) which serve to scarify the soil surface giving access to the moistened substrate. Because of the low moisture-holding capacity of sandy soils, the maintenance of moist seedbed conditions is dependent upon regular spring and early summer rains.

White pine and red pine survival and growth after the initial establishment period is best under conditions of full exposure to sunlight if soil moisture supplies are adequate (Fowells 1965, USDA 1973).

Growth is slow during the 8-15 years following establishment, during which time white pine and red pine may be out-competed by the faster growing species of hardwoods which are able to grow in association with pines on the more nutrient-rich, mesic sites (Stearns 1951, Fowells 1965, USDA 1973, Kozlowski et al. 1974).

Forest Vegetation: White Pine and Red Pine Management
Recommendations

The original as well as the current distribution of white pine and red pine on Outer Island has been discussed within the vegetation-type analyses above. Data are not available to quantitatively compare the relative densities of pine within original and current conditions. However, a reduction in pine stocking levels, since original forest times, is

suspected as having occurred and is believed to be the combined result of selective logging for white pine (ca. 1900) and deminishing reproductive conditions due to a policy of fire suppression.

It is unlikely that white pine or red pine ever comprised a significant portion of the overall forest cover of Outer Island. Brander (1981), in speaking of the original forest conditions of the Apostle Islands, noted that "white pine did not occur in large numbers in the northern hemlock-hardwood forest; probably no more than a dozen stems per acre. But those few stems were usually quite large (25 inches or more in diameter) and old (150-400 years)."

Although relatively few in number, their distinctive occurrence along shorelines (Frederick et al. 1976; also vegetation-types 23, 24, 80, 81, 86, 88, 89 and 90 of Fig. 3) and characteristic silhouette has traditionally given the pines a position of high visibility and subsequently created an association of their presence within northern-mesic forest conditions.

In National Park Service management to facilitate the reproduction of pine on Outer Island, priority should be given to those areas which are most accessible to Park visitors and which also contain some mature pine. This suggestion is in accordance with the goal of AINL forest vegetation management policy which is to expose Park visitors to original forest conditions. Priority management areas

would include the coastal vegetation-types listed above as well as vegetation-types 57 and 58 if these latter areas are made accessible in conjunction with the hemlock management activities proposed above.

Proposed management actions for designated areas of pine management include:

1) The removal of competing vegetation. White pine and red pine grow slowly during the 8-15 years following establishment. During this period they may be out-competed by the faster growing species of hardwoods which are able to grow in association with pine on the more nutrient-rich, mesic sites (Stearns 1951, Fowells 1965, USDA 1973, Kozlowski et al. 1974). The removal of competing vegetation would simultaneously scarify the soil, creating appropriate seedbed conditions for future pine reproduction (Fowells 1965, USDA 1973). Vegetative removal would be most beneficial to pine establishment and growth within vegetation-types 23, 24, 57, 58, 80 and 81 (Fig. 3). These vegetation-types occur on mesic to wet, nutrient-rich soils (Anderson et al. 1979).

2) Minimizing human disturbance within areas of pine reproduction. This management recommendation is in reference to pine reproduction occurring within vegetation-types 86, 88, 89 and 90 (Fig. 3). These vegetation-types occur over sands which have little soil profile development (Anderson et al. 1979). Plant succession within such areas is the result of the sand-stabilizing effects of earlier seral

stages of vegetation. Forces which disrupt the integrity of the existing vegetation (de-stabilizing forces) serve to favor a retrogression towards pioneer plant species such as beach-grass (Ammophila breviligulata) and sand cherry (Prunus pumila) (Coffin 1977, Wells et al. 1982). Wells et al. (1982) states that "as long as shifting sand conditions prevail, a dunes species composition will remain in a pioneer successional stage. A simplified concept of these stages of plant succession would be;

bare sand (to)
 beach-grass (to)
 deciduous shrubs (ex. sand cherry) (to)
 evergreen shrubs (to)
 pine" (to)
 hardwood tree species.

Human-use and disturbance of areas on the Outer Island sand-spit where pine is presently reproducing would therefore serve to threaten the survival of pine in favor of those species which can tolerate the more xeric and less fertile conditions associated with shifting sand.

3) Allowing naturally occurring fires to burn. The destruction of forest floor duff by fire can create ideal conditions for the regeneration of pine (Brown 1960, Fowells 1965, USDA 1973, Kozlowski et al. 1974). Many original forest stands of pine are considered to be of pyric origin (Fowells 1965, Coffin 1977, Brander 1981).

Fire management policy of the AINL (USDI 1982) states that naturally occurring fires may be allowed to burn and further recognizes that periodic fire is necessary to the maintenance of certain vegetative types. Naturally occurring fires would be most likely in the xeric environment of vegetation-types 86, 88, 89 or 90 (Fig. 3); these are presently dominated by a canopy of pine. The natural occurrence of fire within the northern-mesic forests, which compose the remainder of Outer Island, is unlikely but should be monitored closely and the fires suppressed if they threaten areas of hemlock-yellow birch management. The suppression of naturally occurring fire under these circumstances should not be viewed as inconsistent with the general management policy of regaining pristine or natural conditions. The forests of Outer Island are believed less mesic (and therefore more subject to burning) than were the original forests as a result of previous logging and related activities.

Stearns (1949) states that the natural occurrence of fire within original northern-mesic forest conditions was rare, occurring primarily in areas where large numbers of windthrown trees provided extensive fuel buildups. In areas where fire did occur, it normally did not penetrate the mesic understory of the undisturbed forest.

AINL fire management policy (USDI 1982) also allows for the intentional use of fire in its vegetation management programs. The intentional use of fire in an attempt to facilitate the regeneration of pine, and regain original forest conditions

on Outer Island, is not recommended until future research establishes:

a) whether or not fire was an important factor to the maintenance of pine (ca. 1880 or earlier) on Outer Island, and if it was, then to determine

b) the periodicity of naturally occurring fire.

The areas of particular interest would, once again, be those sandy, xeric vegetation-types (86, 88, 89, 90) of the Outer Island sand-spit. If future research determines that previous policies of suppression of naturally occurring fire has fostered the establishment of mesic conditions and the associated dominance of the shrub and herb strata of the Outer Island sand-spit by mesic area species (Table 5), then National Park Service management actions could involve the intentional use of fire. Further, managerial actions to hasten the re-establishment of pine on the sand-spit could include the removal of competing understory vegetation (mainly balsam fir and red maple).

4) Planting selected species for reforestation. Industrial forest management in the Lake States area presently employs large-scale planting of white pine and red pine. Planting is normally done in association with the control of competing vegetation (USDA 1973).

In addition to those management areas discussed above, planting may be necessary to re-establish pine within other selected areas on Outer Island if future research

shows that:

- a) pine was present under original forest conditions but is presently absent, or if
- b) existing levels of reproduction are inadequate to attain stocking levels of pine determined to have been present prior to the logging of pine from Outer Island.

Forest Vegetation: Silvicultural Techniques and Their Application

The recommendations presented above regarding the management of pine on Outer Island generally employ silvicultural techniques which are widely accepted and utilized.

The recommendations presented above regarding the management of hemlock and yellow birch on Outer Island, are the original constructs of the present author and, are conceptually validated by their preceding silvicultural analyses. The techniques proposed are intended to simulate the natural conditions of hemlock and yellow birch reproduction and as such directly respond to the overriding goal of AINL forest vegetation management policy.

These proposed techniques have yet to be field tested. Field-testing in conjunction with comparisons of other conventional silvicultural techniques such as mechanical scarification or planting and the use of alternative

mediums in place of bole sections, should be conducted prior to the extensive implementation of any particular managerial practice.

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APPENDIX A

Letters of correspondence and support
received from the
National Park Service
at the
Apostle Islands National Lakeshore



United States Department of the Interior
NATIONAL PARK SERVICE

APOSTLE ISLANDS NATIONAL LAKESHORE
P.O. BOX 729, OLD COURTHOUSE BLDG.
BAYFIELD, WISCONSIN 54814

IN REPLY REFER TO:

January 14, 1983

N16

Mr. Bill Fraundorf
Box 326-B
Bennett, Wisconsin 54815

Dear Bill:

There are no further documents on management strategies for the Islands. We are in the process of writing specific management action plans for various cultural and natural resources but with the same general National Park Service philosophy and policy with which you are familiar. I am certain your thesis will be a contribution to the various action plans as we write them.

It was good to hear from you again and we will be happy to look at portions of your thesis as you finish them.

Sincerely,

Merryll M. Bailey
Park Ecologist



IN REPLY REFER TO:

United States Department of the Interior

NATIONAL PARK SERVICE

APOSTLE ISLANDS NATIONAL LAKESHORE
 P.O. BOX 729, OLD COURTHOUSE BLDG.
 BAYFIELD, WISCONSIN 54814

November 15, 1983

N1617

Mr. Bill Fraundorf
 Box 326-B
 Bennett, Wisconsin 54815

Dear Bill:

I received the final submittal of your thesis draft and have taken the time to read it thoroughly. Generally, it looks good and it appears there are many of your management concepts and proposals we can integrate into the overall "management action plans" for the forest vegetation, wildlife, and sandspits and beach resources of the Park. Your draft manuscript aptly considers park policy and preliminary conceptual planning in discussing the ecology and recommending management actions for three of the key resources of Outer Island.

I'm sorry I cannot spare the time necessary to discuss your manuscript point by point, but I'm sure your graduate committee will accomplish this.

In conclusion, I wish to thank you for your contribution to the forthcoming active management of the natural resources of the Apostle Islands National Lakeshore.

Sincerely,

Merryll M. Bailey
 Park Ecologist

Authors Note:

Management recommendations, referred to above, regarding the Wildlife and Sand-spit/Beach resources of Outer Island have been submitted to the National Park Service at the Apostle Islands National Lakeshore within the draft typescript:

Fraundorf, W. J. 1983. Natural Resource Management Plan:
 Outer Island, Apostle Islands National Lakeshore. 170 pp.