Voyageurs National Park

Aquatic Research

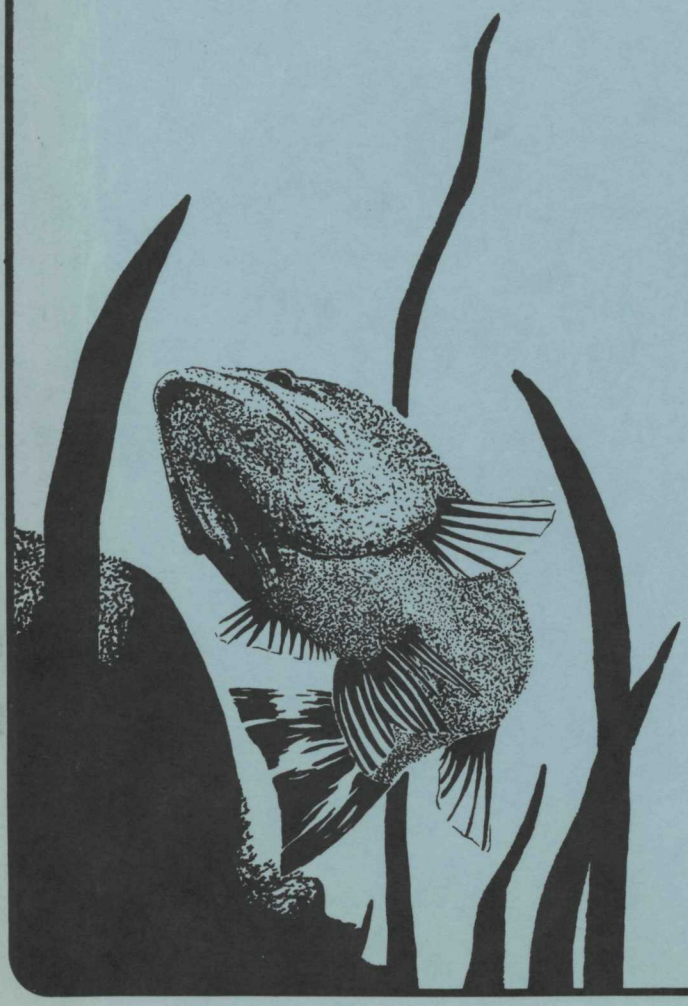
AN ANALYSIS OF THE EFFECTS OF FLUCTUATING
WATER LEVELS ON LITTORAL ZONE MACROPHYTES
IN THE NAMAKAN RESERVOIR/RAINY LAKE SYSTEM
VOYAGEURS NATIONAL PARK

AND

THE FLORA OF VOYAGEURS NATIONAL PARK

by

Dr. Paul H. Monson



Voyageurs National Park
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Studies prepared for

U.S. Department of the Interior, National Park Service

Contract No. CX-6000-2-0039

Final Report

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Duluth, Minnesota

June, 1986

ABSTRACT

In the Rainy Lake/Namakan Reservoir System in Voyageurs National Park, Minnesota, annual water level fluctuations average 3.6 feet in Rainy Lake and 9.3 feet in Kabetogama, Namakan, and Sand Point Lakes. To study the effects of these fluctuations on littoral zone macrophytes, biomass samples were obtained from eleven selected sites during the summers of 1982 and 1983. The data available as the result of these field studies includes site characteristics and above-substrate biomass for each species of plant in each of four 0.25 square meter quadrat samples of emergent, floating-leaf, and submerged zone macrophytes at each site. Data were examined in a comparison with previously published records of the effects of fluctuating water levels on aquatic macrophytes, by a standard analysis of variance, in an adaptation of Morisita's Index of Community Similarity, and by Detrended Correspondence Analysis. The picture which emerges includes a number of inconsistencies but there is little to suggest that the aquatic macrophytes in these four lakes are responding differentially to the annual water level fluctuations. It is suggested that the inconsistencies which occur might be explained on the basis of inadequacies in the sampling effort and by the fact that there is no consistency in either the magnitute or timing of the annual water level fluctuations.

To supplement vouchers included in the Olga Lakela Herbarium specimens of both aquatic and terrestrial plants were obtained during the 1982 and 1983 field seasons. On the basis of the presently available record, the VNP flora includes 602 species of vascular plants in 277 genera of 89 families. The 1982-83 collections added 45 species to the record assembled by Olga Lakela in 1949-55 luding one species, Tillaea aquatica L., previously known in Min ota only from the extreme southwest. The flora does not inclu any species federally designated as endangered or threatened. At the State of Minnesota level, however, two species in the VNP flora are listed as endangered (Littorella americana Fern. and Subularia aquatica L.) and one is listed as threatened (Carex sterilis Willd.) The appended checklists include family name, common name, collector, collection number, collection date, and collection location for each of the approximately 2900 vouchers.

ACKNOWLEDGEMENTS

Throughout the study I was assisted by a team of University of Minnesota, Duluth graduate and undergraduate students in biology with major help from Ms. Judy Gronquist, Mr. Philip Monson, Ms. Jeri Schwerin, and Mr. R. Todd Smith. Substantial contributions were made by Ms. Beth Anderson, Ms. Kriste Ericsson, Ms. Barbara Farrell, Mr. Kurt Marple, Ms. Terry Opheim Monson, Mr. Robert Pillsbury, and Ms. Ellie Schoenberg. Assistance in statistical analysis was provided by UMD Biology Department members, Dr. David Schimpf and Mr. Lyle Shannon. Ms. Gordee Small of the UMD Computer Center prepared the several programs required for data entry and management and also provided assistance in problems of data entry and report preparation.

VNP staff members were helpful throughout the study and included Superintendent Russell Berry, Research Biologist Glen Cole, Aquatic Biologist Larry Kallemeyn, Chief Ranger Joe Cayou, and Kabetogama District Ranger Larry Hoch. The provision of boat and motor in the summer of 1982, space and electrical service for our mobile laboratory in 1982 and part of 1983, and access to the facilities at Hoist Bay during most of the summer of 1983 were major contributions to the success of our study.

Dr. G.B. Ownbey, Curator of the Herbarium, Department of Botany, University of Minnesota, St. Paul, provided assistance in the identification of several unusual plant collections. At the Duluth campus of the University, assistance was provided by Dr. Thomas Wood of the Lake Superior Basin Studies Center and Mr. James Loukes and Ms. Mary Ogren of the Office of Research Administration.

For their very substantial support, the aid of the Olga Lakela Herbarium Fund and the Department of Biology, both at the University of

Minnesota, Duluth is gratefully acknowledged. The support of the Board of Regents of the University of Minnesota is also acknowledged, in particular for the sabbatical leave granted to me from September 1, 1983 to March 2, 1984, when the bulk of the herbarium and laboratory work was conducted. Finally, I wish to thank my wife, Betty Monson. Her assistance and patience were essential to the completion of this project.

To these persons and many others not named, I wish to extend grateful thanks. This study would not have been possible without their help.

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INTRODUCTION

In the relatively brief period since its establishment in 1975, Voyageurs National Park has been the site of a number of studies directed toward an understanding of basic resources and potential management problems. Included here have been inventories of resources and problems associated with four potential public-use development areas, surveys of attitudes of campers, resorters, and Minnesota residents vis-a-vis VNP, and studies on the primary plant communities in the park. A brief review of these studies is presented by Merriam and Kurmis (1981).

Aquatic ecosystems, of major significance in VNP have also been examined but to a lesser extent. Of particular importance is the work of Hargis (1981) on plankton communities in twenty-four lakes in the park. Research underway includes studies of the (1) hydrology of the Namakan Reservoir/Rainy Lake system, (2) fish communities, (3) shore and marsh nesting birds, (4) benthic organisms, and (5) beaver and muskrat communities. This ongoing research is the result of an aquatic research action plan added to the original VNP Management Plan in 1982. The studies reported in this paper are an additional aspect of the research called for in the amended Management Plan (Kallemeyn, 1983).

In essence, the project has been directed toward three objectives:

1. Establishing permanent sites for quantitative studies on the littoral zone macrophytes of the four lakes in the Namakan Reservoir/Rainy Lake System, documenting present conditions in the littoral zone macrophytes at these sites, and using the data obtained to examine the problem of the effect of fluctuating water levels on the macrophyte component of the littoral zone biota.

2. Development of a complete check list of the VNP flora based on the collections of the late Dr. Olga Lakela in years 1949-55, supplemented by collections made during the summers of 1982 and 1983 by myself and my assistants.

3. Preparation of a set of mounted specimens of vascular plants from VNP to be used as reference material by the park staff.

STUDY SITE

Voyageurs National Park is located in extreme northern Minnesota, with its western boundaries approximately ten miles east of International Falls. Most of the 219,000 acres within the park are in St. Louis County with the remainder in the adjacent Koochiching County (Fig. 1). Known occasionally as the "water park", Voyageurs National Park is particularly striking for the approximately 85,000 acres of water included in its boundaries. Ninety-five percent of this water occurs in Kabetogama, Namakan, Sand Point, and Rainy Lakes which make up the Namakan Reservoir/ Rainy Lake System. The impact of these large lakes is heightened both visually and biologically by the fact that the international boundary and thus the park boundary passes through Rainy, Namakan, and Sand Point Lakes, placing most of Rainy Lake and about one-half of each of the other two lakes in Canada. All of Kabetogama Lake lies within the park boundaries.

Although shallow embayments are found throughout, especially along the south and west shores of Kabetogama Lake, the lake shores are characteristically rock-bound, often having cliffs which descend precipitously to well below the water surface. Islands of many sizes are common and the careless boat operator is likely to become fouled on barely-submerged rocky shoals in many places, this despite the fact that charted waters include depths in excess of 60 feet in all but Kabetogama Lake.

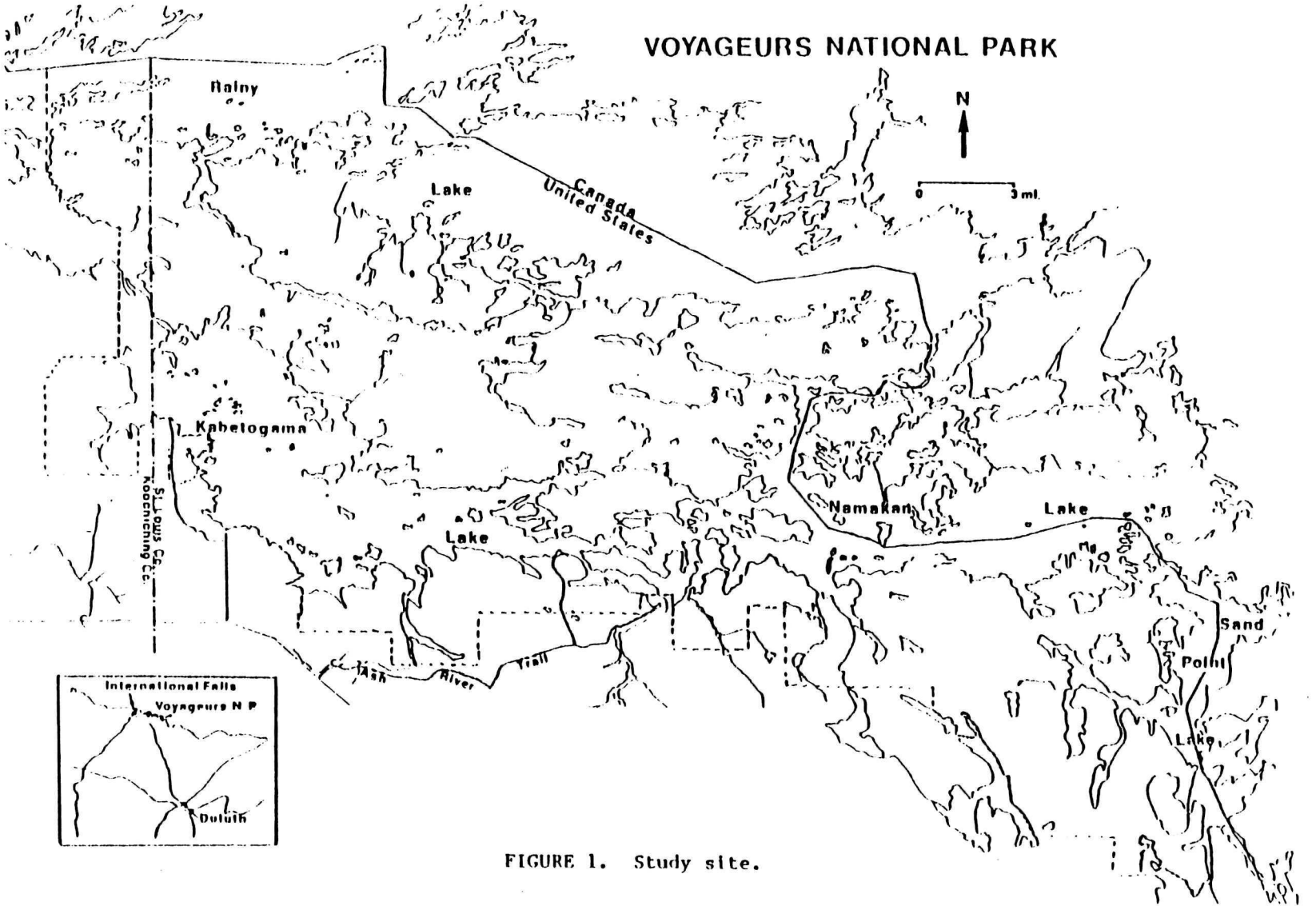

FIGURE 1. Study site.

The area is characterized by a mid-continental climate with temperatures ranging between extremes of -40°C and 36°C. The average rainfall is 627 mm. (25 in.), close to half of which falls in June, July, and August when thunderstorms are also frequent. (Kuehnast, 1972).

As is true of most of northeastern Minnesota, the park occurs on the Precambrian Canadian Shield. This complex has been carved and modified by several advances of glacial ice, the last of which, the Pleistocene, retreated from the area about 10,000 years ago. All of the lakes within the park have been formed as a result of the erosive action of this glacial activity on the softer materials in the bedrock complex. Rather patchy and typically very shallow deposits of till were left in the park area by this glacial activity. Bare or sparsely vegetated bedrock exposures are frequent (Ojakangas and Matsch, 1982; Hobbs and Goebel, 1982).

With scarcely 10,000 years to develop, soils of the park are poorly differentiated. Basically podzolic, the soils over most of the area are light-colored, loamy, and well-drained. At the west end of the Kabetogama Peninsula, the major land area in the park, conditions are more complex with light-colored, clayey, well-drained and non-acid, organic soils predominating (Department of Soil Science, U. of MN., 1977). The lacustrine plain asociated with Glacial Lake Agassiz reaches the park only in a presently swampy area immediately to the west and north of Tom Cod Bay, in western Lake Kabetogama. Soils here are acidic and organic. Lake Agassiz apparently did not have any other direct effect on the area included in the park.

PART I

AN ANALYSIS OF THE EFFECT OF FLUCTUATING WATER LEVELS

ON

LITTORAL ZONE MACROPHYTES

OF THE

NAMAKAN RESERVOIR/RAINY LAKE SYSTEM

VOYAGEURS NATIONAL PARK, MINNESOTA

INTRODUCTION

In the general introduction to this report, reference was made to the recently initiated research on aquatic ecosystems in Voyageurs National Park. A major thrust in that research is expected to be the examination of the biological effects of water level regulation in Kabetogama, Namakan, Sand Point, and Rainy Lakes. The first three lakes are connected by channels and make up what is known as the Namakan Reservoir in the Namakan Reservoir/Rainy Lake System.

Water level regulation in these lakes is accomplished by a dam at the outlet of Rainy Lake near International Falls, Minnesota and two dams on the outlet of Namakan Reservoir in the Kettle Falls area. Because parts of Rainy, Namakan, and Sand Point Lakes lie in Canada, the dams and lake levels are regulated by the International Joint Commission. These dams have been in place and operational since the early 1900's and are intended to minimize the water level fluctuations on Rainy Lake. The effect of this regulation has been an average annual water level fluctuation of 3.6 feet in Rainy Lake during the period, 1909-1980. During the same period, fluctuations in the three lakes of the Namakan Reservoir have averaged 9.3 feet. "Natural" fluctuations for the same period have been calculated and would probably have averaged 6.7 feet in Rainy Lake and 6.4 feet in Namakan Reservoir. As presently regulated, water levels peak in mid-June and remain stable through the late summer and fall. A gradual decline begins in October with minimum levels occurring in April. Other large lakes in the area show peak levels in June with gradual declines rather than stable water levels through the summer and fall (Cole, 1982). The biological impact of these departures from "normal" with respect to both timing and magnitude of water level fluctuations is largely unknown.

The water level fluctuations noted above may be expected to have direct and indirect effects on all parts of a lake. The most obvious impact, however, will be on the shoreward, shallow water area known as the littoral zone. Characterized by rooted, aquatic, vascular plants, this zone extends from the shore to the point where light penetrating to the bottom is insufficient to permit growth of green plants. In a small lake or pond, the littoral zone may extend from shore to shore; in larger lakes it forms a strip along the shore with the width of the strip determined by the interaction of several factors including lake morphometry, water transparency, and exposure to wind and waves. Shallow, protected bays commonly support extensive littoral zone development; exposed points and rocky shores where water depth increases rapidly often have little or no littoral zone in evidence.

Where conditions are favorable, the littoral zone may be subdivided into three segments, each characterized by the growth form exhibited by the dominant vegetation. Along the shore and in shallow water, plants such as Cattails (Typha), and Bullrushes (Scirpus) occur in what is called the zone of emergent aquatics. In somewhat deeper water there is a transition to the zone of floating-leaf aquatics characterized by plants such as Water lilies (Nymphaea and Nuphar) and some species of Pondweed (Potamogeton). This zone in turn gives way in deeper water to the zone of submerged aquatics characterized by many species of Pondweed (Potamogeton), Coontail (Ceratophyllum), and Water milfoil (Myriophyllum). In many lakes, Chara, a genus of algae, will occur at the outer limit of the littoral zone as a whole.

Of the several factors which interact to determine the extent of littoral zone development, lake morphometry is clearly of critical

importance in a great many areas of the Namakan Reservoir/Rainy Lake System. Shores characterized by steep-sided cliffs or large boulders will have a littoral zone in the broad sense of that term but the potential for colonization by plants and animals is extremely limited.

Where the shore slopes gradually toward deep water and where the lake bottom is otherwise suitable, littoral zone development may be extensive and conspicuous. In these situations, light is commonly cited as the controlling factor with macrophyte growth expected at depths where available light is as little as 1 to 4 percent of the average intensity at the water surface (Sculthorpe, 1967). Although data on light transmission in VNP lakes are too limited to justify major concern, Barko, et al. (1982) suggest that Sculthorpe's values are too low and that from 5 to 10 percent of surface radiation is usually required for macrophyte growth. For the lakes in question this translates to the expectation that macrophyte growth would be limited to depths of about 3 meters or less. This on the basis of the studies of Hargis (1981) who classified these lakes as medium clarity lakes with values for percent of light transmission through 1 meter of water ranging from 22 percent (Sand Point Lake) to 30 percent (Kabetogama Lake).

Without discounting the importance of light, Spence (1982) in his review of factors controlling macrophyte zonation argues convincingly for the importance of wave action with its associated control over sediment erosion and deposition. The problem is complex and largely beyond the scope of this study but includes the capacity of various macrophytes to withstand the erosive effects of turbulence in shallow water, to outgrow the sediment being deposited in deeper water, and survive the effect of suspended sediment on light transmission. In his concluding discussion,

Spence postulates that wave action with sediment control will exert primary control on macrophyte zonation in lakes where the macrophyte zone lies largely or entirely within the wave-mixed zone. Such is probably the situation on exposed shores of lakes in the Namakan Reservoir/Rainy Lake System where the substrate is otherwise suitable for growth of macrophytes. In sheltered bays with reduced wind and wave action, light would probably exert primary control. For the lakes in question, the entire issue is further complicated by the annual fluctuations in water level. These fluctuations create a situation where, except in well isolated bays, the entire midsummer littoral zone is subjected to wind and wave action for at least part of every growing season.

Exactly how this combination of factors may interact to control zonation is an open question and beyond the scope of this study. Of importance here is the fact that in Kabetogama, Namakan, and Sand Point Lakes, the magnitude of the annual fluctuations is more than enough to involve the entire littoral zone. In Rainy Lake with its lesser annual fluctuations, the extent of the littoral zone affected would be less but still substantial.

The effect of fluctuating water levels on the biota of lakes and reservoirs has been a subject of investigation since at least the early 1930's when the Tennessee Valley Authority began developing large reservoirs. Many of the early studies were precipitated by the discovery of the importance of marsh and aquatic vegetation as breeding sites for malaria-carrying mosquitoes in the southeastern United States (Hinman, 1938). This early literature has been reviewed by Wood (1951) and most of it is only peripherally related to the present study but mention should be made of the paper by Penfound, Hall and Hess (1945) on the phenology of

marsh and aquatic plants of Alabama. This paper includes information on the biology of several species of plants found in Voyageurs National Park as well as some observations on the effects of fluctuating water levels on these species in Alabama reservoirs.

More recently, concern for the effects of fluctuating water levels has shifted to problems of improved management of natural and artificial lakes and other wetlands. Problems such as excessive macrophyte growth, undesirable fish populations, and degenerating waterfowl management areas have all been addressed to at least some extent by manipulating the water level. The significance of these and related problems is clearly evident from the volume of literature generated in their study as well as the several annotated bibliographies and reviews published in the effort to focus the issues (Dunst, et al., 1974; Good, et al., 1978; Whitlow and Harris, 1979; Cooke, 1980; Triplett, et al., 1980; Ploskey, 1983; Allen and Aggus, 1983).

Despite its volume, this literature presents a picture of the effects of fluctuating water levels that is far from clear. With respect to the effects on macrophytes, problems include a scarcity of quantitative data and frequent instances of conflict between the reports of individual authors.

With full recognition of these and other problems, Cooke (1980) has reviewed available data and presents the response of 63 taxa (55 species, 8 genera) of macrophytes to drawdown. Thirty-eight of these taxa (30 species, 8 genera) are known from one or more locations in the Namakan Reservoir/Rainy Lake System. Unfortunately, the limited data available leads to the situation where the effect of drawdown on many species (15 of the 30 VNP species) is based on a single observation. This becomes a

matter of considerable concern in view of the frequent lack of consistency in the reports of effect on many species. The data presented by Cooke, for example, show a consistent record for only 6 of the 21 taxa for which there are 3 or more observations. The extent of the conflict is not typically great (2 observations of an increase and 1 observation of no change for both Polygonum coccineum and Potamogeton gramineus, for example) but it is clear that caution must be exercised in the utilization of these data. The details of the record will be examined more completely in later sections of this paper where they can be compared with our observations in VNP.

This study is a part of the larger effort to examine the effects of fluctuating water levels on the littoral zone biota of the Namakan Reservoir/Rainy Lake System. Our specific objectives have been:

1. To examine the effects of fluctuating water levels by comparing the maximum, above-ground standing crop and species diversity of littoral zone macrophytes at selected sites in each of the four large VNP lakes, and

2. To obtain baseline data and establish permanent sites for the purpose of long-term studies on the effect of fluctuating water levels on littoral zone macrophytes in the same lakes.

METHODS

Field work on this study began in July, 1982 with several days of reconnaissance in Kabetogama and Namakan Lakes. Our objective at that time was the location of a number of sites with well-developed littoral zone vegetation. Homogeneity of the macrophyte populations present and the presence of reasonably well defined zones of emergent, floating-leaf, and submerged macrophytes were particularly important considerations. We also looked for sites which could be grouped into subsets based on physical characteristics of the sites. Ultimately we expected to be able to select actual study sites from a considerable number of potentially usable sites in each of the four lakes. In this effort we were greatly disappointed. Among the problems encountered were the frequent absence of an identifiable zone of floating-leaf macrophytes, substantial blooms of filamentous and planktonic algae, and major expanses of rocky shore where macrophyte populations are extremely sparse or totally absent. In this situation it was soon evident that we would have to accept study sites which departed considerably from our preconceived ideal.

Ultimately we selected eleven sites, three each in Rainy, Kabetogama, and Namakan Lakes and two in Sand Point Lake (Fig.2). Each site was assigned a name based on a regularly identified geographic feature in the immediate area. As named, the sites are:

In Rainy Lake; Dove Bay, Olson Bay, and Cranberry Bay.

In Kabetogama Lake; Wood Duck Island, Camel Back Island, and Lost Bay.

In Namakan Lake; McManus Island, Sheen Point, and Deep Slough.

In Sand Point Lake; Grassy Bay and Swanson's Bay.

At each site a base point was selected on shore and marked as permanently and inconspicuously as possible. From that point, a baseline

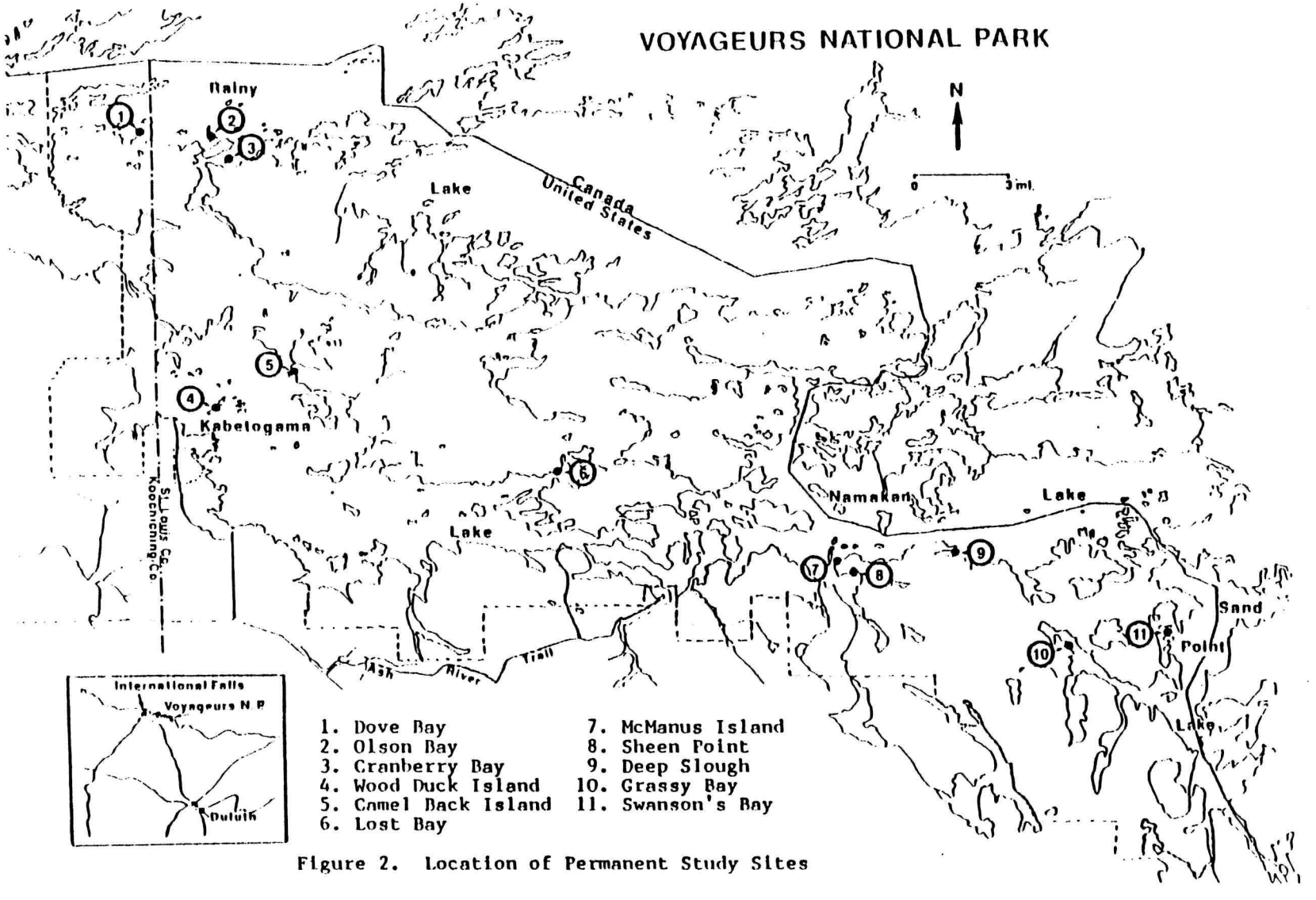

Figure 2. Location of Permanent Study Sites

was laid out through the littoral zone and approximately perpendicular to the shore line (Fig.3). Base point location and baseline orientation were arbitrary decisions based on the intent to approximately bisect the selected littoral zone. For a baseline we used polypropylene rope, marked at one meter intervals and tied to a float at the open water end. The float was in turn secured to an anchor placed another twenty meters out toward open water. The result was a reasonable taut, fully visible, floating line extending from shore to a point well beyond the sampling area.

To sample the vegetation at a site we first examined the littoral zone as a whole to determine where transect lines could be placed perpendicular to the baseline with one transect line approximately centered in each of the recognizable zones of macrophytes present. This placement was an arbitrary decision designed to focus the sampling effort specifically on the populations of emergent, floating-leaf, and submerged macrophytes and to avoid samples from areas of transition between zones.

Transect line location was marked on the lake bottom by using two, 3-meter lengths of 3/4 inch PVC water pipe marked at intervals of 0.5 meter. The lengths of pipe were lowered to the lake bottom and coupled under water to make a transect line 6 meters long, oriented perpendicular to the baseline and centered at a selected point on the baseline. PVC water pipe was also used to construct the square quadrat frames which enclosed an area of $0.25m^2$. By using standard 90° elbows at each corner and leaving one side unattached, the frame could be filled with water, worked into place and then completed by slipping the fourth side into place. For purposes of the sampling effort, quadrat frame placements were at 1-meter intervals along the transect line with two on each side of the base line.

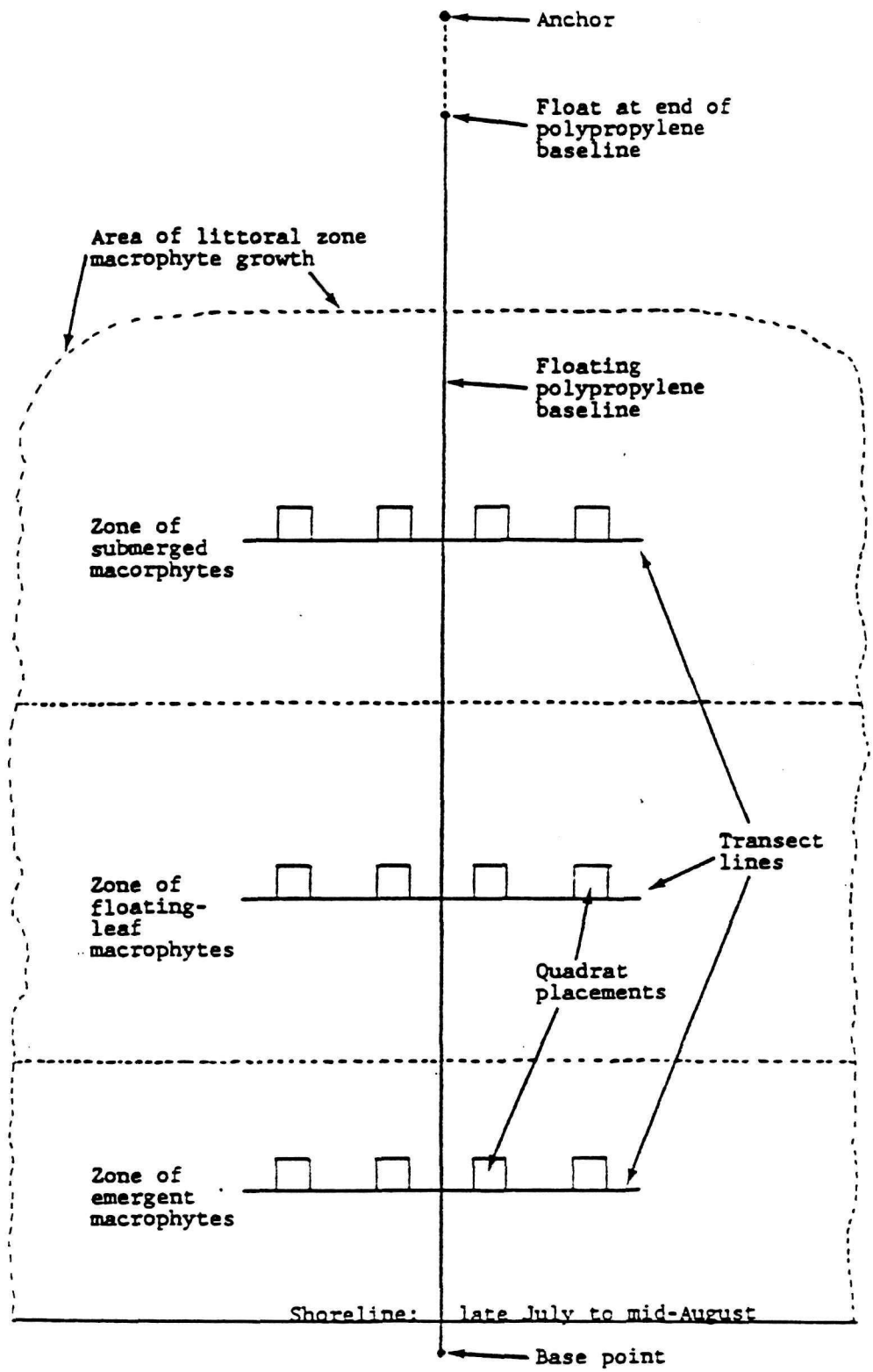

Figure 3. Baseline, transect, and quadrat layout of a hypothetical study site. (Not to scale)

In several instances, especially where Wild celery (Vallisneria americana) was abundant, we used a quadrat frame weighted with segments of iron reinforcing rod and modified to include a "superstructure". A net was draped over the structure and held in place with strips of Velcro. Actively photosynthesizing plant material floated up into the net as it was cut. This unit, with an easily detachable net, made it possible for us to sample vegetation which had proven to be otherwise unmanageable.

At each site we took four biomass samples from each of the identifiable zones. Each sample consisted of the living macrophyte material growing above the lake bottom and within the limits of the $0.25m^2$ quadrat frame. Samples were obtained by using grass clippers to cut the plants just above the lake bottom. All material from each quadrat was placed in a plastic bag and transported as quickly as possible to our base of operations for further treatment. In water up to about one meter deep, sampling was possible with face mask and snorkel. In deeper water, SCUBA was regularly utilized. In most instances, the work at a site was completed in two to three hours with longer periods needed where silt was a major problem.

Upon our return to the base camp, the biomass samples were washed as necessary, separated into component species and dried as quickly as possible. Although we must certainly acknowledge the probable loss of weight from the fresh samples as the result of continuing metabolic activity, every effort was made to reduce such losses including refrigeration of samples awaiting processing at the base camp.

Final processing of biomass samples was carried out in the laboratories of the Biology Department of Duluth. Here, samples were checked to be certain of species identification and then placed in a

drying oven where they were held for at least 12 hours at a temperature of 58°C to 60°C. Prior experimentation had demonstrated that neither higher temperatures nor longer periods of drying had any measurable effect on sample weight.

Using the methods described above, biomass samples were collected from the eleven named sites during each of two successive years with actual sampling from August 1 - August 18, 1982 and between July 17 and July 31 in 1983. Sample collecting dates were selected with the intent of obtaining the maximum above-ground standing crop. In the 1982 effort, however, there were substantial quantities of filamentous algae entangled with the macrophytes and this together with a developing bloom of plantonic plants and animals led to the conclusion that a better record of maximum macrophyte standing crop would be obtained by sampling at an earlier date. In 1983 there appeared to be smaller amounts of the filamentous algae but our effort was complicated by somewhat higher lake levels (higher than in 1982) and generally higher air temperatures. We believe that we obtained at least near-maximum values for above-ground standing crop but exact timing in this matter must be regarded as an open question.

Limitations imposed by our methods led to the exclusion of certain plants from biomass samples. This includes the occasional low-growing rosettes of Sagittaria spp. and Isoetes spp. as well as the rhizomatous Eleocharis acicularis. Also excluded was the alga, Nitella spp.

Although our initial planning included the collection of data on the number of individuals of each species in each quadrat sample, we were forced to abandon this approach early in the 1982 field season. This was necessitated by the frequent presence of silt and finely divided organic

matter on the plants and lake bottom. In this situation, a disturbance such as wind action, quadrat placement, or plant removal often reduced visability to such an extent that low-growing, extensively branched or rosette forming plants could not be seen as individuals.

The data available as the result of these field studies includes a checklist of species from each site, biomass per species (as grams, dry weight of above-ground living plant material on date of collection), frequency for species occurring within sample areas, and observations on the physical characteristics of each study site including location of the baseline and each transect, water depths, and nature of the lake bottom materials. Data on biomass and frequency have been combined to provide a calculated Importance Value for each species at each of the 11 study sites and data on biomass have been used to provide values for mean, standard deviation, and coefficient of variation.

In addition to presentation in various tabular and graphic forms, the available data on biomass and number of species have been used in the calculation of a one-way analysis of variance (ANOVA) using the standard SPSS package (Nie, et al, 1975). ANOVA has been used specifically to determine whether or not significant differences exist among lakes with respect to either biomass or number of species for any of the 3 zones of macrophytes in 1982 or 1983. ANOVA has also been used to determine if significant differences exist among lakes with respect to the difference between the 1982 and 1983 data for either biomass or number of species in any of the 3 zones of macrophytes. As available from the UMD Computer Center, ANOVA is followed by a series of Student's t-tests which make it possible to determine which lake accounts for any observed differences.

An alternative approach to data analysis utilizes quadrat sample data on name and biomass of the species present in calculation of Morisita's

Index of Community Similarity (Brower and Zar, 1977). This index presents the probability that two individuals drawn randomly from populations X and Y will both belong to the same species relative to the probability of randomly drawing two individuals of the same species from X or Y alone. Thus, both species composition of the populations being compared and the relative abundance of the individual species in the two populations are entered into the calculation.

For purposes of calculating Morisita's Index, each population in each zone of macrophytes, at each study site, in each year of the study is regarded as a separate population. In the ideal situation this would provide 66 populations. Problems in locating ideal sites were substantial, however, with the result that data are available for 53 populations as follows:

Emergent zone macrophytes - 21 populations

Floating-leaf zone macrophytes - 10 populations

Submerged zone macrophytes - 22 populations

The single emergent zone population missing is from Deep Slough (Namakan Lake) where, in 1983, a large power boat was anchored at the site for several days with its bow near the established base point. The shortfall in the floating-leaf zone is the result of the absence of an identifiable zone of floating-leaf macrophytes in 1982 and/or 1983 at 7 of the 11 sites.

In the typical use of Morisita's Index, the abundance of a species is simply the number of individuals of that species in the population sample. In the absence of the required count, species abundance is derived by converting grams of biomass per species to "biomass units" where 0.1 gm of biomass equals one biomass unit. Certain distortions of

the data are an unavoidable consequence of this conversion. The worst case is that of a single, heavy-bodied specimen which will enter the calculations as a large number of biomass units. It is important to note, however, that such distortions are largely the reciprocal of the distortion which occurs when the same plant is regarded simply as one individual for purposes of calculation.

The calculated values for Morisita's Index are made available in a series of computer-generated matrices with comparisons as follows:

1. For the same zone of macrophytes and the same year, the population samples from each of the 11 study sites.
2. For the same zone at each of the 11 sites, the population samples from 1982 and 1983.

Although statistical significance cannot be attached to these calculated values, the instances of a moderate or high degree of community similarity are highlighted in a series of figures based on the appropriate data.

RESULTS

Details of site location, site characteristics, and sampling efforts are provided in Appendix I. Also presented there are the tabulations of Importance Value for the individual species in each population as well as the statistical descriptors of mean, standard deviation, and coefficient of variation for the data on biomass. For purposes of a more immediate examination, selected data from Appendix I have been combined to provide the values presented in Table 1. Thus, for each site, zone, and year, the biomass value is the number of grams (dry weight) per meter^2. The number of species is the number of different species, again per site, zone, and year. Where a zone of floating-leaf macrophytes was not present, the symbol "NA" has been entered. The symbol "P" has been used to distinguish the situation in the emergent zone of Deep Slough in 1983 where plants were clearly present but unsuitable for sampling. This condition resulted from the presence of a large cabin cruiser anchored at the site with its bow near the on-shore base point.

To facilitate an overview of the data in Table 1, Figures 4 and 5 have been prepared. These histograms show, respectively, the total biomass and number of species in lakes of the Rainy Lake/Namakan Reservoir System by zone of macrophytes, lake, year, and study site.

The most striking feature of these data is the wide variation: variation from zone to zone, site to site, and year to year. There is some basis for suggesting that Lake Kabetogama is distinctive, at least with respect to productivity, but this "advantage" may be more apparent than real. On the other hand, Hargis (1981), presents data which show Kabetogama to be quite different from the other three lakes with respect to a number of physical and biotic parameters including greater productivity.

TABLE 1

Biomass Study : Field Data Summary

Study site	Year	Total Biomass (gms., dry wt.) Zone Emer.	Fl-L.	Sub.	Number of species Zone Emer.	Fl-L.	Sub.
Rainy Lake							
Dove Bay	1982	189.3	84.7	16.3	5	5	1
	1983	60.7	141.4	34.5	8	5	2
Olson Bay	1982	135.5	NA	19.2	3	NA	1
	1983	118.3	NA	15.2	2	NA	1
Cranberry Bay	1982	48.0	3.4	5.3	5	4	1
	1983	26.5	6.1	3.2	4	3	3
Kabetogama Lake							
Wood Duck Island	1982	267.0	NA	20.6	2	NA	2
	1983	190.9	NA	30.8	4	NA	5
Camel Back Island	1982	102.8	NA	55.6	1	NA	7
	1983	438.7	NA	121.6	4	NA	4
Lost Bay	1982	129.4	9.0	136.9	6	6	6
	1983	417.2	NA	25.4	3	NA	3
Namakan Lake							
McManus Island	1982	77.0	13.2	0.6	4	3	2
	1983	72.7	13.9	0.0	5	4	0
Sheen Point	1982	189.1	NA	37.0	8	NA	5
	1983	254.9	16.4	8.0	8	5	2
Deep Slough	1982	219.6	NA	35.5	3	NA	5
	1983	P	NA	40.6	P	NA	1
Sand Point Lake							
Grassy Bay	1982	127.0	21.7	17.9	3	5	5
	1983	62.2	4.2	18.3	4	3	7
Swanson's Bay	1982	44.2	NA	11.2	2	NA	2
	1983	40.7	NA	3.7	2	NA	3

NA = Zone or Floating-leaf macrophytes not distinguishable

P = Plants present but site damaged

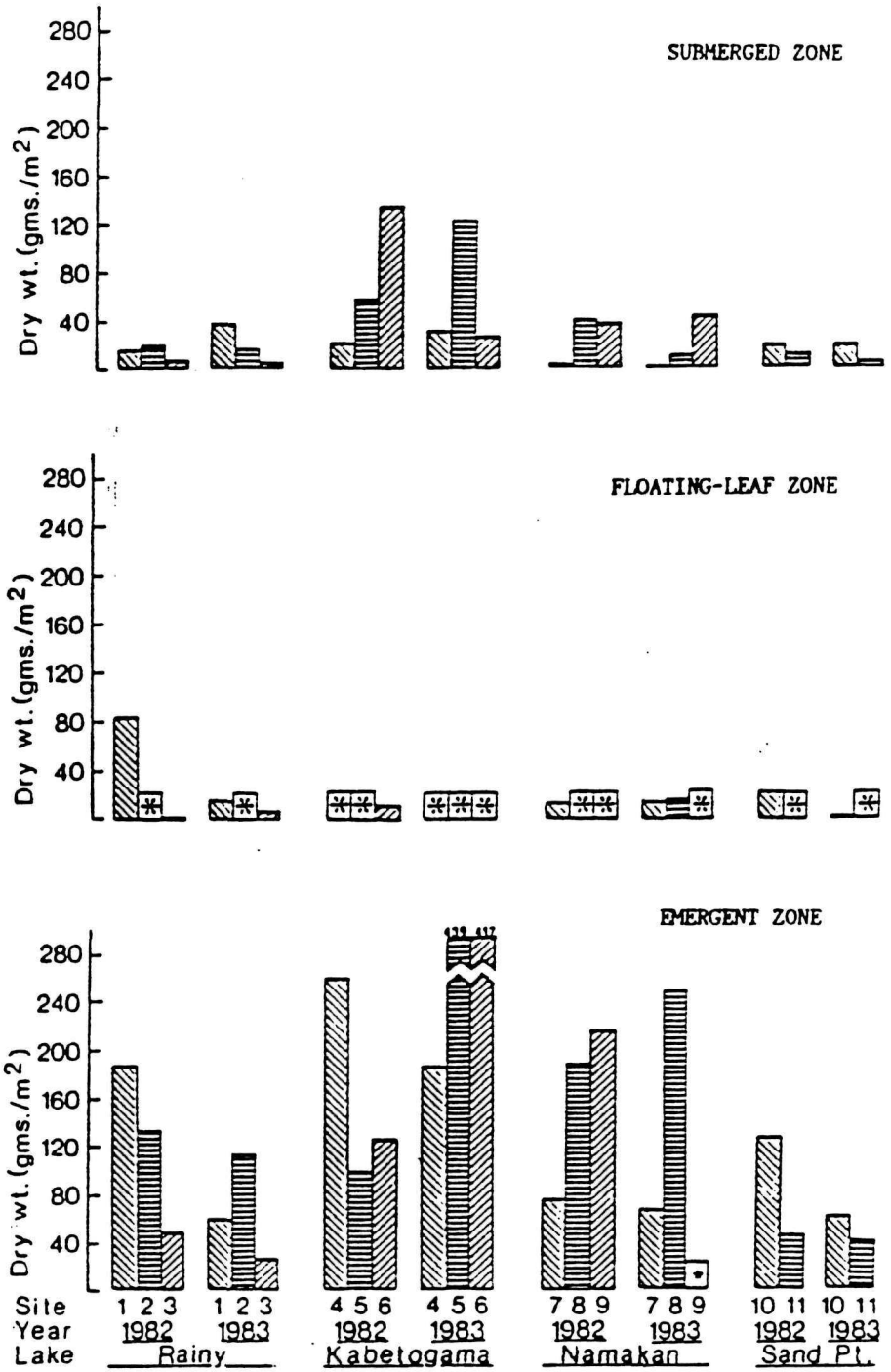

FIGURE 4. Biomass of littoral zone macrophytes in lakes of the Namakan Reservoir/Rainy Lake system by zone, lake, year, and site.
*--no identifiable zone present.
★--plants present but not sampled.

KEY TO SITES

1. Dove Bay - Rainy L.
2. Olson Bay - Rainy L.
3. Cranberry Bay - Rainy L.
4. Wood Duck Is. - Kabetogama L.
5. Camel Back Is. - Kabetogama L.
6. Lost Bay - Kabetogama L.
7. McManus Is. - Namakan L.
8. Sheen Point - Namakan L.
9. Deep Slough - Namakan L.
10. Grassy Bay - Sand Point L.
11. Swanson's Bay - Sand Point L.

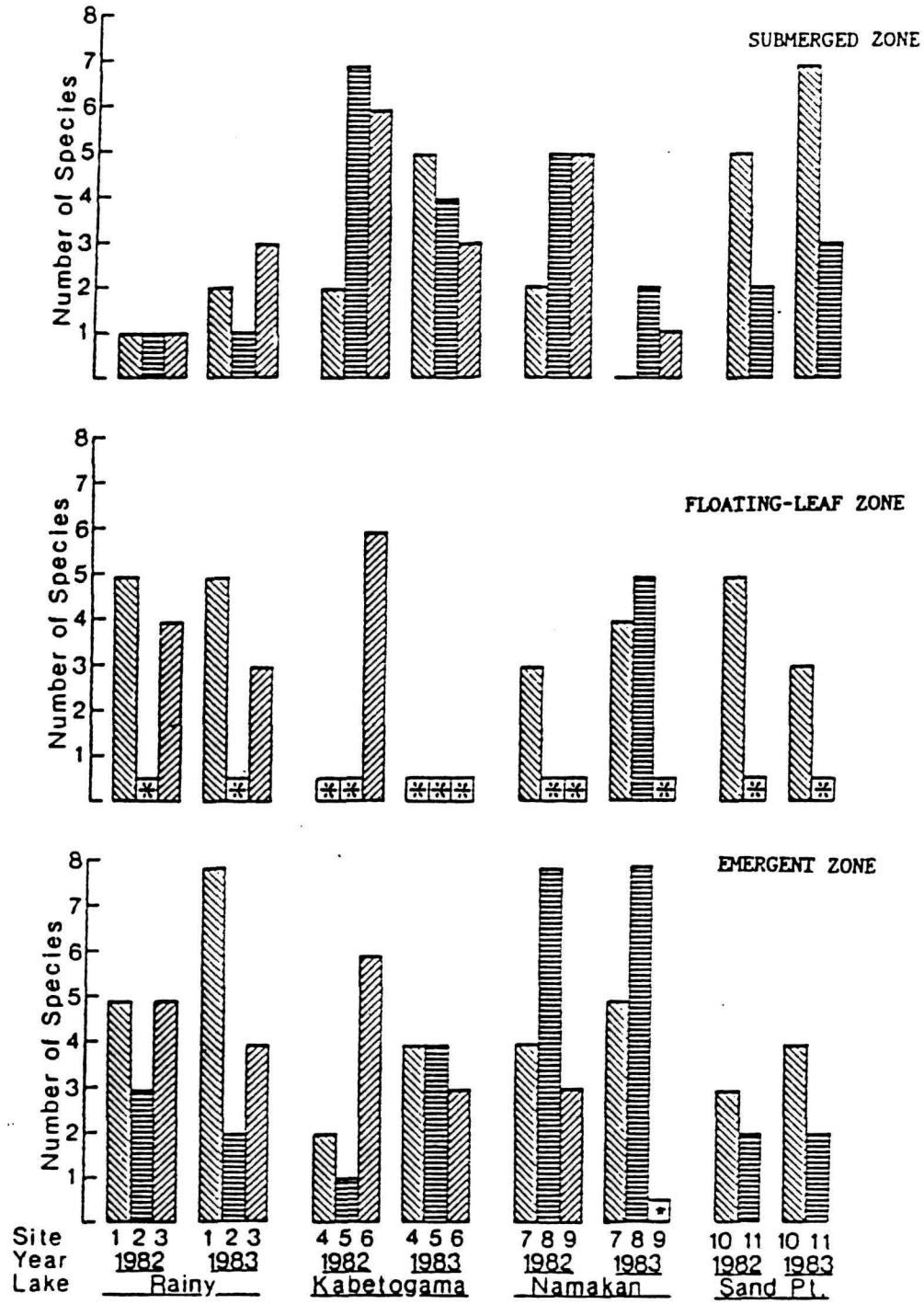

FIGURE 5. Number of species of littoral zone macrophytes in lakes of the Namakan Reservoir/Rainy Lake system by zone, lake, year, and site.
*--no identifiable zone present.
★--plants present but not sampled.

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9. Deep Slough - Namakan L.
10. Grassy Bay - Sand Point L.
11. Swanson's Bay - Sand Point L.

The paucity of data from the zone of floating-leaf macrophytes is particularly evident in the histograms. Supporting data are scarce but it is reasonable to suggest that this situation is a direct result of the annual fluctuations in water level. This is on the basis of the high probability of critical disturbances in the segment of the littoral zone with potential for development in mid-summer as a zone of macrophytes with floating leaves. Thus, plants which characterize the floating-leaf zone (primarily Glyceria borealis and Sparganium fluctuans in these lakes) begin annual growth on muddy flats or in shallow water where the effects of wind and waves are at a maximum. Late summer biomass may be contributed by other species growing in this zone but these species are mostly casuals which reproduce from fragments, are very loosely rooted, and are more typical of the zone of submerged plants.

Along with the disturbances caused by low and rising water levels in the spring, the total exposure of the potential floating-leaf zone during the winter might be expected to have damaging effects. Freezing, per se, is probably not important but if snow cover is not present, desiccation could destroy or at least reduce the vigor of seeds, rhizomes, or rootstocks. Indeed, the entire concept of aquatic weed control by dewatering is based on the probability that exposure will destroy or at least reduce viability in aquatic plants. In addition to the effects of exposure, frost action in northern climates may sever the roots of a plant with subsequent deleterious effects. This has been suggested as the reason for the major reduction in quantities of Nuphar in the Murphy Flowage in Wisconsin (Beard, 1973). Although Nuphar is typically a plant of the zone of floating-leaf macrophytes and occurs in lakes of the VNP reservoir system, it is rare and never contributed to biomass in our studies.

In a system of lakes as large and variable as that involved in this study, the designation of a "typical" suite of littoral zone macrophytes is problematical, at best. As an approach to that problem, however, Table 2 has been prepared. That Table is a composite checklist of the plants encountered in the littoral zone at one or more of the 11 study sites. The symbol "B" is used to designate those species which contributed to biomass in one or more of three zones of macrophytes during one or both of the years of sampling activity. Species which were observed at the study site but which never appeared within the sampled quadrats are indicated by the symbol "X".

Of the 48 taxa included, 37 contributed to the measured biomass on at least 1 occasion. The 11 taxa sometimes present but never contributing to our measures of biomass includes 3, low-growing, mat or rosette-forming taxa which could not be sampled by our procedures and 1 genus of macroscopic algae. Although the potential significance of these plants must be acknowledged, they are not considered in the work reported here.

For a more meaningful characterization of the littoral zone macrophytes of the lakes it is appropriate to consider those species which contributed to biomass or were observed at 6 or more sites and are part of the record for each of the 4 lakes. The 7 species thus selected are *Glyceria borealis*, *Myriophyllum* sp. (probably *M. spicatum* var. *exalbescens*), *Najas flexilis*, *Potamogeton gramineus*, *P. spirillis*, *Scirpus fluviatilis*, and *Sium suave*. The first 4 in this list are particularly characteristic, occurring in at least 9 of the 11 study sites. To this list it is reasonable to add 3 species which we found at 6 or more of the study sites and which the complete VNP flora includes for the single lake where we did not find it in our biomass studies.

TABLE 2. Cumulative check list of littoral zone macrophytes from eleven sites in the Namakan Reservoir/Rainy Lake system.
B--contributed to biomass one or more times at the site.
X--present at the siet but not contributing to the biomass.
See Appendix III for complete nomenclature.

	Dove Bay	Olson Bay	Cranberry Bay	Wood Duck Is.	Canal Back Is.	Lost Bay	McManus Is.	Sheen Point	Deep Slough	Grassy Bay	Swanson's Bay	
Alopecurus aequalis												
Bidens bekii	B		X					X	B			
Callitriche verna				B	B	X	X		B			
Cardamine sp.							B					
Carex atherodes			B		B							
Carex lacustris										X		
Carex rostrata	B	X				B	B	B	B			
Carex sp.					B				B	X		
Ceratophyllum demersum	B	X							B			
Eleocharis acicularis		X		X		X	X					Excluded
Eleocharis palustris	B	B				B	B	B	B	X		
Elodea canadensis	B	B			B	X	B	B				
Glyceria borealis	X	B	X			B	B	B	B	B		
Isoetes sp.	X					X	X	X				Excluded
Myriophyluum sp.	B		B	B	B	X	X	B	B	X		
Najas flexilis	B	B	B	B	B	B	B	B	B	B		
Nitella sp.									X	X		Excluded
Nuphar variegatum		X										
Nymphaea tuberosa								X				
Phragmites communis	B			X								
Poa pratensis							B					
Polygonum coccineum							B					
Polygonum natans							B					
Polygonum punctatum							B					
Polygonum sp.					X				X			
Potamogeton epihydrus		X										
Potamogeton gramineus	B	B	X	B		B	B	X	B	B		
Potamogeton richardisonii	X		B	B	B		X	B				
Potamogeton spirilis	B		B		B		B		B	B		
Potamogeton vaseyi							B					
Potamogeton zosteriformis	B				B							
Potamogeton sp.		X		B	B				B			
Ranunculus circinatus				B	B							
Ranunculus sp.			B	B		X						
Sagittaria sp.		B	X			X	X					
Scirpus acutus			B	B								
Scirpus cyperinus							B		X			
Scirpus fluviatilis		X	B	B	B	B				B		
Scirpus validus	B	B	X									
Scirpus sp.							B					
Sium suave	B	X	X				E		X	X		
Sparganium eurycarpum	X											
Sparganium fluctuans	B	B										
Subularia aquatica						X						Excluded
Typha latifolia	B			B								
Utricularia intermedia		X										
Utricularia vulgaris		X							B			
Vallisneria americana	B	B							B	B		

Thus Carex rostrata, Eleocharis palustris, and Potamogeton richardsonii are added. Elodea canadensis almost qualifies but there are no records of that species from Sand Point Lake. It should be noted, however, that this designation of 10, "characteristic" species is based on totally arbitrary criteria in a situation where data are limited.

Prior to considering factors which might account for the differences in the macrophyte communities from one site to another, it is appropriate to summarize our observations on the physical characteristics of the 11 sites. This summary is drawn from the data presented in Appendix I where they are part of the complete summary of characteristics of the permanent study sites.

In an examination of these data, 2 sites, Olson Bay in Rainy Lake and Swanson's Bay in Sand Point Lake stand out. The Olson Bay site is the most obviously distinctive with its broad expanses of sand, both along the shore and lakeward to at least 75 meters from shore where the baseline at this site was anchored. There was almost no silt at this site and detritus was restricted to deposits in shallow depressions in the lake bottom. The Olson Bay site is also distinctive for its exposure to wind and wave action. It is totally open to the northeast and located such that waves generated by winds from the north or east could also be important. The significance of wave action at this site is clearly indicated by the developing, off-shore sand bar which lies parallel to and about 15 meters out from the midsummer water's edge.

The Swanson's Bay site is less obviously unusual but close to unique within the limits of our observations. This is because, except for the area immediately adjacent to the shore, the lake bottom materials are exclusively a gray clay. The clay is quite firm but, in spite of protection from the wind, the apparent source of the generally muddy appearance of the water.

The remaining 9 sites are much less amenable to catagorization with respect to bottom type. Varying amounts of unconsolidated silt and detritus cover much of the bottom in these areas with pebbles and cobbles or sand below. It is reasonable, however, to group the Dove Bay and Cranberry Bay sites in Rainy Lake together with the Wood Duck Island and Lost Bay sites in Lake Kabetogama on the basis of the pebbly or cobbled lake bottom. Silt and detritus are present but do not appear to be the biologically effective substrate. Similarly sand appears to be the effective substrate at Camel Back Island in Lake Kabetogama as well as in Namakan Lake at the McManus Island and Deep Slough sites. The 2 sites not yet accounted for are unusually well protected and have deposits of silt and detritus thick enough to totally obscure the underlying sand. These sites are Sheen Point in Namakan Lake and Grassy Bay in Sand Point Lake. At these 2 sites, silt and detritus are reasonably understood to be the effective substrate.

Overall, the sites appear to separate into 4 groups on the basis of substrate with 1 site on clay, 4 on pebbles and cobble, 4 on sand and 2 on silt and detritus. In all situations, the extent of exposure to wind and wave action appear to combine with access to a deep water "sink" for deposit of unconsolidated material to control the amount of silt and detritus present.

As noted earlier, our sampling effort was designed to focus specifically on the populations of emergent, float-leaf, and submerged macrophytes and to avoid the areas of transition between zones. This decision led to considerable site to site variation in both the depth of water and distance from shore where biomass sampling occurred. For example, the water depth where emergent zone plants were sampled ranged

from 20 cm. to 90 cm. while distance from shore to the sampling site ranged from 3 m. to 40 m. (Appendix I). As might be expected, the coefficient of correlation between water depth and distance from shore to the sampling site in the emergent zone is highly significant ($r = .746$; d.f. = 9). For sampling sites in the submerged zone, on the other hand, the coefficient of correlation between water depth and distance from shore to the sampling site is low ($r = -.245$; d.f. = 9).

As one approach to the evaluation of the relationship between the physical and biological characteristics at the eleven study sites, Table 3 has been prepared. This is a matrix of the values for the coefficient of correlation between either mean annual biomass or mean annual number of species present per site and water depth or distance to shore where sampling occured. Plants and collecting sites in both the emergent and submergent zones are considered. Data relative to the float-leaf zone are too limited to provide meaningful values and have not been considered.

TABLE 3

Values for coefficient of correlation between mean biomass or mean number of species per site and water depth or distance from shore to the sampling site for emergent and submerged zone macrophytes at eleven sites in the Rainy Lake/Namakan Reservoir System.

	Mean Biomass/Site		Mean No. Species/Site	
	Emergent	Submerged	Emergent	Submerged
Depth	-.189	.505	-.669*	.655*
Distance to Shore	-.232	-.330	-.303	-.570

*Significant at 5% level; d.f. = 9.

As is indicated, the only significant values for "r" involve the correlation between mean number of species per site and depth of water at the sampling site. This is reasonably understood to be a consequence of the annual increase in water depth in these lakes with the effect being positive on species which can grow totally submerged amd negative on species which survive only if upper parts of the plant are emergent.

The relatively low correlation between mean biomass or mean number of species per site and distance from shore in combination with the less than perfect correlation between water depth and distance from shore suggests that distance from shore, per se, is not a major factor in determining macrophyte success.

To look at the effect of fluctuating water levels on individual species found at VNP we return to the paper by Cooke (1980). For purposes of this examination, Cooke's data on 15 species are combined with an evaluation of abundance for the same 15 species as they occur in VNP to prepare Table 4. The resulting tabulation includes all species for which data on the effects of drawdown are available and are also part of the record for 1 or more of the 11 VNP study sites (Table 2). Because the effect of drawdown is species specific, references to an effect at the generic level have not been included.

As can be seen, the reported effect of drawdown on this group of species is extremely variable except for the few species occurring at the extreme ends of the scale of abundance in VNP. The number of reports in the literature is limited but it is reasonable to conclude that the abundance of at least Najas flexilis and Potamogeton gramineus in the Namakan Resevoir/Rainy Lake System is an effect of the water level fluctuations which occur in that system. That water level fluctuation

TABLE 4. Relative abundance and effects of drawdown on selected species of macrophytes from the Namakan Reservoir/Rainy Lake system.

Species	Abundance	Effect of Drawdown*		
		Decrease	Increase	No Change
Glyceria borealis	Abundant		1 obs.	
Najas flexilis	Abundant		4 obs.	1 obs.
Potamogeton gramineus	Abundant		2 obs.	1 obs.
Elodea canadensis	Common	1 obs.	1 obs.	
Potamogeton richardsonii	Common		1 obs.	1 obs.
Vallisneria americana	Frequent to Common	1 obs.		1 obs.
Sium suave	Frequent		1 obs.	
Ceratophylllum demersum	Occasional	2 obs.	3 obs.	2 obs.
Scirpus validus	Occasional		2 obs.	
Typha latifolia	Occasional		1 obs.	1 obs.
Utricularia vulgaris	Occasional	2 obs.		
Polygonum coccineum	Occasional to rare		2 obs.	1 obs.
Polygonum natans	Occasional to Rare		1 obs.	
Scirpus cyperinus	Occasional to Rare	1 obs.		
Nymphaea tuberosa	Rare	1 obs.		

*Adapted from Cooke, 1980

Key to scale of abundance

Abundance	Present at:	Contributing to biomass at:
Abundant	8 or more sites	5 or more sites
Common	6 or more sites	3 or 4 sites
Frequent	6 or more sites	1 or 2 sites
Occasional	3 or more sites	1 or 2 sites
Rare	1 or 2 sites	no sites

have an effect on macrophytes is also suggested by the absence of any record of Potamogeton robbinsii from our 11 study sites. This species is not common but does occur throughout northern Minnesota. There is no way of knowing whether or not P. robbinsii ever occurred in the VNP reservoir system, but its absence is logical on the basis of the record which, with 2 observations, points to a decrease under conditions of drawdown.

While the fluctuating water levels in VNP lakes appear to have had an effect on certain species of macrophytes, this approach to the data does not show a differential effect that can be related to the magnitude of the fluctuations. This may be illustrated by examining our data for Najas flexilis and Potamogeton gramineus to the extent that these species are part of the biomass in the submerged zone. For Najas flexilis, values for biomass, frequency and importance value (Appendix I) vary considerably from one site to another with the values for Rainy Lake generally at the low end of the range. For Potamogeton gramineus the situation is comparable except that the values for Rainy Lake occur at the upper end of the range. Recall that for these species there is reasonable documentation of an increase as the result of drawdown.

For another example, it may appear that Vallisneria americana is favored by conditions in the submerged zone of Rainy Lake. The details of the record, however, show that this species is of major significance only at the Dove Bay and Cranberry Bay sites in Rainy Lake and the Deep Slough site in Namakan Lake. For this species at these sites, frequency was always 100 and importance values are high and totally comparable from site to site. Actual biomass values range considerably (from 3 gm/m^2 to 40 gm/m^2) with the higher values from Deep Slough. The limited record on the effects of drawdown on this species includes one observation of a decrease and one of no change.

Examination of data for other species reveals similar patterns. Thus on the basis of the record for individual species which contribute to biomass in lakes of the VNP system, differences in the magnitude of water level fluctuation are not correlated with differences in species biomass, frequency, or importance value.

From the several available options for examining our data at the population level, we have chosen Morisita's Index of Community Similarity (Brower and Zar, 1977). As described in some detail in an earlier section of this paper, Morisita's Index (I_m) is a measure of the probability that two individuals drawn at random from the two populations being compared will belong to the same species relative to the probability that two individuals drawn at random from one of the populations will both be members of the same species. Values range from 0.00 (no similarity) to about 1.0 (identity). Although no statistical significance can be attached to the values for I_m, we find reasonable breaks in the range of the calculated values which permit acceptance of the following:

I_m = 0.00 through 0.39; low level of community similarity

I_m = 0.40 through 0.69; intermediate level of community similarity

I_m = 0.70 through 1.00; high level of comunity similarity

As a first examination of values for Morista's Index, Table 5 has been prepared. In this table the values for I_m provide a measure of the similarity between the pairs of populations sampled in 1982 and 1983 in the same zone at the same site.

Again the effect of missing data is conspicuous (NA) and accounts for 8 of the 33 positions in the matrix. Of the 25 calculated values for I_m, 17 range upwards from 0.70, 4 are in the range from 0.40 - 0.69, and 4 are in the range of 0.39 or less. Overall, then, there is a rather high

TABLE 5. Morisita's Index of Community Similarity for the 1982 and 1983 population samples from the same site and zone of macrophytes.

SITE	ZONE		
	Emergent	Float-leaf	Submerged
Dove Bay	0.02	1.00	1.00
Olson Bay	0.92	NA	1.00
Cranberry Bay	0.64	0.41	1.00
Wood Duck Is.	0.89	NA	0.94
Camel Back Is.	1.00	NA	0.60
Lost Bay	0.81	NA	1.00
McManus Is.	0.96	0.70	0.00
Sheen Point	0.91	NA	0.55
Deep Slough	NA	NA	1.00
Grassy Bay	0.23	0.95	0.22
Swanson's Bay	0.95	NA	0.85

NA = Macrophytes absent or not suitable for sampling in 1982 and/or 1983.

degree of similarity between the 1982 and 1983 populations occurring at the same site and zone.

Further support for this claim comes from the fact that a close examination of the raw data (Appendix I) reveals a rather simple explanation for many of the instances where I_m is 0.70 or less. The value of 0.00 for the submerged zone at McManus Island, for example, is a consequence of no biomass whatever in the 1983 sampling effort but this fact should be balanced against the finding of very little biomass in 1982. The calculated value for I_m is obviously accurate even though the populations for 1982 and 1983 may be quite similar.

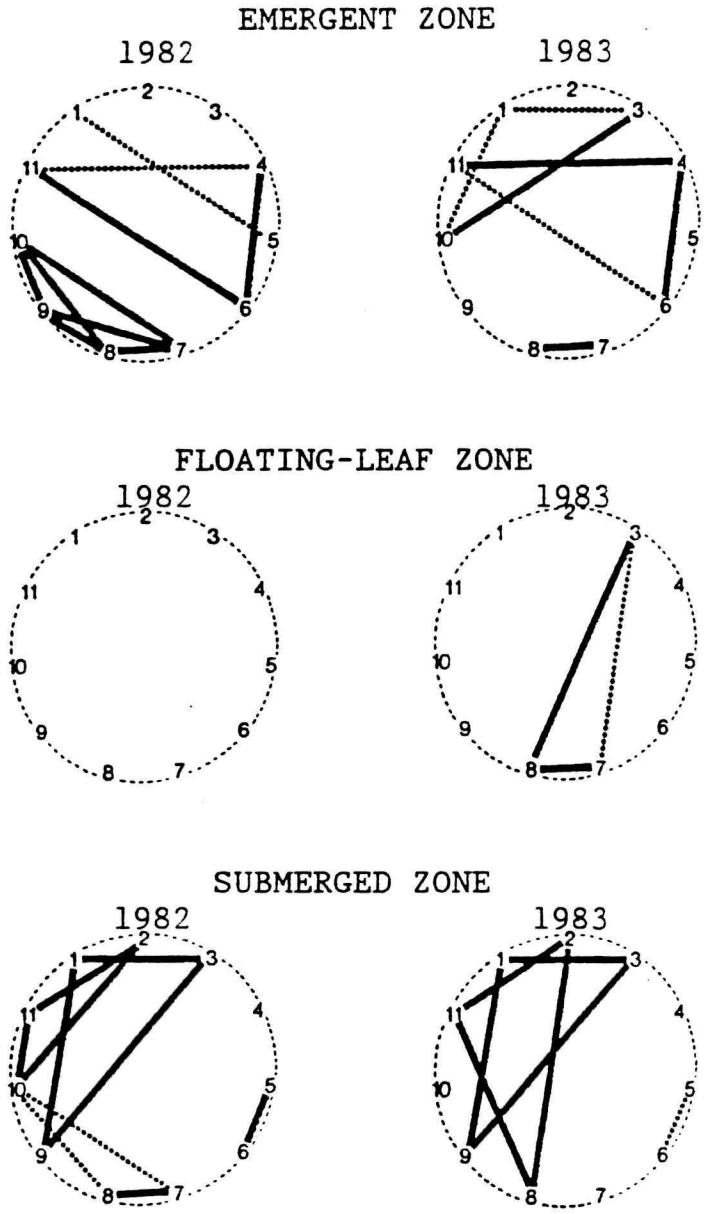
A very different but equally simple explanation accounts for the intermediate values for I_m in the submerged zone at both Camel Back Island and Sheen Point. In these populations, the quantities of Najas flexilis is the key. This species is an annual which produces substantial amounts of seed which can easily be transported by water movements in the fall or spring. For a final example, the low value for the emergent zone at Grassy Bay is probably just a taxonomic problem arising from our inability to make a complete identification of the Carex which was a major component of the 1983 biomass. Only one calculated value is a complete mystery, that being for the emergent zone of Dove Bay where there was an almost complete replacement of the 1982 population by the plants present in 1983.

The bulk of our calculated values for I_m provide a measure of similarity between all possible pairs of populations sampled during the same year and in the same zone of macrophytes at the 11 different study sites. These values are presented in a series of 6 matrices as Appendix II. As a supplement and simplification of the data in Appendix II,

Figure 6 has been prepared. Here, only the intermediate and high values for I_m are considered. An even more generalized but still reasonably valid picture of the patterns of distribution for values of I_m may be produced by ignoring the distinction between intermediate and high values and mentally superimposing the diagrams for 1982 and 1983. This is reasonable because, as noted earlier, the designation of "low", "intermediate", or "high" for specific ranges of I_m values is totally subjective and because of the previously discussed generally high degree of community similarity between the samples of 1982 and 1983 at any one site and zone.

For the data in their totality, 330 values of I_m are possible, exclusive of the comparison of one population with itself. Missing data, largely from the populations of floating-leaf macrophytes, account for 119 of this total. The distribution of the 221 actually calculated values reveals 126 with no similarity (I_m = 0.00), 59 with a low level of similarity (I_m = 0.01 - 0.39), 8 with an intermediate level of similarity (I_m = 0.40 - 0.69), and 28 with a high level of similarity (I_m = 0.70 - 1.03). It should be noted that the mechanics of calculating Morisita's Index occasionally leads to values fractionally in excess of 1.00.

In the examination of Figure 6, the infrequency of even an intermediate level of community similarity is particularly striking. Of special interest is the fact that this lack of similarity includes the comparison of sites in the same lake to nearly the same extent as the comparisons of sites from one lake to another. Also emerging from Figure 6 is the high degree of isolation for sites in Lake Kabetogama. The major exception to this generalization is the similarity between the



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7. McManus Is. - Namakan L.
8. Sheen Point - Namakan L.
9. Deep Slough - Namakan L.
10. Grassy Bay - Sand Point L.
11. Swanson's Bay - Sand Point L.

FIGURE 6. Morisita's Index of Community Similarity for selected pairs of populations located in the same zone of macrophytes and sampled during the same year.
Solid lines---I_m 0.70 or greater
Broken lines--I_m 0.40 - 0.69.

emergent populations of Swanson's Bay in Sand Point Lake and Wood Duck Island and Lost Bay in Kabetogama. Biologically, Scirpus fluviatilis is the common denominator but nothing in our observations suggests a reason for the strong showing of this species at these sites. The only other exception is that of an intermediate level of similarity between the 1982 emergent populations of Camel Back Island and Dove Bay. Typha latifolia is the critical plant in this instance and this may well be an example of the distortion of data resulting from the use of biomass data instead of number of individuals in calculating Morisita's index.

The most surprising feature of the data presented in Figure 6 is the frequency of a low degree of correspondence between the 1982 and 1983 data. Given the high degree of similarity between the 1982 and 1983 populations at any one site (Table 5), it is reasonable to expect at least intermediate values of I_m between sites in both years when I_m is high in one or the other of the two years. The previously mentioned Swanson's Bay, Wood Duck Island, and Lost Bay sites are an example of the expected relationship. Other such examples occur but there appear to be at least minor shifts in the species composition at many sites from one year to the next.

When I_m values from 0.20 to 0.39 are added to the graphs, the picture shifts toward greater correspondence between 1982 and 1983 data for both emergent and submerged zones. In the emergent zone, for example, similarity is shown to prevail between sites 7 and 10 for both 1982 and 1983 rather than just 1982. At the same time, these low values of I_m tie site 7 to sites 1, 4, 6, and 11 for 1982 data and to site 3 in 1983. There remains, however, some evidence of an apparent independence of the macrophyte population at some sites from the population at the same sites in a different year.

In summary, the values for Morisita's Index of Community Similarity suggest a high degree of similarity between the 1982 and 1983 macrophyte populations at any one site in the same zone. The degree of similarity between populations at different sites but in the same zone and year is clearly less but still evident. Overall, the most conspicuous feature is the isolation of Lake Kabetogama sites from on another and from sites in other lakes.

Complicating an understanding of the overall picture is the frequent lack or correspondence between the 1982 and 1983 data. this suggests the possibility of a significant difference in the year to year details of the water-level fluctions, especially in the early part of the growing season. This is a problem which should be examined in greater detail.

Examination of our data on a system-wide basis is provided by analysis of variance (ANOVA) using SPSS (Nie, at al, 1975). In this analysis, our data from Table 1 are examined from 2 prospectives:

1. To determine if significant differences exist among lakes for either biomass or number of species with data from each zone , and year taken separately (12 analyses). This analyses specifically compares Rainy Lake to each lake in the Namakan Reservoir and Rainy Lake to the lakes of the Namakan Reservoir taken as a group.
2. To determine if significant differences exist among lakes in the difference between 1982 and 1983 data for either biomass or number of species with data for each zone taken separately (6 analyses). Again, the analyses specifically compare Rainy Lake to each lake in the Namakan Reservoir and Rainy Lake to the lakes of the Namakan Reservoir taken as a group.

With respect specifically to biomass, the ANOVA indicates no significant difference among lakes in either year of the study (P values greater than 0.23), except for a significant difference among lakes in emergent zone biomass in 1983 ($F = 5.3$; $P = 0.04$). This reflects the substantially higher biomass in the emergent zone in 1983 for two Kabetogama Lake sites when compared to the emergent zone biomass of Rainy Lake for the same year (Student's t-test: $P = 0.01$; d.f. = 6).

In the comparable analysis of data on the number of species, ANOVA indicated no significant difference among lakes in either year of study (P values all greater than 0.05). Because it is very close to significant, however, the ANOVA for the number of species in the submerged zone in 1983 is worthy of special mention ($P = 0.052$). In this instance, the accompanying values for Student's t-test indicate the special importance of the data from Namakan Lake (Student's t-test: $P = 0.053$; d.f. = 7). It will be recalled, however, that these data include those from the McManus Island site where the submerged zone populations were sparse in both 1982 and 1983 with no plants collected in the 1983 sampling effort.

The last in this series is the among lakes ANOVA for the difference between the 1982 and 1983 data on the biomass and number of species. These analyses indicate that the difference between the 1982 and 1983 data for both biomass and species number is not significant (P values all greater than 0.1). As might be expected, the among lakes ANOVA for the difference between 1982 and 1983 data on the number of species in the submerged zone comes the closest to being significant ($P = 0.11$). Again as expected, Student's t-test points to the importance of the Namakan Lake data. At the same time it should be noted that there is no indication of

significance for the among lakes ANOVA for differences between the 1982 and 1983 data on emergent biomass (P = 0.24).

Overall, the ANOVA shows only isolated instances of statistically significant differences among lakes on the basis of our data on biomass and number of species. It must be acknowledged, however, that our data are very limited in quantity and are characterized by a high degree of variability (Appendix I).

Although not worked up for a complete presentation, preliminary work with the ordination technique known as Detrended Correspondence Analysis (Hill and Gauch, 1980) should be mentioned. Several runs have been completed including 1982 and 1983 data independently for each zone and 1982 with 1983 data for each zone. In these analyses, the relative independence of the populations remains, especially in the comparison of 1982 and 1983 data where the data for each year were analyzed in separate runs. When 1982 and 1983 data for any one zone are analyzed in the same run (21 populations of emergents, 22 populations of submerged plants), much of the independence of 1982 from 1983 data is lost. There remain, however, several obvious inconsistencies (Dove Bay, Cranberry Bay, and Grassy Bay in the emergent zone data; Camel Back, Sheen Point, Grassy Bay, and Swanson's Bay in the submerged zone data).

Finally and with particular significance for our initial objectives DCA does not provide evidence to suggest that Rainy Lake macrophytes are responding to water-level fluctuations in a manner which differs from that in lakes of the Namakan Reservoir.

THE WILD RICE PROBLEM

No aquatic species and perhaps no species in the entire VNP flora generates more interest than Wild rice (Zizania aquatica). Although there are no verifiable records, the claims of "old timers" and the historical importance of this grass to American Indians of the region force the conclusion that it was more abundant in the past than it is now. Why this might be true is not known but an examination of the biology of the species might provide some insights. The studies of Dore (1969) and Moyle (1944) are especially useful at this point and are the source of most of what follows.

Wild rice is an annual which grows preferentially on loosely consolidated silt and detritus in moving water two to three feet deep. The movement of water appears to be associated with regular renewal of soil fertility such as occurs in rivers, but flooding and erosion into a lake near an inlet appears to provide the same conditions. The regular required supply of seed falls from the plants which mature in August and early September. The seed is rather dense and sinks to the lake bottom where it remains in water, ice, or soil material until the following spring. Unlike the situation in most plants, the seed tends to fall close to the parent plant and remain where it falls. Freezing obviously does not cause damage but the percentage of germinating grains drops rapidly in seed which has been allowed to dry completely.

Viable seed will germinate in May or early June to produce a seedling with two or three ribbon-like, submerged leaves. Surface water must be present at this time, although depths of one or two inches will suffice. The first leaves must reach the water surface with the terminal portion floating for some time before the emergent flowering stem will develop.

If early growth of the flowering stem occurs where water depths are no greater than two to three feet, the resultant stem will be stout, with relatively short internodes, and maximum potential for seed production. In deeper water, the stems are thin, the internodes elongated, and flower development is restricted.

By late July, Wild rice plants will be fully developed and in full flower. At this stage either major increases or sudden decreases in water depth are likely to produce conditions which lead to damage to the plants and reduced productivity.

Although available data are largely nonspecific, this summary of the requirements for good growth of Wild rice suggests that certain aspects of water level regulation are likely to be detrimental. The most critical problem appears to be the timing and rate of increase in water level. Unfortunately, this problem is complicated by an assortment of factors, any or all of which may be operational in any one year and/or location.

1. Neither the rate or timing of water level increase is consistent from year to year in the large, VNP lakes.

2. As mentioned above, Wild rice requires free surface water for seed germination, but will not grow well in water that is more than about three feet deep. Thus, in Namakan Reservoir, growth is restricted to the upper one-third of the range of the average annual water level fluctuations.

3. Studies in marsh management (Weller, 1978) show that emergents are favored where water levels have been lowered. In some area such as Tom Cod Bay and Daley Bay (both in Kabetogama Lake) and Black Bay (Rainy Lake), emergents such as Cattail (Typha latifolia) and Sedge (Carex spp.) occur in rather solid stands in water two or more feet in depth in mid-summer. Since Wild rice is a poor competitor, growth of this

species in these locations will occur only where the water is too deep for optimum growth. Our 1982 and 1983 collections include Wild rice from four locations, all in water three or more feet deep.

4. Our limited observations indicate that the submerged leaves of Wild rice seedlings elongate at a rate of several inches per week. This rate of elongation may, however, be exceeded by the rate of water level increase in some years.

5. The increase in water depth over mud flats and similar areas, the preferred substrate for Wild rice, will commonly lead to considerable turbidity. This is especially true in areas which are exposed to wind and waves from adjacent open water. In some years, however, the same conditions will develop in more protected areas. As suggested by Spence (1982), this turbidity will restrict early growth of all macrophytes.

6. A longer-than-usual delay or extremely slow rate in the increase in water level, may, at least in the Namakan Reservoir, lead to a substantial decrease in the percent of viable seeds.

Although the conditions described above are, individually, rather well-documented or easily observed, their interrelationships and combined effect on Wild rice populations are largely unknown. Kadlec (1962), in the only such report dealing with Wild rice, reports "no change" in productivity as the result of drawdown but this was under conditions of a summer drawdown. Thus, the effects of water level fluctuations as they occur in VNP are also larely unknown. The reality of the Wild rice problem is therefore the need for further research. The review presented here may suggest appropriate paths for that research.

PART II

VASCULAR PLANT FLORA

VOYAGEURS NATIONAL PARK, MINNESOTA

INTRODUCTION

Recently published studies on the vegetation of Voyageurs National Park and vicinity have been largely ecological in nature. Most directly related to park conditions have been the work of Coffman et. al. (1980) on the fire and logging history and that of Kurmis et. al. (1980) on primary plant communities. The latter of these includes a checklist of the 327 species of vascular plant species encountered in that study as well as a summary of several more general studies which have a bearing on the vegetation of the area. Those details will not be repeated here.

Substantially pre-dating the establishment of Voyageurs National Park, botanizing by the late Dr. Olga Lakela of the University of Minnesota, Duluth, included the collection of nearly 2200 specimens of vascular plants from the park area in the years from 1949-1955. These collections are a part of the record utilized in her preparation of The Flora of Northeastern Minnesota (Lakela, 1965), which includes keys for identification and maps showing the distribution of vascular plants of St. Louis and Lake counties in Minnesota. The maps included make it possible to organize a list of species from the St. Louis County portions of VNP, but the procedure is rather cumbersome. The resulting list is also incomplete in that it does not include her records from Koochiching County. While Lakela's flora will continue to be a valuable resource, especially for professional botanists, park management is better served by an alternative approach. That alternative is provided by this study.

Our objectives in this work have been:

1. Completion of a checklist of the vascular plants of Voyageurs National Park with the final record to include data on the distribution of these plants in the park.

2. Identification of those elements in the VNP flora which are of special concern in park management. Included would be species which are designated by Federal or State of Minnesota agencies as threatened, endangered, or of special concern as well as those which are introduced from elsewhere in the world.

3. Preparation of a set of mounted specimens representative of at least a majority of the vascular plants found in the park.

METHODS

In June and July of 1982, a preliminary checklist of the VNP flora was prepared on the basis of the reports which are included in Lakela's flora (op cite). This checklist was in turn used to locate and segregate the voucher specimens collected by Lakela and presently incorporated in the Olga Lakela Herbarium, Department of Biology, University of Minnesota, Duluth. In the absence of any evidence that persons other than Lakela have botanized to any extent in the park area, the search for vouchers was restricted to the herbarium in Duluth where a full set of Lakela's collections is known to exist.

Field work on the project was conducted during the summers of 1982 and 1983 as follows: July 27 - August 19, 1982; June 13-20, 1983; July 16 - August 9, 1983; and August 28 - September 5, 1983. Standard plant collection and processing techniques were used throughout the study with collections in duplicate whenever possible. All-season, intensive collecting occurred at a few sites such as the area near the Kabetogama Narrows Ranger Station. More often, however, the need for specimens of a wide variety of species dictated a "hit and run" style, where the objective was the collection of a small number of specimens from each of a variety of habitats.

Although we were able to visit representatives of all of the primary plant communities identified in the park, these visits did not always provide us with what we regarded as a satisfactory range of the plants characteristic of each community. In particular, we were disappointed by our lack of success in finding specimens characteristic of cedar swamps. To resolve this problem we visited cedar swamps just to the south and west of the park boundaries along the Ash River Trail and Kabetogama Road (Co.

Road No. 122). These sites had been studied by Lakela and proved to be valuable in this study.

At the same time that our collections from 1982 and 1983 were being identified, Lakela's VNP collections of the same and related species were checked and annotated as needed. In this task, the studies of Olga Lakela Herbarium specimens by specialists in several genera were especially helpful. These workers and the date of their annotations are Dr. Warren H. Wagner, 1977 (several genera of ferns); Dr. Jerry Wheeler, 1982 (the genus Carex) and Dr. Norman Russel, 1956 (the genus Viola). In all instances, the Principal Investigator involved on this project takes full responsibility for the nomenclatorial assignments that have been made.

With identification and annotation complete, appropriate data from ch collection were transmitted to the Cyber 815 at the Computer Center, University of Minnesota, Duluth. For our 1982 and 1983 collections we used a program designed to provide for the preparation of the labels which ultimately accompany each specimen, and at the same time, transfer selected portions of the input to a separate data base file. Since Lakela's collections are already provided with labels, a separate program was written and used to prepare a second data base file which includes the appropriate data from those earlier collections. A third program was used to prepare a file which includes, for each species, the appropriate family name, as well as the most widely-used common name. These three files were sorted and merged to prepare the printouts which are a part of this paper. Except for the file used to generate labels, these files have been stored on magnetic tape and may be supplemented, modified, sorted, and merged in alternate ways, or otherwise utilized to serve the needs of persons interested in the VNP flora.

In a previous section, the work of the late Dr. Olga Lakéla was noted. In her Flora of Northeastern Minnesota she followed the nomenclature of the eighth edition of Gray's Manual of Botany (Fernald, 1950). Currently available as alternatives in matters of nomenclature are Manual of Vascular Plants of Northeastern United States and Adjacent Canada (Gleason and Cronquist 1963), Checklist of species for flora North America (Sheter and Skog, 1978), and A synonymized checklist of the vascular flora of the United States, Canada, and Greenland (Kartesz and Kartesz, 1980).

The first of these is an altogether viable alternative; the last two are strictly checklists, albeit very complete and authoritative. After examination of these alternatives, I decided that the interests of the VNP staff would be best served by using Manual of vascular plants. Relatively conservative in nomenclature, this manual has the advantages of being backed by a totally comparable, fully illustrated version (Gleason, 1952), and being the most "user friendly" of the available alternatives. With two exceptions, the nomenclature used in this paper is that of the Manual of vascular plants. The exceptions are the use of Elodea in place of Anacharis (Hydrocharitaceae) and the placement of Sweet fern in the genus Comptonia (Myricaceae) rather than Myrica.

In addition to the manuals mentioned above, we used several locally significant manuals as aids in plant identification. Included are Spring Flora of Minnesota (Morley, 1966), Ferns of Minnesota (Tyron, 1980), Flora of Manitoba (Skoggan, 1957), Flora of Michigan, Vol. 1 (Voss, 1972), Manual of Aquatic Plants (Fassett, 1957), and How to Know the Grasses (Pohl, 1968).

The common names which have been used here have been derived from a

number of sources, the most notable being Standard Names of Weeds (Weed Science Society of America, 1966).

In those instances where a generally acceptable "common" name is not available we have used the "NCN" (no common name) designation.

RESULTS AND DISCUSSION

On the basis of the present record, the vascular plant flora of Voyageurs National Park includes 602 species distributed in 277 genera in 89 families (Appendix III). A complete set of vouchers involving over 2900 specimens is on file in the Olga Lakela Herbarium, University of Minnesota, Duluth. Duplicates of most of these are on file in the Herbarium of the University of Minnesota, St. Paul, Department of Botany. The collections of 1982 and 1983 have added nearly 700 numbers representing 375 species. The mounted plants sent to the International Falls office of Voyageurs National Park provides them with a reference and voucher collection of 330 species.

The taxonomic distribution of the VNP flora includes 7 families of ferns and fern allies, 3 families of gymnosperms, 16 families of monocots, and 63 families of dicots. The largest families are the Cyperaceae (62 species in 6 genera), Gramineae (51 species in 36 genera), Compositae (48 species in 23 genera), Rosaceae (33 species in 11 genera), Ericaceae (20 species in 11 genera), Polygonaceae (20 species in 2 genera), and Ranunculaceae (19 species in 8 genera). Twenty-six families are represented by a single species. Carex (Cyperaceae) with 44 species is by far the largest genus. Other large genera are Potamogeton (Najadaceae) and Polygonum (Polygonaceae) each with 14 species, Juncus (Juncaceae) and Salix (Salicaceae) each with 11 species, and Viola (Violaceae) with 10 species.

Of the 602 species in the flora, 43 are included exclusively on the basis of collections made in 1982 and 1983. One species, Tillaea aquatica (Crassulaceae) has previously been recorded in Minnesota only from Rock

County in the extreme southwest. The remaining newly-added species, while generally rather rare, were collected by Lakela in one or more locations in St. Louis or Lake Counties but outside of the park area.

Two species, Ranunculus lapponicus and R. gmelini (Ranunculaceae) should be understood as tentative in the VNP flora. Both are rare and while collected in 1983 in areas outside the park boundaries, they are included because they can be expected to occur within the park. Park managers and naturalists are urged to be on the lookout for these as well as a number of other rare species.

Appendix III provides a complete listing of the VNP flora and includes the documented VNP distribution for each species. The listing is alphabetical by scientific names. To facilitate the use of this primary listing, two additional checklists have been included, these without the distribution records. Appendix IV provides an alphabetical listing with the primary sort based on the family name. The most widely-used common name is the basis for the alphabetical listing in Appendix V.

Although the record presented in Appendix III provides some indication of both range and frequency of individual species, such a record is often misleading. Factors such as the ease of sight recognition, the collector's perception of the need for documentation, the rarity of a species and ease of access to collecting sites often play a disproportionate role.

Protected Species

In Minnesota, the problem of endangered, threatened, and special interest species is somewhat complicated as the result of actions taken by independent agencies, all with legitimate responsibilities in the state. The details of these concerns are presented in Table 6.

At the Federal level, the most recent listing of endangered or threatened plant species (U.S. Department of the Interior, 1980; 1983)does not include any which are known to be a part of the VNP flora. The U.S. Department of the Interior lists referred to above do, however, include two species from the VNP flora with the designation of "Under Review" - Category 2. These species are the New England violet (Viola novae-angliae, Violaceae) and Woodsia oregana var. cathcartiana (Polypodiaceae).

Although pertinent to an area outside the limits of VNP, managers should be aware of the efforts of the U.S Forest Service in the Superior National Forest (Lederle, 1985). For this area located to the southeast of the park, Ms. Lederle has compiled a booklet in which 60 species are treated. For each species there is a full-page illustration as well as notes on habitat, flowering period, and plant structure. Ten elements in the VNP flora are included in that publication.

For the State of Minnesota, independent action has led to the preparation of a list of endangered, threatened, and special concern species of plants and animals (Minnesota Department of Natural Resources, 1983). This study, along with the U.S. Forest Service study can be recommended as a source of information on management of these critical species. Following a period of public comment and review, the recommended list, effective January 1, 1984, was incorporated into Minnesota Statutes with administration by the Minnesota Department of Natural Resources. With respect to the VNP flora, the Minnesota listing includes 2 species as endangered, 1 species as threatened, 3 species of special concern, and 4 species designated as "status undetermined".

Finally, in separate State of Minnesota Statutes administered by the Minnesota Department of Agriculture, a status of "protected" is conferred on several plant species. Included are all species in the Orchidaceae (19 VNP species), all species of Trillium (1 VNP species), all species of Gentiana (1 VNP species), and Trailing arbutus (Epigaea repens, not found in the park).

Introduced Species

Although our studies do not indicate the existence of any significant problems, introduced species are often rather aggressive and may displace the native flora in selected areas. A listing of these species is included as Table 7. Details of their known distribution is available from Appendix III.

Table 6. Voyageurs National Park vascular plant species now protected or being considered for protection under Federal or State of Minnesota statutes.

Federal (Dept. of the Interior, Fish & Wildlife Service)

Currently listed:

None

Currently under review:

Viola novae-angliae House Category 2.	Violaceae
Woodsia oregana Eaton var. cathcartiana (Robins.) Morton Category 2.	Polypodiacea

Federal (Dept. of Agriculture, Forest Service)

Calypso bulbosa (L.) Oakes	Orchidaceae
Elatine triandra Schkuhr.	Elatinaceae
Littorella uniflora (L.) Ascherson (= L. americana Fern.)	Plantaginaceae
Myriophyllum tenellum Bigel.	Haloragaceae
Potamogeton vaseyi Robbins.	Najadaceae
Ranunculus gmelini DC.	Ranunculaceae
Ranunculus lapponicus L. (found near VNP along the Ash R. Trail)	Ranunculaceae
Salix humulis Marsh.	Salicaceae
Subularia aquatica L.	Cruciferae
Viola novae-angliae House	Violaceae

State of Minnesota (Dept. of Natural Resources)

Endangered:

Littorella uniflora (L.) Ascherson (= L. americana Fern.)	Plantaginaceae
Subularia aquatica L.	Cruciferae

Threatened:

Carex muricata L. var. sterilis (Carey) Gleason (= C. sterilis Willd.)	Cyperaceae

Special concern:

Potamogeton vaseyi Robbins.
Ranunculus lapponicus L.
Viola novae-angliae House

Status undetermined:

Agrostis hyemalis (Walt.) BSP.	Gramineae
Myriophyllum tenellum Bigel	Haloragaceae
Sagittaria graminea Michx.	Alismaceae
Tillaea aquatica L.	Crassulaceae

State of Minnesota (Dept. of Agriculture)	"Protected"
Gentiana andrewsii Griseb.	Gentianaceae
Lilium philadelphicum L.	Liliaceae
Trillium cernuum L.	Liliaceae
Calypso bulbosa (L.) Oakes	Orchidaceae
Corallorhiza maculata Raf.	Orchidaceae
Corollorhiza striata Lindl.	Orchidaceae
Corollorhiza trifida Chat.	Orchidaceae
Cypripedium acaule Ait.	Orchidaceae
Cypripedium calceolus L.	Orchidaceae
Cypripedium reginae Walt.	Orchidaceae
Goodyera repens (L.) R.Br.	Orchidaceae
Goodyera tesselata Lodd.	Orchidaceae
Habenaria hookeri Torr.	Orchidaceae
Habenaria hyperborea (L.) R.Br.	Orchidaceae
Habenaria obtusata (Pursh) Richards	Orchidaceae
Habenaria orbiculata (Pursh) Torr.	Orchidaceae
Habenaria psycodes (L.) Spreng.	Orchidaceae
Listera cordata (L.) R.Br.	Orchidaceae
Malaxis monophylla (L.) Sw.	Orchidaceae
Malaxis unifolia Michx.	Orchidaceae
Orchis rotundifolia Banks	Orchidaceae
Spiranthes gracilis (Bigel.) Beck	Orchidaceae

Table 7. Introduced Species

Amaranthus retroflexus L.
Arctium minus Schk.
Capsella bursa-pastoris (L.) Medic.
Cerastium arvense L.
Cerastium vulgatum L.
Chenopodium album L.
Chrysanthemum leucanthemem L.
Cirsium arvense (L.) Scop.
Cirsium vulgare (Savi) Tenore
Galinsoga ciliata (Raf.) Blake
Glecoma hederacea L.
Linaria vulgaris Hill
Lychnis alba Mill.
Lychnis chalcedonica L.
Matricaria matricarioides (Less.) T.C. Porter
Medicago sativa L.
Melilotus alba Desr.
Mollugo verticillata L.
Myosotis scorpioides L.
Oxalis europaea Jord.
Plantago major L.
Polygonum hydropiper L.
Polygonum persicaria L.
Portulaca oleraceae L.
Potentilla argentea L.
Ranunculus acris L.
Rumex acetosella L.
Rumex crispus L.
Rumex patientia L.
Sonchus arvensis L.
Stellaria aquatica (L.) Scop.
Taraxacum officinale Weber
Trifolium hybridum L.
Trifolium pratense L.
Trifolium procumbens L.
Trifolium repens L.

RECOMMENDATIONS FOR FURTHER STUDY

On the basis of the studies reported here, the flora of Voyageurs National Park may be described as reasonably well known. For an area of its size, however, it supports an unusually diverse flora and the challenge of adding new species as well as new distribution records will remain. There is the desirability of full-season collecting in one or more representatives of each of the primary plant communities identified in the park and obtaining vouchers in support of that earlier work. Finally, the availability of the distribution records on magnetic tape provides the possibility of preparing computer-generated maps of the distribution of each species. The major work required would be the conversion of Dr. Lakela's records to a computer-readable system of coordinates.

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APPENDIX I

Field Data Summary for each Site Including:

1) Site Location and Physical Characteristics

2) Biomass Values for each Species and Zone

3) Calculated Importance Value for each Species

4) Basic Statistics

Appendix I. Study Site Location

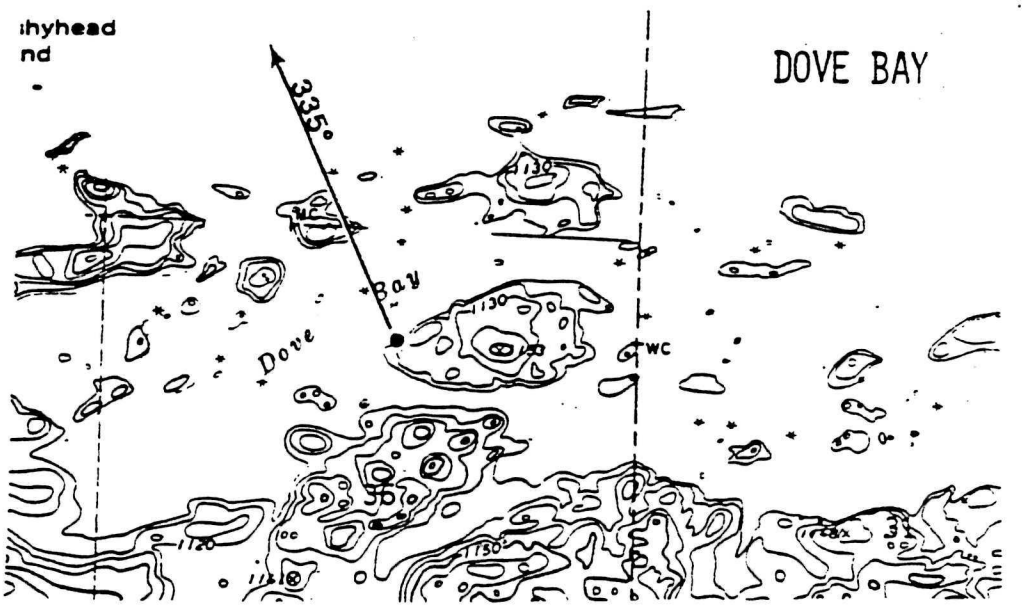
Rainy Lake, Dove Bay
R-22W, T-71N, NW1/4 NE1/4 S-36

Baseline heading: 335°. Baseline origin is marked with a metal pipe at the base of a clump of Beaked willow about 1 m. from shore. A specimen of Paper birch occurs about 6 m. inland from the stake.

Collection dates: August 13, 1982; July 30, 1983

Transect locations and characteristics

Zone	Dist. to shore	Depth	Bottom type
Emergent	7 m.	50 cm.	stone/rubble
Float-leaf	18 m.	80 cm.	stone/silt
Submerged	30 m.	110 cm.	soft silt



Appendix I. Field data. Rainy Lake, Dove Bay.
For each species, 1982 data are on line one, 1983 data are on line two.

Zone/Species	Quadrat Number 1	2	3	4	Total	Rel. Freq.	Rel. Dom.	Imp. Value
EMERGENT ZONE								
Bidens beckii		0.30	0.50	0.90	1.70	18.75	2.80	21.55
Carex rostrata			23.80		23.80	12.50	12.57	25.07
Eleocharis palustris	1.00	0.80		1.00	2.70	37.50	1.43	38.93
	1.90	2.80	4.60	16.60	25.80	25.00	42.50	67.50
Elodea canadensis	1.40	18.20	8.30	2.70	30.60	25.00	50.41	75.41
Myriophyllum sp.	1.20				1.20	6.25	1.98	8.23
Phragmites communis	12.70			29.20	41.90	25.00	22.13	47.13
Potamogeton spirilis				T	T	6.25	0.00	6.25
P. zosteriformis				0.40	0.40	6.25	0.66	6.91
Scirpus validus	38.10				38.10	12.50	20.13	32.63
Sium sauve				0.30	0.30	6.25	0.45	6.70
Sparganium fluctuans				0.60	0.60	6.25	0.99	7.24
Typha latifolia		82.80			82.80	12.50	43.74	56.24
Biomass Totals 1982	51.80	83.60	23.80	30.20	189.30			
Biomass Totals 1983	4.50	21.30	13.40	21.50	60.70			
FLOATING-LEAF ZONE								
Bidens beckii			1.10		0.10	11.11	0.68	11.79
Ceratophyllum demersum			T		T	11.11	0.00	11.11
Elodea canadensis	T		0.20		0.20	20.00	0.24	20.24
	0.20	T			0.20	22.22	1.37	23.59
Najas flexilis			0.10		0.10	10.00	0.12	10.12
	T				T	11.11	0.00	11.11
Potamogeton gramineus	0.20				0.20	10.00	0.24	10.24
Sparganium fluctuans	29.70	16.80	18.90	17.40	82.80	40.00	97.76	137.76
	33.10	31.60	26.10	50.20	141.00	44.44	96.57	141.01
Vallisneria americana			1.20	0.20	1.40	10.00	1.65	21.65
Biomass Totals 1982	29.90	16.80	20.40	17.60	84.70			
Biomass Totals 1983	33.30	31.60	26.20	50.20	141.40			
SUBMERGED ZONE								
Najas flexilis	0.10		0.10		0.20	33.33	0.58	33.91
Vallisneria americana	Present in all quadrats				16.30	100.00	100.00	200.00
	8.90	7.60	8.10	9.70	34.30	66.66	99.42	165.08
Biomass Totals 1982					16.30			
Biomass Totals 1983	9.00	7.60	8.20	9.70	34.50			

BASIC STATISTICS

		Emergent Zone	Float-leaf Zone	Submerged Zone
Mean Biomass/Quadrat	1982	47.32	21.17	
	1983	15.17	35.34	8.61
Standard Deviation	1982	26.93	06.02	
	1983	08.05	10.37	00.91
Coef. of Variation	1982	56.90	28.42	
	1983	53.07	29.33	10.59

Appendix I. Study Site Location

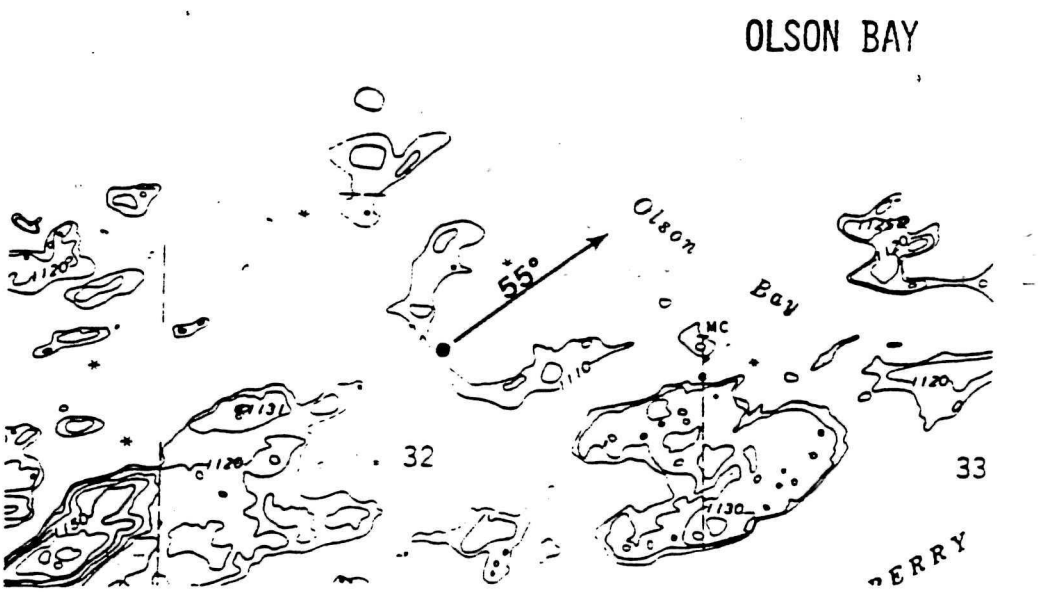
Rainy Lake, Olson Bay
R-21W, T-71N, SW1/4 NE1/4 S-32

Baseline heading: 55°. Site located at the "belly" of an unnamed, "U"-shaped island. Baseline origin is marked with a PVC pipe in the sand at the base of a Meadow willow clump adjacent to trail leading to a marsh area. Site has a classic off-shore bar about 15 m. from the shoreline.

Collection dates: August 13, 1982; July 30, 1983

Transect locations and characteristics

Zone	Dist. to shore	Depth	Bottom type
Emergent	40 m.	90 cm.	firm sand
Float-leaf	Absent at this site		
Submerged	62 m.	140 cm.	firm sand



Appendix I. Field data. Rainy Lake, Olson Bay.
For each species, 1982 data are on line one, 1983 data are on line two.

Zone/Species	Quadrat Number 1	2	3	4	Total	Rel. Freq.	Rel. Dom.	Imp. Value
EMERGENT ZONE								
Phragmites communis	14.20	5.80	43.00	19.70	82.70	44.44	61.03	105.47
	71.70	9.60	4.70	13.40	99.40	66.00	84.02	150.02
Scirpus acutus	13.00	9.10	6.60	23.90	52.60	44.44	38.82	83.26
		11.00		7.90	18.90	33.00	15.99	48.99
Vallisneria americana		0.20			0.20	11.11	0.14	11.25
Biomass Totals 1982	27.20	15.10	49.60	43.60	135.50			
Biomass Totals 1983	71.70	20.60	4.70	21.30	118.30			
FLOATING-LEAF ZONE								
Not distinguishable 1982								
Not distinguishable 1983								
SUBMERGED ZONE								
Potamogeton gramineus	4.30	4.60	6.40	3.80	19.20	100.00	100.00	200.00
	5.80	3.40	2.50	3.40	15.20	100.00	100.00	200.00
Biomass Totals 1982	4.30	4.60	6.40	3.80	19.20			
Biomass Totals 1983	5.80	3.40	2.50	3.40	15.20			

BASIC STATISTICS

		Emergent Zone	Float-leaf Zone	Submerged Zone
Mean Biomass/Quadrat	1982	33.88	No data	04.79
	1983	29.57	No data	03.80
Standard Deviation	1982	15.68	No data	01.12
	1983	29.12	No data	01.41
Coef. of Variation	1982	46.28	No data	23.46
	1983	98.48	No data	37.04

Appendix I. Study Site Location

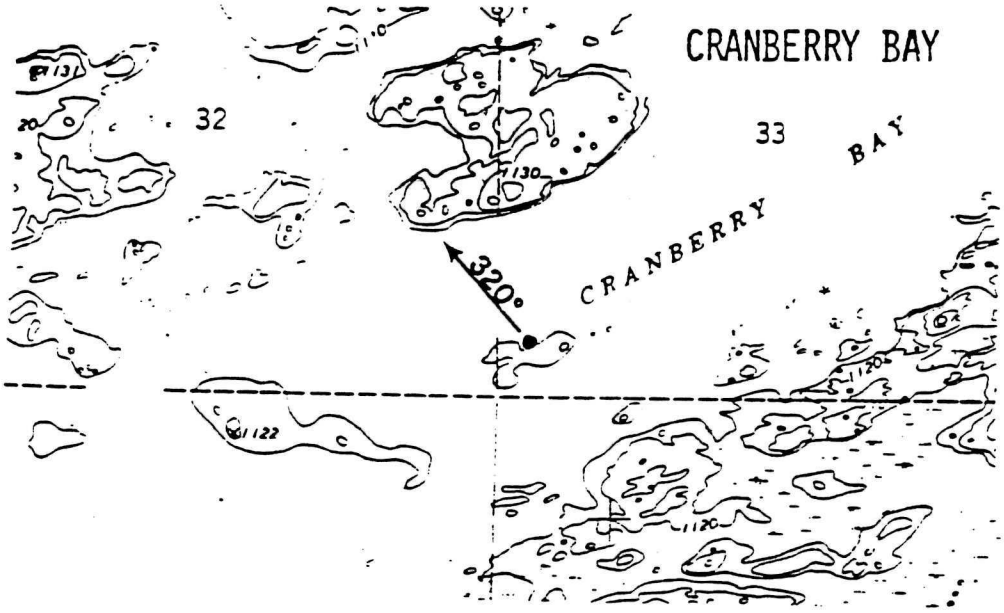
Rainy Lake, Cranberry Bay
R-21W, T-71N, SW1/4 SW1/4 S-33

Baseline heading: 320°. Site is located on an island west-southwest of a large, light-colored erratic. The island appears to be part of the mainland due to extensive marsh development. Baseline origin is marked by a metal pipe in the ground on the inland side of a long, low, rock outcrop which rises abruptly at the water's edge.

Collection dates: August 13, 1982; August 4, 1983.

Transect locations and characteristics

Zone	Dist. to shore	Depth	Bottom type
Emergent	12 m.	70 cm.	stone/silt
Float-leaf	27 m.	100 cm.	stone/silt
Submerged	45 m.	120 cm.	silt



Appendix I. Field data. Rainy Lake, Cranberry Bay. For each species, 1982 data are on line one, 1983 data are on line two.

Zone/Species	Quadrat Number 1	2	3	4	Total	Rel. Freq.	Rel. Dom.	Imp. Value
EMERGENT ZONE								
Eleocharis palustris	4.80	6.30	4.60	4.30	20.00	33.33	41.58	74.91
	3.90	6.30	6.80	4.20	21.20	50.00	79.70	129.70
Glyceria borealis	2.40	0.80			3.20	16.66	6.65	23.31
			1.00		1.00	12.50	3.76	16.26
Potamogeton gramineus	0.80	0.20		0.50	1.60	25.00	3.33	28.33
				1.80	1.80	12.50	6.77	19.27
Sagittaria sp.	0.30				0.30	8.33	0.62	8.95
			2.10	0.50	2.60	25.00	9.77	34.77
Scirpus validus			7.60	15.40	23.00	16.66	47.82	64.48
Biomass Totals 1982	8.30	7.30	12.20	20.20	48.00			
Biomass Totals 1983	3.90	6.30	9.90	6.50	26.50			
FLOATING-LEAF ZONE								
Elodea canadensis				0.20	0.20	10.00	6.06	16.06
Glyceria borealis			1.30	2.40	3.70	22.22	60.25	82.87
Najas flexilis	0.20	0.30	0.30	0.70	1.50	40.00	45.45	85.45
	0.40	0.30		0.30	1.00	33.33	16.39	49.72
Sparganium fluctuans			0.40		0.40	10.00	12.12	22.12
Vallisneria americana	0.30	0.30	0.10	0.60	1.20	40.00	36.36	76.36
	0.50	0.30	0.60	0.10	1.40	44.44	22.95	67.39
Biomass Total 1982	0.50	0.60	0.80	1.50	3.40			
Biomass Total 1983	0.90	0.60	1.90	2.80	6.10			
SUBMERGED ZONE								
Najas flexilis	0.10	T	T	T	0.10	40.00	3.13	43.13
Potamogeton gramineus	T	0.10			0.10	20.00	3.13	23.13
Vallisneria americana	1.00	2.40	0.80	1.10	5.30	100.00	100.00	200.00
	1.20	0.80	0.70	0.30	3.00	40.00	93.75	133.75
Biomass Total 1982	1.00	2.40	0.80	1.10	5.30			
Biomass Total 1983	1.30	0.90	0.70	0.30	3.20			

BASIC STATISTICS

		Emergent Zone	Floating-Leaf Zone	Submerged Zone
Mean Biomass/Quadrat	1982	12.00	00.82	01.32
	1983	06.62	00.35	00.80
Standard Deviation	1982	05.86	00.41	00.72
	1983	02.47	00.22	00.43
Coef. of Variation	1982	48.84	49.34	54.63
	1983	37.29	61.91	53.90

Appendix I. Study Site Location

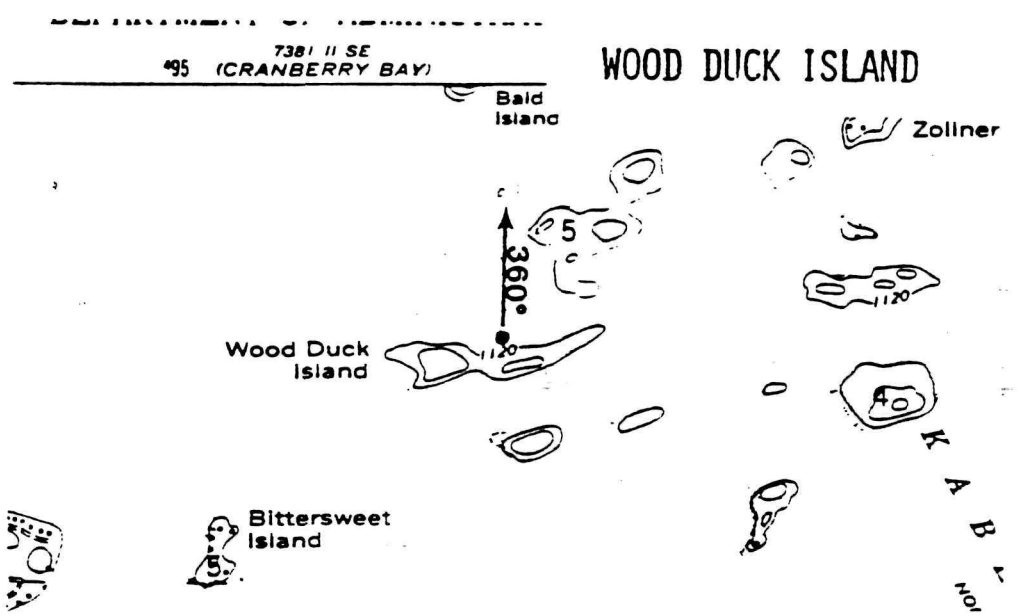
Kabetogama Lake, Wood Duck Island
R-21W, T-69N, NW1/4 SE1/4 S-5

Baseline heading: 360°. Baseline origin is marked by a large spike in a 30 cm. dbh Green ash. An 80 cm. dbh Silver maple occurs 4 m. to the east. There is a large rock on the shore at this site.

Collection dates: August 19, 1982; August 1, 1983.

Transect location and characteristics

Zone	Dist. to shore	Depth	Bottom type
Emergent	9 m.	65 cm.	stone/sand/detritus
Float-leaf	Absent at this site		
Submerged	33 m.	170 cm.	stone/silt



Appendix I. Field data. Kabetogama Lake, Wood Duck Island
For each species, 1982 data are on line one, 1983 data are on line two.

Zone/Species	Quadrat Number 1	2	3	4	Total	Rel. Freq.	Rel. Dom.	Imp. Value
EMERGENT ZONE								
Carex atherodes	74.30	14.30		54.20	142.80	42.86	53.48	96.34
	12.30	43.30			55.60	25.00	29.10	54.10
Potamogeton richardsonii				0.10	0.10	12.50	0.05	12.55
P. spirilis		T			T	12.50	0.00	12.50
Scirpus fluviatilis	44.40	32.80	39.90	7.10	124.20	57.14	46.51	103.65
	24.60	13.60	36.00	34.00	135.20	50.00	70.79	120.79
Biomass Totals 1982	118.70	47.10	39.90	61.30	267.00			
Biomass Totals 1983	36.90	56.90	63.00	34.10	190.90			
FLOATING LEAF ZONE								
Not distinguishable 1982								
Not distinguishable 1983								
SUBMERGED ZONE								
Myriophyllum sp.	0.20	1.20	0.10	0.50	2.00	50.00	9.70	59.70
	3.00				3.00	7.70	9.70	17.40
Najas flexilis			0.90	1.20	2.10	15.38	6.80	22.18
Potamogeton richardsonii	2.70	4.70	6.40	4.80	18.60	50.00	90.29	140.29
	6.40	11.80	0.40	2.20	20.70	30.77	66.99	97.76
P. spirilis	1.50	2.90	0.30	0.20	5.00	30.77	16.18	46.95
Biomass Totals 1982	2.90	5.90	6.50	5.30	20.60			
Biomass Totals 1983	10.90	14.70	1.60	3.60	30.80			

BASIC STATISTICS

		Emergent Zone	Floating-Leaf Zone	Submerged Zone
Mean Biomass/Quadrat	1982	66.75	No data	05.14
	1983	47.73	No data	07.70
Standard Deviation	1982	35.57	No data	01.56
	1983	14.39	No data	06.15
Coef. of Variation	1982	53.57	No data	30.39
	1983	30.14	No data	79.89

Appendix I. Study Site Location

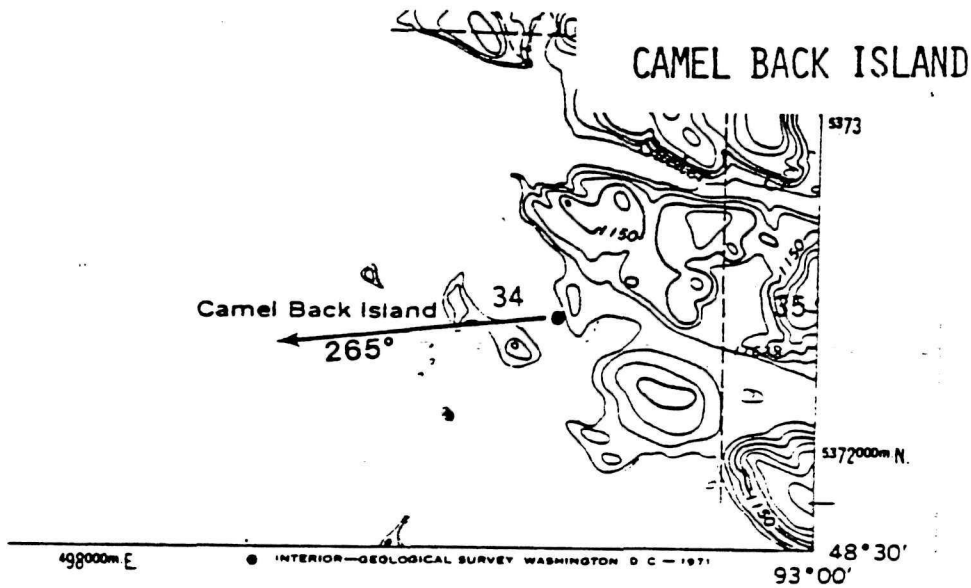
Kabetogama Lake, Camel Back Island
R-21W, T-70N, NW1/4 SE1/4 S-34

Baseline heading: 265°. Baseline originates on Kabetogama Peninsula, northeast of the south end of Camel Back Island. Origin is marked by a stake in the sand on an ice-ridge.

Collection dates: August 18, 1982; August 1, 1983.

Transect locations and characteristics

Zone	Dist. to shore	Depth	Bottom type
Emergent	3 m.	50 cm.	sand
Float-leaf	Absent at this site		
Submerged	24 m.	135 cm.	silt



Appendix I. Field data. Kabetogama Lake, Camel Back Island. For each species, 1982 data are on line one, 1983 data are on line two.

Zone/Species	Quadrat Number 1	2	3	4	Total	Rel. Freq.	Rel. Dom.	Imp. Value
EMERGENT ZONE								
Myriophyllum sp.	0.90				0.90	14.29	0.21	14.50
Scirpus acutus		5.40			5.40	14.29	1.23	15.52
S. fluviatilis	1.10				1.10	14.29	0.25	14.54
Typha latifolia	13.80	3.30	58.50	27.20	102.80	100.00	100.00	200.00
	41.20	135.30	126.50	128.30	431.30	57.14	98.31	155.45
Biomass Totals 1982	13.80	3.30	58.50	27.20	102.80			
Biomass Totals 1983	43.20	140.70	126.50	128.30	438.70			
FLOATING-LEAF ZONE								
Not distinguishable 1982								
Not distinguishable 1983								
SUBMERGED ZONE								
Callitriche verna		T	T		T	15.38		15.38
Myriophyllum sp.	7.90	13.90	18.50	14.40	54.70	30.77	98.03	128.80
	7.00	34.30	2.90	8.90	53.10	33.33	43.63	77.99
Najas flexilis		T		0.10	0.10	15.38	0.18	15.56
	8.40	7.10	17.50	34.70	67.70	33.33	55.62	88.95
Potamogeton gramineus		T	0.10		0.10	15.38	0.18	15.56
P. richardsonii			0.60		0.60	7.70	1.08	8.78
	0.10			T	0.20	16.66	0.16	16.82
Potamogeton sp.				0.10	0.10	7.70	0.18	7.88
Ranunculus circinatus			T		T	7.70		7.70
Ranunculus sp.	0.50			0.20	0.70	16.66	0.58	17.24
Biomass Totals 1982	7.90	13.90	19.20	14.60	55.60			
Biomass Totals 1983	16.00	41.40	20.40	43.80	121.60			

BASIC STATISTICS

		Emergent Zone	Floating-Leaf Zone	Submerged Zone
Mean Biomass/Quadrat	1982	25.70	No data	13.90
	1983	109.68	No data	34.28
Standard Deviation	1982	23.95	No data	04.63
	1983	44.75	No data	10.69
Coef. of Variation	1982	93.21	No data	33.35
	1983	40.80	No data	31.19

Appendix I. Study Site Location

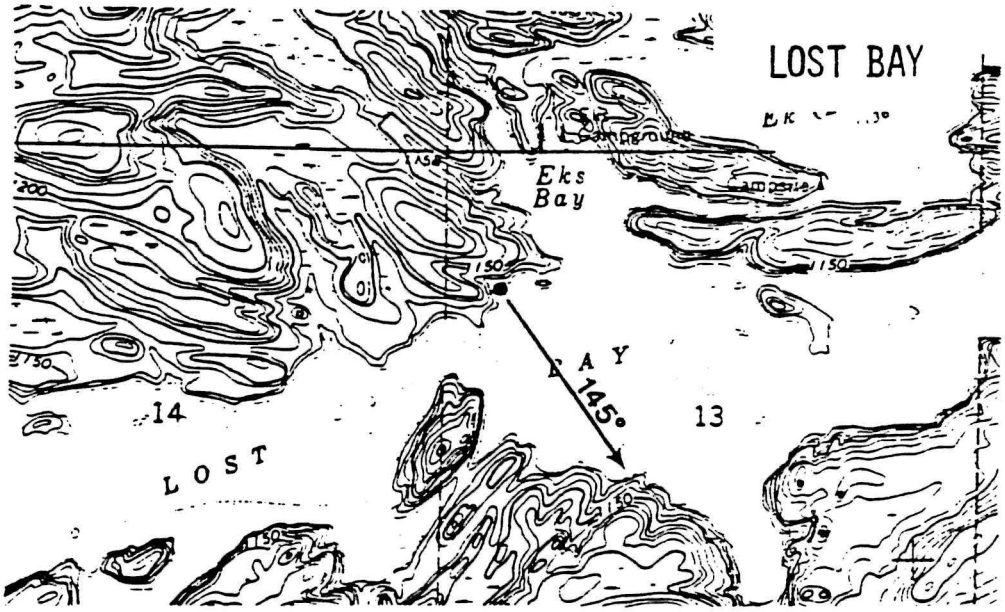
Kabetogama Lake, Lost Bay
R-20W, T-69N, SW1/4 NW1/4 S-13

Baseline heading: 145°. Baseline originates on Kabetogama Peninsula at the west of end of a small bay just west of Eks Bay. Origin is marked by a spike near the base of 25 cm. dbh White spruce.

Collection dates: August 19, 1982; August 2, 1983.

Transect locations and characteristics

Zone	Dist. to shore	Depth	Bottom type
Emergent	5 m.	60 cm.	stone/silt
Float-leaf	12 m.	140 cm.	stone/silt
Submerged	24 m.	240 cm.	sand



Appendix I. Field data. Kabetogama Lake, Lost Bay. For each species, 1982 data are on line one, 1983 data are on line two.

Zone/Species	Quadrat Number 1	2	3	4	Total	Rel. Freq.	Rel. Dom.	Imp. Value
EMERGENT ZONE								
Carex atherodes			42.30		42.30	8.33	32.69	41.02
	163.50	32.70	23.20	59.00	278.40	44.44	66.71	111.15
Carex sp.	0.20			5.40	5.60	16.66	4.32	20.98
Elodea canadensis				T	T	8.33	0.00	8.33
Myriophyllum sp.			T	0.10	0.10	16.66	0.07	16.73
Najas flexilis			T	0.50	0.50	16.66	0.38	17.04
Potamogeton spirilis			T	T	0.10	22.22	0.02	22.24
Scirpus fluviatilis	25.80	32.00	21.10	1.80	80.80	33.33	62.44	95.77
	15.10	91.10		32.60	138.80	33.33	33.26	66.59
Biomass Totals 1982	26.00	32.00	63.50	7.80	129.40			
Biomass Totals 1983	178.60	123.80	23.20	91.60	417.20			
FLOATING-LEAF ZONE								
Callitriche verna	0.10				0.10	10.00	1.10	11.10
Myriophyllum sp.	0.30			0.10	0.40	20.00	4.44	24.44
Najas flexilis	0.40		0.80	0.50	1.70	30.00	18.90	48.90
Potamogeton richardsonii	1.00				1.00	10.00	11.11	21.11
P. zosteriformis	0.10				0.10	10.00	1.10	11.10
Ranunculus circinatus	2.40		3.30	5.70	20.00	63.33	83.33	
Biomass Totals 1982	4.30		0.80	3.90	9.00			
Not distinguishable 1983								
SUBMERGED ZONE								
Elodea canadensis	0.50				0.50	8.33	0.37	8.70
Myriophyllum sp.	31.40	26.60	42.50	18.70	119.20	33.33	87.07	120.40
	8.20	4.20	2.90	5.90	21.20	50.00	83.46	133.46
Najas flexilis		0.20			0.20	8.33	0.15	8.48
			T		T	12.50	0.00	12.50
Potamogeton sp.	T				T	8.33	0.00	8.33
P. zosteriformis	0.40	3.20	6.60	6.60	16.80	33.33	12.27	45.60
	0.10	2.90		1.10	4.10	32.50	16.14	53.64
Ranunculus circinatus				T	T	8.33	0.00	8.33
Biomass Totals 1982	32.20	30.00	49.10	25.30	136.90			
Biomass Totals 1983	8.30	7.10	2.90	7.00	25.40			

BASIC STATISTICS

		Emergent Zone	Floating-Leaf Zone	Submerged Zone
Mean Biomass/Quadrat	1982	32.35	02.25	34.22
	1983	104.31	No data	06.35
Standard Deviation	1982	23.16	02.16	10.33
	1983	64.89	No data	02.36
Coef. of Variation	1982	71.60	96.16	30.19
	1983	62.21	No data	37.26

Appendix I. Study Site Location

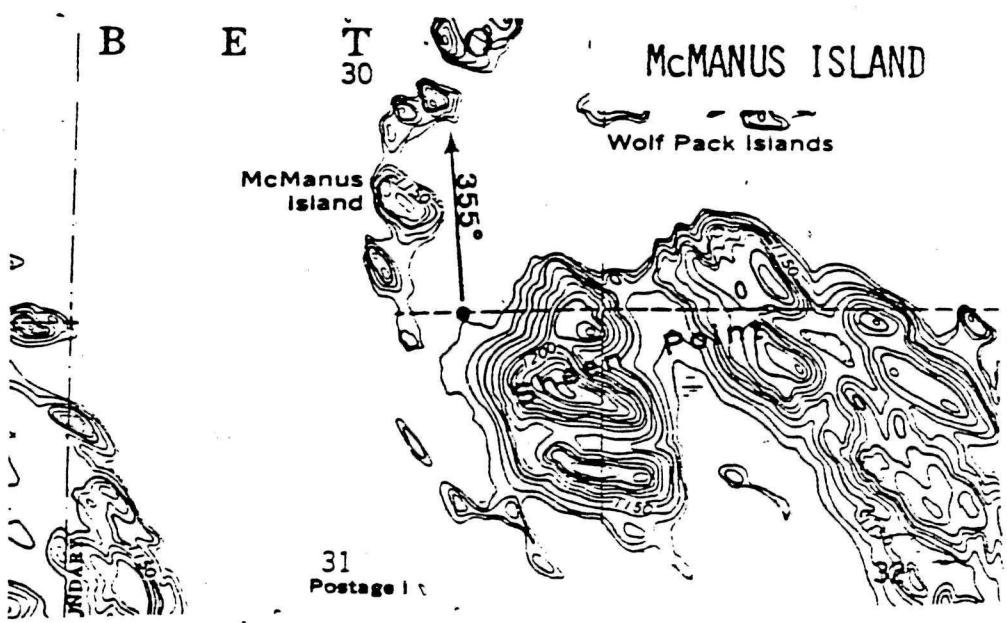
Namakan Lake, McManus Island
R-18W, T-69N, NW1/4 NW1/4 S-31

Baseline heading: 355°. Baseline originates on Sheen Point and is marked by a section of PVC placed about 3 m. from the end of a short sandbar projecting into the channel from Sheen Point.

Collection dates: August 17, 1982; July 31, 1983.

Transect locations and characteristics

Zone	Dist. to shore	Depth	Bottom type
Emergent	4 m.	40 cm.	sand/silt
Float-leaf	14 m.	60 cm.	soft silt
Submerged	33 m.	110 cm.	soft silt



Appendix I. Field data. Namakan Lake, McManus Island. For each species, 1982 data are on line one, 1983 data are on line two.

Zone/Species	Quadrat Number 1	2	3	4	Total	Rel. Freq.	Rel. Dom.	Imp. Value
EMERGENT ZONE								
Carex rostrata		26.20	1.20	21.50	48.90	37.50	63.50	101.00
	30.40	9.00		6.40	45.80	27.27	62.91	90.18
Eleocharis palustris		2.20		5.40	7.60	25.00	9.87	34.87
	0.20	1.50		7.90	9.70	27.27	13.32	40.59
Glyceria borealis			8.60		8.60	9.09	11.81	20.90
Najas flexilis			T		T	12.50	0.00	12.50
		T			T	9.09	0.00	9.09
Scirpus fluviatilis	15.80	4.60			20.40	25.00	26.49	51.49
	2.50	3.30		2.80	8.60	27.27	11.81	39.08
Biomass Totals 1982	15.80	33.00	1.20	26.90	77.00			
Biomass Totals 1983	33.10	13.80	8.60	17.10	72.70			
FLOATING-LEAF ZONE								
Carex rostrata			5.90		5.90	20.00	42.14	62.14
Eleocharis palustris			0.60		0.60	20.00	4.28	24.28
Glyceria borealis	1.60	11.30			12.90	40.00	96.99	136.99
	5.10	1.70			6.80	40.00	48.57	88.57
Najas flexilis			T		T	20.00	0.00	20.00
Potamogeton gramineus			0.20	0.10	0.30	40.00	2.25	42.25
Scirpus fluviatilis				0.70	0.70	20.00	5.00	25.00
Biomass Totals 1982	1.60	11.30	0.20	0.10	13.20			
Biomass Totals 1983	5.10	1.70	6.50	0.70	13.90			
SUBMERGED ZONE								
Najas flexilis	0.20	0.30	0.10	T	0.50	66.66	83.33	149.99
Potamogeton gramineus	0.10			0.10	0.10	33.33	16.66	49.99
Biomass Totals 1982	0.30	0.30	0.10	0.10	0.60			
Biomass Totals 1983	No plant in quadrats							

BASIC STATISTICS

		Emergent Zone	Floating-Leaf Zone	Submerged Zone
Mean Biomass/Quadrat	1982	19.24	03.29	00.16
	1983	18.17	03.48	No data
Standard Deviation	1982	13.94	05.38	00.09
	1983	10.57	03.24	93.09
Coef. of Variation	1982	72.46	163.75	55.44
	1983	58.15	93.09	No data

Appendix I. Study Site Location

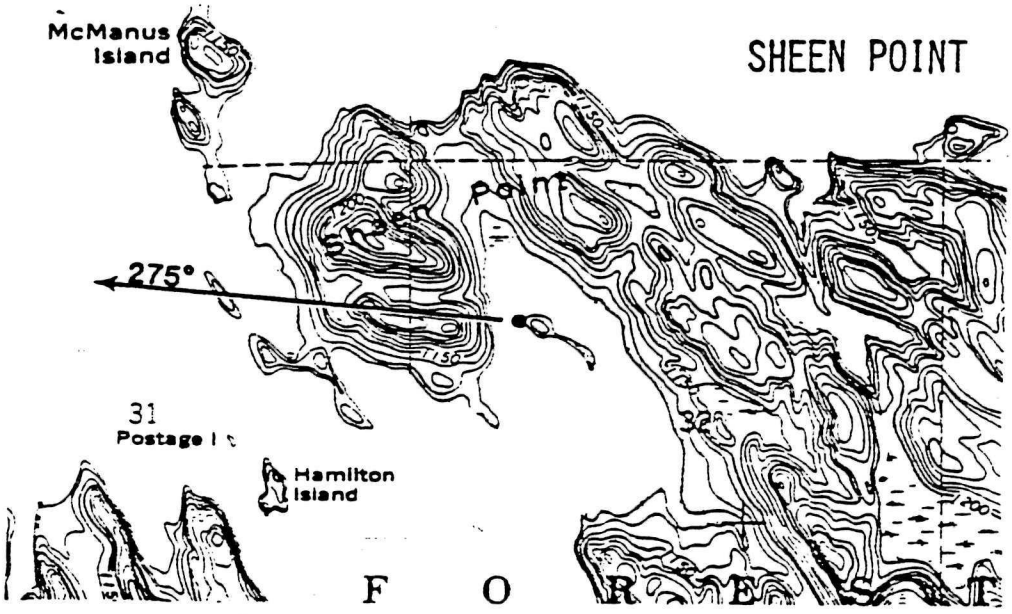
Namakan Lake, Sheen Point
R-18W, T-69N, SW1/4 NW1/4 S-32

Baseline heading: 275°. Baseline originates near the west tip of a small, unnamed island "enclosed" by the arc of Sheen Point. Origin marked by a stake at the base of a clump of Pussy willow.

Collection dates: August 17, 1982; August 3, 1983.

Transect locations and characteristics

Zone	Dist. to shore	Depth	Bottom type
Emergent	4 m.	20 cm.	silt/detritus
Float-leaf	Absent at the site		
Submerged	20 m.	150 cm.	soft silt



Appendix I. Field data. Namakan Lake, Sheen Point. For each species, 1982 data are on line one, 1983 data are on line two.

Zone/Species	Quadrat Number 1	2	3	4	Total	Rel. Freq.	Rel. Dom.	Imp. Value
EMERGENT ZONE								
Alopecurus aequalis		0.70	1.60	0.20	2.50	20.00	1.32	21.32
Cardamine sp.		0.40			0.40	6.60	0.21	6.81
Carex rostrata	11.11	44.80	55.70	37.80	149.40	26.66	79.05	105.71
	37.90	38.30	55.10	46.30	177.60	23.53	69.65	93.18
Eleocharis palustris	1.90				1.90	5.90	0.74	6.64
Glyceria borealis	0.80	1.60	0.30		2.60	17.64	1.02	18.66
Poa pratensis			1.50	0.50	1.90	11.76	0.74	12.50
Polygonum coccineum				2.20	2.20	5.90	0.86	6.76
P. natans	1.20				1.20	6.60	0.63	7.23
P. punctatum	17.00	13.40	1.00		31.40	20.00	16.61	36.61
Potamogeton vaseyi				T	T	5.90	0.00	5.90
Scirpus cyperinus			67.90		67.90	5.90	26.63	32.53
Scirpus sp.			0.70	2.70	3.40	13.33	1.80	15.13
Sium sauve		0.70			0.70	6.60	0.37	6.97
	0.10	0.40	0.20	T	0.80	23.53	0.31	23.84
Biomass Totals 1982	29.30	60.00	59.00	40.70	189.10			
Biomass Totals 1983	40.70	40.30	125.00	49.00	254.90			
FLOATING-LEAF ZONE								
Glyceria borealis			5.60	6.30	11.90	14.28	72.56	86.84
Najas flexilis		0.10	0.90	1.10	2.00	21.43	12.20	33.45
Potamogeton gramineus	0.10	0.10	1.10	0.90	2.30	28.57	14.02	42.59
P. spirilis			0.10	0.10	0.10	14.28	0.60	14.68
P. vaseyi		T	0.10	T	0.10	21.43	0.60	22.03
Biomass Totals 1982	Not distinguishable							
Biomass Totals 1983	0.10	0.20	7.80	8.40	16.40			
SUBMERGED ZONE								
Elodea canadensis		0.90	T		0.90	15.38	2.44	17.82
Najas flexilis	2.10	10.10	11.30	3.70	27.20	30.77	73.71	104.48
	1.70	T	0.10	T	1.80	50.00	22.50	72.50
Potamogeton gramineus	0.60	0.90	2.10	4.90	8.50	30.77	23.04	53.81
	2.20	0.20	1.80	2.00	6.20	50.00	77.50	127.50
P. spirilis			0.20		0.20	7.70	0.54	8.24
P. vaseyi		0.10		T	0.10	15.38	0.27	15.65
Biomass Totals 1982	2.70	12.00	13.60	8.60	37.00			
Biomass Totals 1983	3.90	0.20	1.90	2.00	8.00			

BASIC STATISTICS

		Emergent Zone	Floating-Leaf Zone	Submerged Zone
Mean Biomass/Quadrat	1982	47.27	No data	09.25
	1983	63.73	04.10	02.00
Standard Deviation	1982	14.92	No data	04.48
	1983	40.99	04.58	01.45
Coef. of Variation	1982	31.57	No data	52.32
	1983	64.33	111.52	72.82

Appendix I. Study Site Location

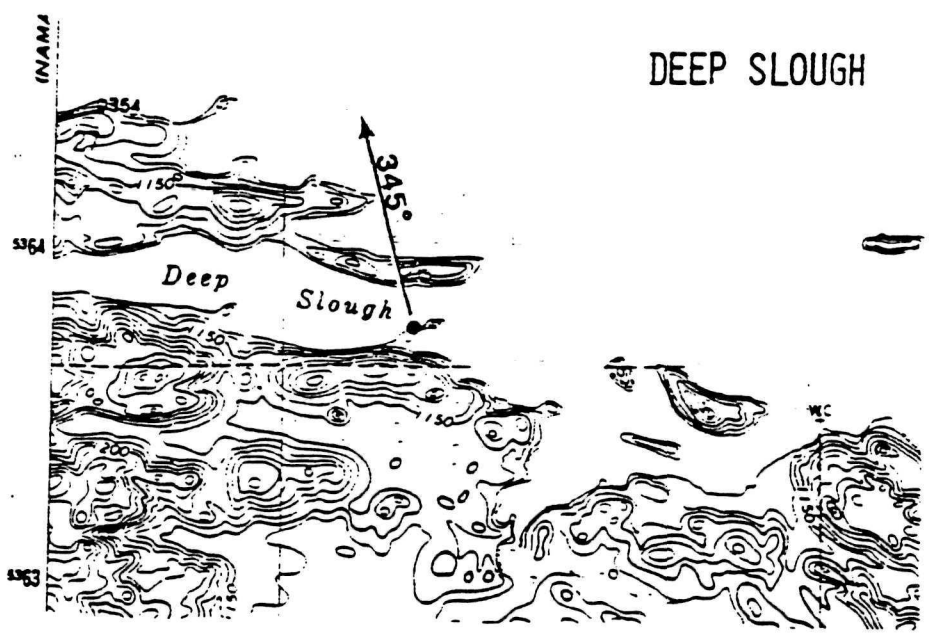
Namakan Lake, Deep Slough
R-18W, T-69N, SW1/4 SW1/4 S-26

Baseline heading: 345°. Baseline originates on the sandbar on the south side of the mouth of Deep Slough. Baseline origin is marked by a stake in a clump of Beaked willow. A small Jack pine can be seen about 3 m. away.

Collection dates: August 17, 1982; August 3, 1983.
Note: A large cabin cruiser was anchored on this site during early August, 1983. There was substantial disturbance in the zone of emergent macrophytes. Collections of 1983, therefore, include only submerged macrophytes.

Transect locations and characteristics

Zone	Dist. to shore	Depth	Bottom type
Emergent	5 m.	60 cm.	sand/detritus
Float-leaf	Absent at this site		
Submerged	18 m.	175 cm.	soft silt



Appendix I. Field data. Namakan Lake, Deep Slough. For each species, 1982 data are on line one, 1983 data are on line two.

Zone/Species	Quadrat Number 1	2	3	4	Total	Rel. Freq.	Rel. Dom.	Imp. Value
EMERGENT ZONE								
Carex rostrata	41.20	40.80	66.00	2.60	150.60	40.00	68.58	108.58
Eleocharis palustris	0.80	38.00	13.30	3.10	55.20	40.00	25.14	65.14
Glyceria borealis	0.80		13.00	13.80	20.00	6.28	26.28	
Biomass Totals 1982	42.80	78.80	92.30	5.70	219.60			
Biomass Totals 1983	Site damaged:		No data					
FLOATING-LEAF ZONE								
Not distinguishable 1982								
Not distinguishable 1983								
SUBMERGED ZONE								
Elodea canadensis		0.10	T	0.20	0.30	25.00	0.84	25.84
Myriophyllum sp.			0.70		0.70	8.33	1.97	10.30
Najas flexilis	0.20	T	0.10		0.30	25.00	0.84	25.84
Potamogeton richardsonii		0.90			0.90	8.33	2.54	10.87
Vallisneria americana	7.00	7.90	10.80	7.60	33.30	33.33	93.80	127.13
	11.20	8.00	5.70	15.70	40.60	100.00	100.00	200.00
Biomass Totals 1982	7.20	8.90	11.60	7.80	35.50			
Biomass Totals 1983	11.20	8.00	5.70	15.70	40.60			

BASIC STATISTICS

		Emergent Zone	Floating-Leaf Zone	Submerged Zone
Mean Biomass/Quadrat	1982	54.89	No data	08.87
	1983	No data	No data	10.15
Standard Deviation	1982	38.90	No data	02.45
	1983	No data	No data	04.33
Coef. of Variation	1982	70.87	No data	27.60
	1983	No data	No data	42.69

Appendix I. Study Site Location

Sand Point Lake, Grassy Bay
R-17W, T-68N, NE1/4 NE1/4 S-8

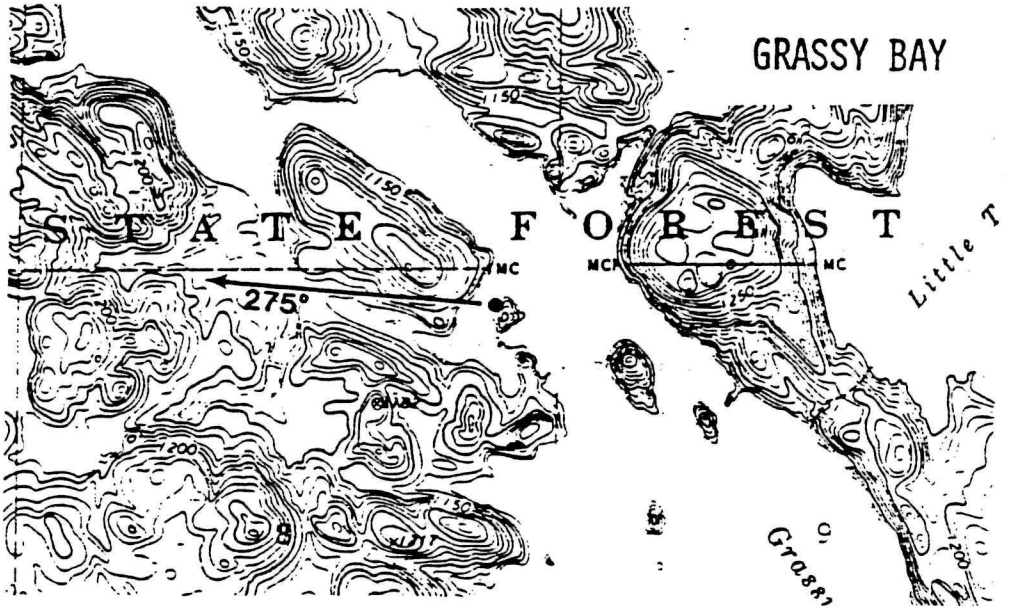
Baseline heading: 275°. Baseline origin is marked by a PVC pipe in soil at the base of an 8 cm. dbh White Pine.

Collection dates: August 15, 1982; Sugust 5, 1983.

Note: Because of substantial but inexplicable changes in littoral zone structure at this site, transect placement was further from shore and in deeper water in 1983 than in 1982.

Transect locations and characteristics

Zone	Dist. to shore		Depth (cm.)		Bottom type
	1982	1983	1982	1983	
Emergent	3 m.	4 m.	35	50	soft silt
Float-leaf	8 m.	10 m.	90	120	soft silt
Submerged	15 m.	30 m.	180	240	soft silt



Appendix I. Field data. Sand Point Lake, Grassy Bay. For each species, 1982 data are on line one, 1983 data are on line two.

Zone/Species	Quadrat Number 1	2	3	4	Total	Rel. Freq.	Rel. Dom.	Imp. Value
EMERGENT ZONE								
Carex rostrata	22.60	17.30	45.80	9.70	95.40	44.44	75.18	119.62
Carex sp.	4.90		6.50	8.00	19.40	27.27	31.19	58.46
Eleocharis palustris	9.40	5.80	11.00	4.70	30.90	44.44	24.35	68.79
	4.30	1.30	9.00	14.20	28.80	36.36	46.30	82.66
Glyceria borealis		0.60			0.60	11.11	0.47	11.58
	2.70	8.90		2.30	13.90	27.27	22.35	49.62
Myriophyllum sp.	0.10				0.10	9.09	0.16	9.25
Biomass Totals 1982	32.00	23.70	56.80	14.40	127.00			
Biomass Totals 1983	12.00	10.20	15.50	24.50	62.20			
FLOATING-LEAF ZONE								
Glyceria borealis		0.40	0.10	0.90	1.30	23.08	5.94	29.02
Najas flexilis	1.50	1.30	3.10	0.60	6.50	30.77	29.68	60.45
	0.20	0.20	0.20		0.60	42.86	14.28	58.14
Potamogeton gramineus	2.20	2.70	3.50	5.40	13.90	30.77	63.47	94.24
	0.80	1.50	1.30		3.60	42.86	85.71	128.57
P. spirilis		T			T	7.70	0.00	7.70
			T		T	14.29	0.00	14.29
Potamogetan sp.				T	T	7.70	0.00	7.70
Biomass Totals 1982	3.70	4.40	6.70	6.90	21.70			
Biomass Totals 1983	1.00	1.70	1.50		4.20			
SUBMERGED ZONE								
Bidens beckii		T	0.20		0.20	9.52	1.09	10.61
Callitriche verna	T	T				0.10	9.52	0.54
Ceratophyllum demersum	0.80	1.20	0.30		2.40	25.00	13.40	38.40
	2.90	1.10	6.20	5.40	15.70	19.05	85.33	104.38
Myriophyllum sp.	T		T	T	0.10	14.29	0.54	14.83
Najas flexilis		1.00	0.60	3.00	4.60	25.00	25.70	50.70
	0.40	0.10	0.40	0.20	1.20	19.05	6.52	25.57
Potamogeton gramineus	5.30	3.10	0.10	2.20	10.70	33.33	59.78	93.11
Potamogeton sp.			0.10		0.10	8.33	0.56	8.89
	0.20	0.20	0.10	0.10	0.70	19.05	3.80	22.85
Utricularia vulgaris		0.40		T	0.40	9.52	2.17	11.67
Vallisneria americana		0.10			0.10	8.33	0.56	8.89
Biomass Totals 1982	6.10	5.40	1.10	5.20	17.90			
Biomass Totals 1983	3.50	1.80	6.90	5.70	18.30			

BASIC STATISTICS

		Emergent Zone	Floating-Leaf Zone	Submerged Zone
Mean Biomass/Quadrat	1982	31.75	05.42	04.47
	1983	15.54	01.05	04.57
Standard Deviation	1982	18.18	01.61	02.21
	1983	06.36	00.77	02.25
Coef. of Variation	1982	57.27	29.66	49.51
	1983	40.90	72.74	49.26

Appendix I. Study site location

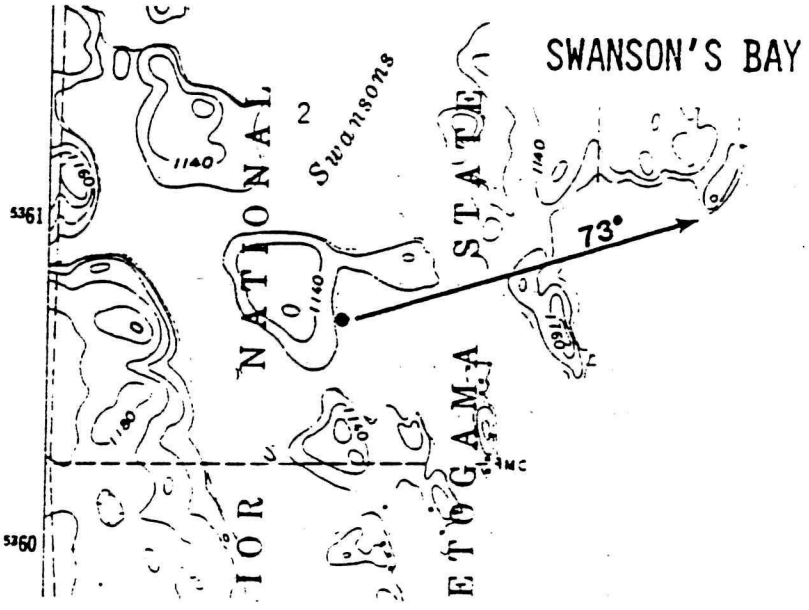
Sand Point Lake, Swanson's Bay
R-17W, T-68N, NE1/4 SW1/4 S-2

Baseline heading: 73°. Baseline origin is marked with metal pipe in soil at base of small Green ash about 4.5 m. from shore. A Jack pine 30 cm. dbh is located about 10 m. inland from the baseline marker.

Collection dates: August 15, 1982; August 5, 1983.

Transect locations and characteristics

Zone	Dist. to shore	Depth	Bottom type
Emergent	9 m.	65 cm.	clay
Float-leaf	Absent at this site		
Submerged	20 m.	95 cm.	clay



Appendix I. Field data. Sand Point Lake, Swanson's Bay. For each species, 1982 data are on line one, 1983 data are on line two.

Zone/Species	Quadrat Number 1	2	3	4	Total	Rel. Freq.	Rel. Dom.	Imp. Value
EMERGENT ZONE								
Glyceria borealis	6.80		2.60		9.30	40.00	21.04	61.04
Potamogeton gramineus			1.30		1.30	20.00	3.19	23.19
Scirpus fluviatilis	6.40	18.50		10.00	34.90	60.00	78.96	138.96
	4.10	3.00	26.40	6.00	39.40	80.00	96.80	176.80
Biomass Totals 1982	13.20	18.50	2.60	10.00	44.20			
Biomass Totals 1983	4.10	3.00	27.70	6.00	40.70			
FLOATING-LEAF ZONE								
Not distinguishable 1982								
Not distinguishable 1983								
SUBMERGED ZONE								
Najas flexilis		0.20	0.20		0.40	33.33	3.57	36.90
	T	0.40	0.50	0.10	1.10	33.33	29.73	63.06
Potamogeton gramineus	0.50	4.10	5.30	1.00	10.80	66.66	96.43	136.09
	T	1.20	0.80	0.10	2.20	33.33	59.46	92.79
P. spirilis	0.10	T	T	0.20	0.40	33.33	10.81	44.14
Biomass Totals 1982	0.50	4.30	5.50	1.00	11.20			
Biomass Totals 1983	0.10	1.60	1.30	0.40	3.70			

BASIC STATISTICS

		Emergent Zone	Floating-Leaf Zone	Submerged Zone
Mean Biomass/Quadrat	1982	11.06	No data	02.80
	1983	10.18	No data	00.91
Standard Deviation	1982	06.66	No data	02.45
	1983	11.74	No data	00.73
Coef. of Variation	1982	60.25	No data	87.46
	1983	115.23	No data	79.40

APPENDIX II

Matrices of values for Morisita's Index of Community Similarity for all possible pairs of populations sampled during the same year (1982 or 1983) and occurring in the same zone of macrophytes (emergent, floating-leaf, or submerged).

MORISITA'S INDEX OF SIMILARITY FOR EMERGENT DATA FOR 1982

	1	2	3	4	5	6	7	8	9	10	11
1	1.00										
2	0.33	1.00									
3	0.29	0.00	1.00								
4	0.00	0.00	0.00	1.00							
5	0.67	0.00	0.00	0.00	1.00						
6	0.00	0.00	0.00	0.93	0.00	1.00					
7	0.21	0.00	0.09	0.25	0.00	0.34	1.00				
8	0.21	0.00	0.00	0.00	0.00	0.00	0.88	1.00			
9	0.22	0.00	0.23	0.00	0.00	0.00	0.90	0.91	1.00		
10	0.21	0.00	0.20	0.00	0.00	0.00	0.91	0.93	0.99	1.00	
11	0.00	0.00	0.03	0.63	0.00	0.85	0.36	0.00	0.02	0.00	1.00

1. DOVE BAY EMERGENTS 82
2. OLSON BAY EMERGENTS 82
3. CRANBERRY BAY EMERGENTS 82
4. WOOD DUCK ISLAND EMERGENTS 82
5. CAMEL BACK ISLAND EMERGENTS 82
6. LOST BAY EMERGENTS 82
7. MCMANUS ISLAND EMERGENTS 82
8. SHEEN POINT EMERGENTS 82
9. DEEP SLOUGH EMERGENTS 82
10. GRASSY BAY EMERGENTS 82
11. SWANSON'S BAY EMERGENTS 82

MORISITA'S INDEX OF SIMILARITY FOR EMERGENT DATA FOR 1983

	1	2	3	4	5	6	7	8	9	10	11
1	1.00										
2	0.00	1.00									
3	0.62	0.00	1.00								
4	0.00	0.00	0.00	1.00							
5	0.00	0.00	0.00	0.00	1.00						
6	0.00	0.00	0.00	0.75	0.00	1.00					
7	0.13	0.00	0.20	0.16	0.00	0.08	1.00				
8	0.01	0.00	0.01	0.00	0.00	0.00	0.88	1.00			
9	NA	NA	NA	NA	NA	NA	NA	NA	NA		
10	0.49	0.00	0.75	0.00	0.00	0.00	0.22	0.01	NA	1.00	
11	0.00	0.00	0.00	0.90	0.00	0.43	0.17	0.00	NA	0.00	1.00

1. DOVE BAY EMERGENTS 83
2. OLSON BAY EMERGENTS 83
3. CRANBERRY BAY EMERGENTS 83
4. WOOD DUCK ISLAND EMERGENTS 83
5. CAMEL BACK ISLAND EMERGENTS 83
6. LOST BAY EMERGENTS 83
7. MCMANUS ISLAND EMERGENTS 83
8. SHEEN POINT EMERGENTS 83
9. DEEP SLOUGH EMERGENTS 83
10. GRASSY BAY EMERGENTS 83
11. SWANSON'S BAY EMERGENTS 83

MORISITA'S INDEX OF SIMILARITY FOR THE FLOAT-LEAF SPECIES FOR 1982

	1	2	3	4	5	6	7	8	9	10	11
1	1.00										
2	NA	NA									
3	0.19	NA	1.00								
4	NA	NA	NA	NA							
5	NA	NA	NA	NA	NA						
6	0.00	NA	0.22	NA	NA	1.00					
7	0.00	NA	0.01	NA	NA	0.00	1.00				
8	NA	NA	NA	NA	NA	NA	NA	NA			
9	NA	NA	NA	NA	NA	NA	NA	NA	NA		
10	0.00	NA	0.33	NA	NA	0.12	0.10	NA	NA	1.00	
11	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

1. DOVE BAY FLOAT LEAF 82
2. OLSON BAY FLOAT LEAF 82
3. CRANBERRY BAY FLOAT LEAF 82
4. WOOD DUCK ISLAND FLOAT LEAF 82
5. CAMEL BACK ISLAND FLOAT LEAF 82
6. LOST BAY FLOAT LEAF 82
7. MCMANUS ISLAND FLOAT LEAF 82
8. SHEEN POINT FLOAT LEAF 82
9. DEEP SLOUGH FLOAT LEAF 82
10. GRASSY BAY FLOAT LEAF 82
11. SWANSON'S BAY FLOAT LEAF 82

MORISITA'S INDEX OF SIMILARITY FOR THE FLOAT LEAF SPECIES FOR 1983

	1	2	3	4	5	6	7	8	9	10	11
1	1.00										
2	NA	NA									
3	0.00	NA	1.00								
4	NA	NA	NA	NA							
5	NA	NA	NA	NA	NA						
6	NA	NA	NA	NA	NA	NA					
7	0.00	NA	0.69	NA	NA	NA	1.00				
8	0.00	NA	0.92	NA	NA	NA	0.73	1.00			
9	NA	NA	NA	NA	NA	NA	NA	NA	NA		
10	0.00	NA	0.04	NA	NA	NA	0.00	0.21	NA	1.00	
11	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

1. DOVE BAY FLOAT LEAF 83
2. OLSON BAY FLOAT LEAF 83
3. CANBERRY BAY FLOAT LEAF 83
4. WOOD DUCK ISLAND FLOAT LEAF 83
5. CAMEL BACK ISLAND FLOAT LEAF 83
6. LOST BAY FLOAT LEAF 83
7. MCMANUS ISLAND FLOAT LEAF 83
8. SHEEN POINT FLOAT LEAF 83
9. DEEP SLOUGH FLOAT LEAF 83
10. GRASSY BAY FLOAT LEAF 83
11. SWANSON'S BAY FLOAT LEAF 83

MORISITA'S INDEX OF SIMILARITY FOR THE SUBMERGED SPECIES FOR 1982

	1	2	3	4	5	6	7	8	9	10	11
1	1.00										
2	0.00	1.00									
3	1.00	0.00	1.00								
4	0.00	0.00	0.00	1.00							
5	0.00	0.00	0.00	0.12	1.00						
6	0.00	0.00	0.00	0.11	0.98	1.00					
7	0.00	0.20	0.00	0.00	0.00	0.00	1.00				
8	0.00	0.29	0.00	0.00	0.00	0.00	1.03	1.00			
9	1.00	0.00	1.00	0.03	0.02	0.02	0.01	0.01	1.00		
10	0.01	0.83	0.01	0.00	0.00	0.00	0.57	0.63	0.01	1.00	
11	0.00	1.00	0.00	0.00	0.00	0.00	0.24	0.33	0.00	0.86	1.00

1. DOVE BAY SUBMERGED 82
2. OLSON BAY SUBMERGED 82
3. CRANBERRY BAY SUBMERGED 82
4. WOOD DUCK ISLAND SUBMERGED 82
5. CAMEL BACK ISLAND SUBMERGED 82
6. LOST BAY SUBMERGED 82
7. MCMANUS ISLAND SUBMERGED 82
8. SHEEN POINT SUBMERGED 82
9. DEEP SLOUGH SUBMERGED 82
10. GRASSY BAY SUBMERGED 82
11. SWANSON'S BAY SUBMERGED 82

MORISITA'S INDEX OF SIMILARITY FOR SUBMERGED SPECIES FOR 1983

	1	2	3	4	5	6	7	8	9	10	11
1	1.00										
2	0.00	1.00									
3	1.00	0.03	1.00								
4	0.00	0.00	0.00	1.00							
5	0.00	0.00	0.00	0.16	1.00						
6	0.00	0.00	0.00	0.13	0.60	1.00					
7	NA	NA	NA	NA	NA	NA	NA				
8	0.00	0.94	0.03	0.03	0.22	0.00	NA	1.00			
9	1.00	0.00	1.00	0.00	0.00	0.00	NA	0.00	1.00		
10	0.00	0.00	0.00	0.01	0.06	0.01	NA	0.02	0.00	1.00	
11	0.00	0.83	0.03	0.08	0.35	0.00	NA	0.97	0.00	0.03	1.00

1. DOVE BAY SUBMERGED 83
2. OLSON BAY SUBMERGED 83
3. CRANBERRY BAY SUBMERGED 83
4. WOOD DUCK ISLAND SUBMERGED 83
5. CAMEL BACK ISLAND SUBMERGED 83
6. LOST BAY SUBMERGED 83
7. MCMANUS ISLAND SUBMERGED 83
8. SHEEN POINT SUBMERGED 83
9. DEEP SLOUGH SUBMERGED 83
10. GRASSY BAY SUBMERGED 83
11. SWANSON'S BAY SUBMERGED 83

APPENDIX III

Checklist of the flora of Voyageurs National Park with the species sorted on the basis of scientific names and including complete distribution records for each species.

(Copies of checklist are available at Voyageurs National Park headquarters.)