National Park Service
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Wetland Vegetation Monitoring
Voyageurs National Park

Natural Resource Technical Report NPS/NRPC/WRD/NRTR—2009/202

ON THE COVER
Wetlands on Namakan Reservoir
Photograph by Allan Harris

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James E. Meeker
Northland College
1411 Ellis Ave.
Ashland, WI 54806
USA

Allan G. Harris
Northern Bioscience
363 Van Horne St.
Thunder Bay, ON P7A 3G3
Canada

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Contents

Contents (continued)

Contents (continued)

Page

Contents (continued)

Page

Figures

Page

Figures (continued)

Page

Figures (continued)

Page

Tables

Page

Tables (continued)

Page

Tables (continued)

Page

Tables (continued)

Page

Tables (continued)

Page

Tables (continued)

Page

Tables (continued)

Page

Tables (continued)

Page

Executive Summary

Regulation of water levels to a set of rule curves may have degraded the biotic resources of Voyageurs National Park (VNP) as suggested by a number of studies conducted during the period 1986-1990. Under the 1970 rule curve, water-level fluctuations on the Namakan Reservoir were more extreme compared to the relative "natural" conditions of non-regulated Lac la Croix. Fluctuations on Rainy Lake were less extreme than on Lac la Croix. A 1987 study indicated that aquatic vegetation was dominated by mat-forming species tolerant of extreme drawdowns on the Namakan Reservoir, while that on Rainy Lake was dominated by dense erect aquatics. Vegetation on Lac la Croix was intermediate between the two. The extreme drawdowns on the Namakan Reservoir were reduced between 1987 and the beginning of the present study.

This study establishes a baseline for monitoring wetland vegetation and offers some observations on the impacts of the water level regulation since 1987 based on comparison between the three basins and repeat sampling of the 1987 sites.

Some measurements suggest that the vegetation of the Namakan Reservoir is recovering to a more natural state. However, we also saw unpredicted patterns on other basins.

Shoreline communities of Rainy Lake are significantly different from those of Lac la Croix and Namakan in species composition. Differences between the basins include the prevalence of poor fen taxa and lack of aggressive taxa such as the hybrid cattail (*Typha* spp.) in Lac la Croix and prevalence of annual species in Rainy. Lac la Croix is poorly represented by emergent aquatics but has significantly greater facultative wetland herbaceus cover compared to Namakan. Although species composition differed, there were little differences in total cover or species richness at the shorelines between the basins, and a few taxa accounted for most of the cover in all basins. Although not all these findings could be supported statistically, collectively they suggest that water level management does influence the shoreline communities.

Shoreline vegetation has changed since 1987, particularly with an increase in woody cover in all basins. These results are consistent with the establishment of the new rule curve's annual water level peak in late May followed by gradual decline in water level the rest of the growing months. However, the uniform increase of woody taxa in shorelines across all basins with a disparate water level history, including Lac la Croix, suggests that hydrologic control may not be the only factor influencing change. Only future sampling of the shorelines at each basin will assist in determining whether lake level management or another factor such as climate change is the stronger influence. Low water levels in 2003 may have influenced the shoreline flora in Rainy and the interpretation is complicated by the invasion of *Typha* on parts of the Namakan Reservoir and Rainy Lake and by differing water levels among the basins during sampling.
The species composition of the aquatic vegetation communities of Lac la Croix are significantly different from those of Rainy Lake and Namakan at the 1.25 m depth. Namakan has significantly more emergent vegetation than the other two basins. Lac la Croix has more floating leaf vegetation, but less tall submergent vegetation.

The species composition of the aquatic vegetation communities are different from each other in all three basins at the 2.0 m depth. Lac la Croix has more floating leaf vegetation and less tall submergent vegetation than the other two basins. Lac la Croix continues to have greater vegetation structural diversity than the other basins, but no significant difference in cover or richness in aquatic vegetation (1.25 m or 2 m depth) was observed between the three basins. Aquatic vegetation has changed since 1987 in all basins. Vegetation in Namakan appears to be recovering to a more natural state. At 1.25 and 2 m the vegetation was formerly dominated by mat-forming species, but now has more structural diversity, as predicted with the reduction in extreme water levels. Namakan continues to have less emergent and floating leaf cover than the other basins and has significantly fewer overall species than Lac la Croix. Species rare or absent in Namakan but present in the other basins include *Potamogeton robbinsii* and *Potamogeton epihydrus* at both the 1.25 m and 2.0 m depths. Unexpectedly, the other basins also changed. Aquatic vegetation cover in Lac la Croix declined while that in Rainy increased.

The different water regimes have apparently influenced peatland development on the shores of the three basins. *Sphagnum* dominated fens (intolerant of regular flooding) are most common on Rainy Lake where water level fluctuations are the smallest. Shore fens (tolerant of regular flooding) are most frequent on Lac la Croix with intermediate water levels.   Peatlands on both Rainy and Namakan are relatively young, having developed since the dams were built in the early 1900s.

This study also established new baselines for monitoring changes in floating and aquatic vegetation (“extensive sampling”), wild rice, and invasive taxa on shorelines. Sampling bias was also tested to guide interpretation of subsequent monitoring. Recommendations for future monitoring are provided.

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Introduction

Regulation of water levels to a strict regime (a set of rule curves) may have degraded the biotic resources of VNP as suggested by a number of studies conducted during the period 1986-1990 (for vegetation see Meeker and Wilcox 1989 and Wilcox and Meeker 1991, for a synthesis see Kallemeyn et al. 1993). Under the 1970 rule curve, water-level fluctuations on the Namakan Reservoir (including Namakan, Kabetogama, Sandpoint, Little Vermilion, and Crane lakes) were more extreme compared to the relative “natural” conditions of non-regulated Lac la Croix, while those on the Rainy Lake basin were less so (Figure 1).

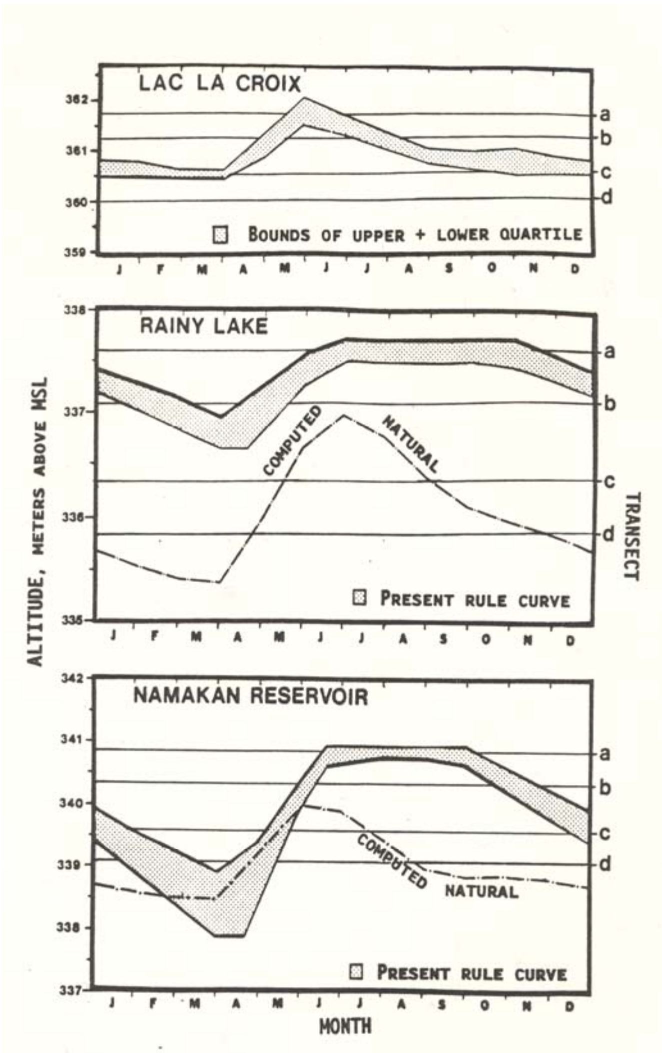


Figure 1. Water regimes for Lac la Croix, Rainy Lake, and Namakan Reservoir showing bounds of variation and computed natural water levels (adapted from Flug 1986).

In 1987 as part of these initial studies, the aquatic vegetation of the three basins was assessed (Meeker and Wilcox 1989; Wilcox and Meeker 1991). These studies found differences in structure and composition among the three lake systems, especially among deep elevation aquatic macrophytes. Vegetation in the Namakan Reservoir was exclusively dominated by mat-forming species tolerant of extreme drawdowns, while that in Rainy was dominated by dense, erect aquatics; vegetation in Lac la Croix was intermediate to the other two lakes (Figure 2). These vegetative structural differences between the regulated lakes and Lac la Croix were implicated in the degradation of other biota that depend on the vegetation in the regulated lakes (Wilcox and Meeker 1992; Kallemeyn et al.1993).

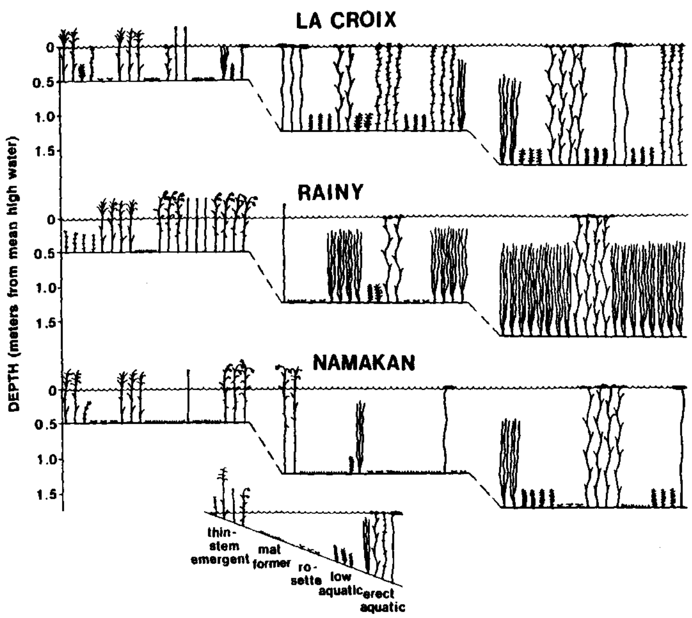


Figure 2. Schematic diagram representing the vegetation structure in 1987 at select elevations across two regulated basins, Namakan and Rainy, as compared to the unregulated Lac la Croix (adapted from Meeker and Wilcox 1989).

Background

Industry responsible for the regulation of water levels in the Namakan Reservoir and Rainy Lake responded to the suggested degradation of the biotic resources in two ways. First, beginning about 1987-88, the middle, rather than the extremes of the previous rule curves (1970 rules), began to be targeted, resulting in a reduction of the extreme fluctuations in the Namakan Reservoir (Figure 3, Figure 4). Second, following a ruling by the International Joint Commission, a new rule curve was established in 2000 as indicated in Figure 5. The changes include:

1) A considerable reduction of the drawdown in the Namakan Reservoir and the establishment of its annual peak in late May, followed by gradual decline in water level the rest of the growing months.

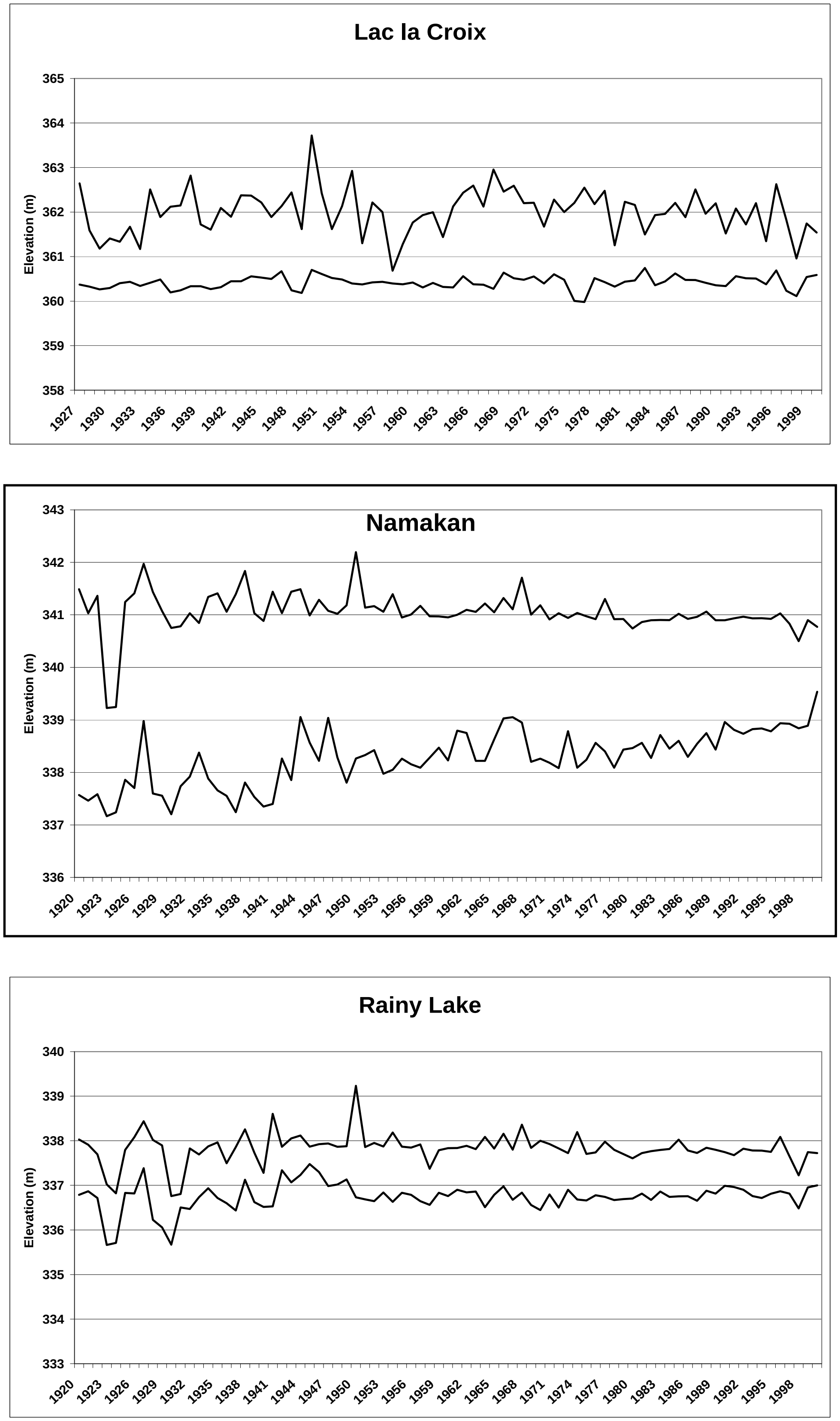


Figure 3. Annual extreme water levels for the period 1920 to 2000 for Lac la Croix, Namakan Reservoir, and Rainy Lake (Meeker and Harris 2004).

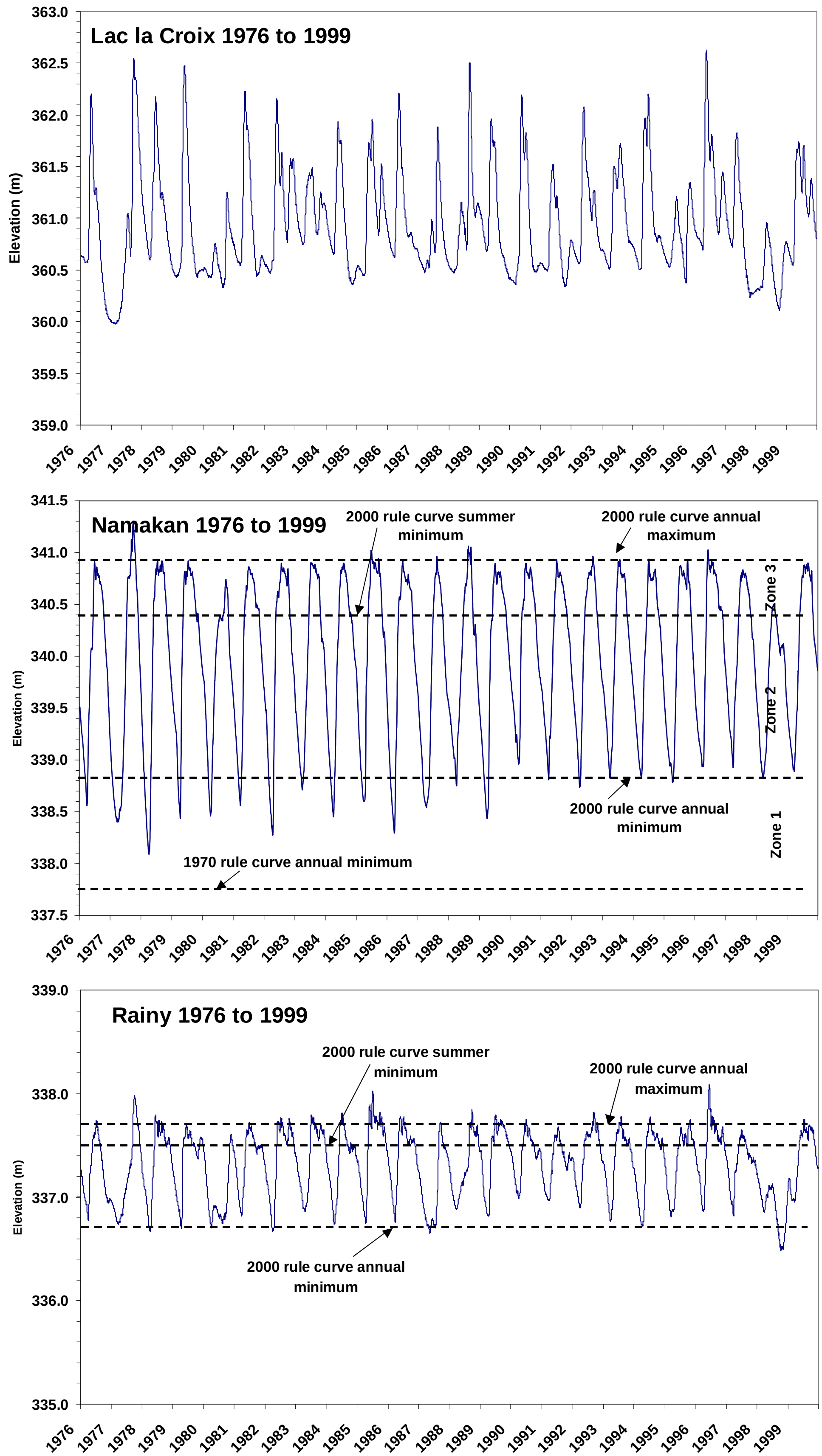
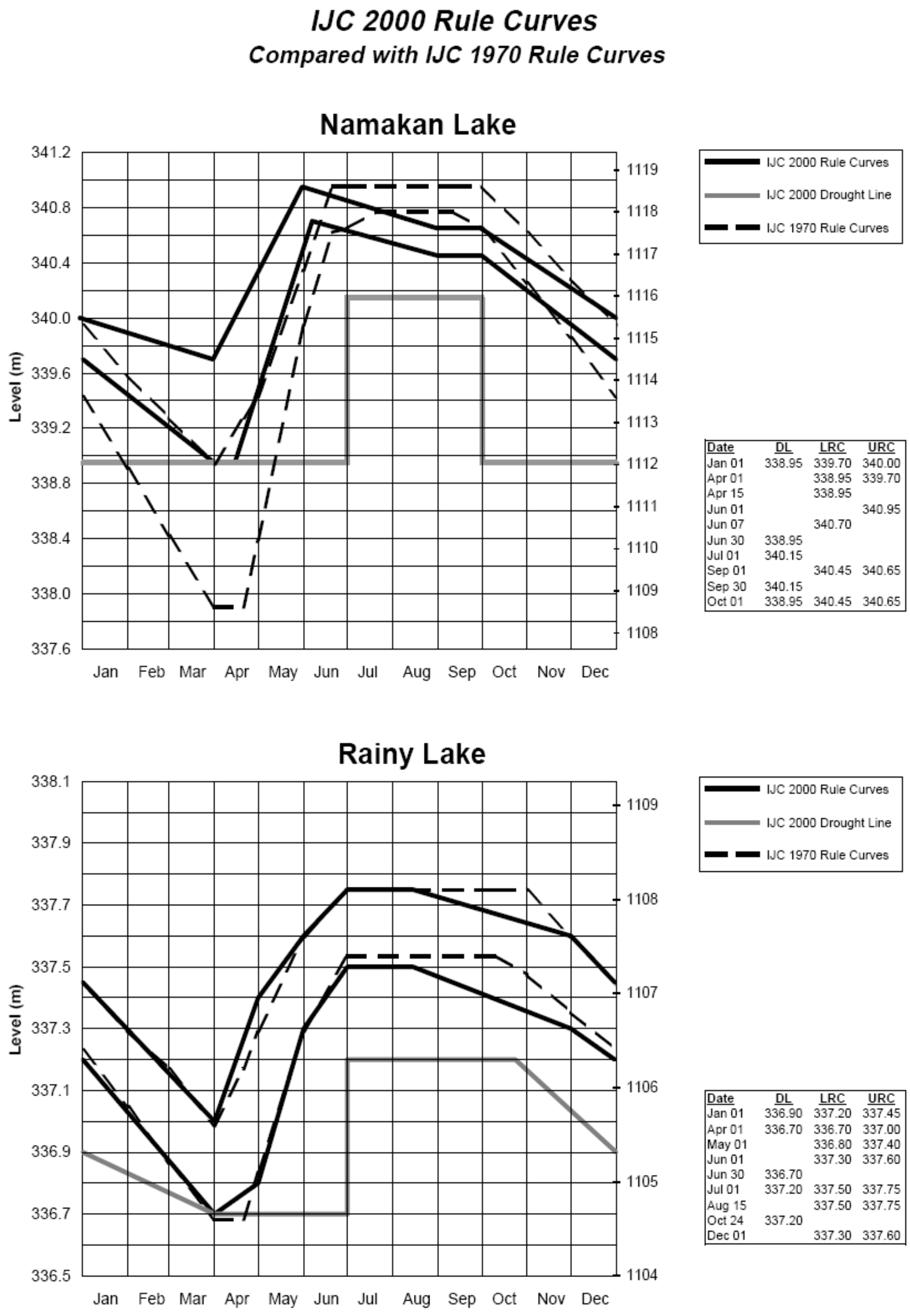


Figure 4. Water levels for the periods 1976 to 1999 for Lac la Croix, Namakan Reservoir, and Rainy Lake relative to the 1970 and 2000 rule curves (Meeker and Harris 2004).



Date	DL	LRC	URC
Jan 01	338.95	339.70	340.00
Apr 01		338.95	339.70
Apr 15		338.95	
Jun 01			340.95
Jun 07		340.70	
Jun 30	338.95		
Jul 01	340.15		
Sep 01		340.45	340.65
Sep 30	340.15		
Oct 01	338.95	340.45	340.65

Date	DL	LRC	URC
Jan 01	336.90	337.20	337.45
Apr 01	336.70	336.70	337.00
May 01		336.80	337.40
Jun 01		337.30	337.60
Jun 30	336.70		
Jul 01	337.20	337.50	337.75
Aug 15		337.50	337.75
Oct 24	337.20		
Dec 01		337.30	337.60

Figure 5. Rule curves for Rainy Lake and Namakan Reservoir. 1970 rule curve (dashed) and 2000 rule curve (solid) (adapted from Kallemeyn et al. 2003).

2) A slight increase in summer drawdown on Rainy Lake.

3) Instructions for the dam operators to officially target the middle levels of the rule curve bands.

For Rainy Lake these changes are minimal, but for Namakan Reservoir we identified four distinct zones (Figure 6) that characterized the difference between the 1970 and 2000 rule curves (Meeker and Harris 2004):

Zone 1: Formerly dewatered (i.e., exposed) in late winter, now permanently covered. (approx. 339.0 m – 337.9 m a.s.l.).

Zone 2: Areas temporarily exposed under old and new curves. Flooding and dewatering cycle is similar under old and new rule curves, but the depths and time are shifted (approx. 340.8 m - 339.0 m). Example: For areas at 340.0 meters elevation, the duration of exposure is reduced by approximately one month.

Zone 3: Formerly flooded with water throughout most of the growing season, now gradually dewatered through the growing season (approx. 340.9 m – 340.7 m).

Zone 4: Shoreline fens that rise and fall with changing water level (for example the west end of Kabetogama Lake). The vegetation is not rooted to mineral substrate, but floats on a mat of organic material.

The recognition of these zones allowed predictions of how the aquatic vegetation should change relative to the new regime and directed the 2001-2002 monitoring in the Namakan Reservoir (Meeker and Harris 2004). These predictions include:

Zone 1. Aquatic vegetation (other than rosette-forming species) will increase in cover, diversity, and frequency in Zone 1 in the Namakan Reservoir. Maintaining water cover during the winter should reduce desiccation and freezing damage to plant tissues and reduce ice-scour of sediments.

Zone 2. Aquatic vegetation will show little net change in Zone 2 in the Namakan Reservoir.

Zone 3. Cover of shrubs and other species intolerant of prolonged flooding through the growing season will increase in Zone 3 in the Namakan Reservoir. Summer drawdown increases oxygen availability in the rooting zone and enhances vegetative reproduction of clonal species and germination of seeds of some emergent species.

Zone 4. Floating mat vegetation in Zone 4 will show little change under the new rule curve. Floating mats rise and fall with water levels and provide a relatively constant environment for the rooting zone.

Aquatic vegetation will show little change under the new rule curve on Rainy Lake.

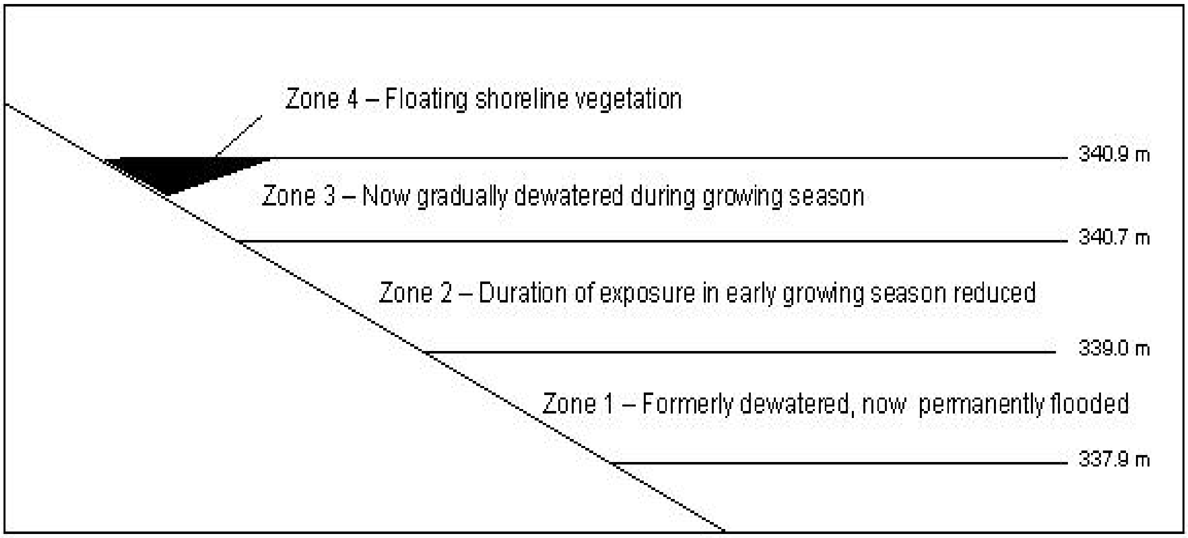


Figure 6. Vegetation zones for Namakan Reservoir relative to 2000 rule curve. Each zone represents a different water level regime and offers predictions as to the vegetative response over time.

Since water levels have generally been maintained close to the middle of rule curve since 1987, we suggested that wetland vegetation likely increased in cover and diversity between 1987 and 2002 in the Namakan Reservoir.

Purpose

This study had the general purpose of building a robust baseline for wetland monitoring at VNP relying on the background assessment efforts of the 2001-2002 study (Meeker and Harris 2004). The 2003 Study Plan that guided this present study identified four general objectives necessary to create a new vegetative baseline for the 2000 rule curve. They included: 1) establishing a baseline for monitoring that will gauge the response of VNP aquatic plant communities to the 2000 rule curve, 2) providing quality control by estimating the variability and sources of error in all of the various vegetation sampling, 3) establishing a baseline to detect changes in abundance of invasive plants such as narrow-leaved cattail (*Typha* spp.) and common reed grass (*Phragmites australis*), and 4) determining the response of wild rice (*Zizania palustris*) to the new rule curve. These objectives are discussed in greater detail below.

1. In order to strengthen the existing evidence that Namakan and Rainy aquatic plants are responding to the new regime, both intensive and extensive sampling are required. Those responses are compared to those of Lac la Croix, a control site that is not regulated. Intensive sampling (quadrat-based) is designed to look at a smaller pool of sites in more depth, while extensive sampling looks at a greater number of sites in less detail. The baseline monitoring to achieve this goal is presented in the Intensive Sampling and Extensive Sampling sections. In addition, we have analyzed year to year vegetative changes at select sites in the Namakan Reservoir over short time periods when we did not expect significant change, 2002, 2004, and 2006, as well as change across all basins (Namakan, Rainy, and Lac la Croix) over a longer time period from 1987 to 2002 when

changes were expected (see Vegetative Change section). Finally, we examine satellite image analysis as a potential tool for monitoring basin-wide changes in wetland distribution (see Satellite Image section).

2. Investigating the sources of variability in aquatic macrophyte sampling would allow stronger inferences about the response of vegetation to the rule curves and determine the optimum number of quadrats for monitoring change in vegetation. Interpreting the results from the above-mentioned, intensive quadrat-based sampling requires that we should have an estimate of the variability associated with it. Sources of variability in our intensive sampling (quadrats along transects) include differences in perception among observers, differences in estimates by one observer at repeat times, differences in placement of quadrats along transects from one time to the next (mimicking repeat sampling at different years). In the section on Sampling Bias, we have addressed intra-observer bias, inter-observer bias, comparing experienced vs. recently trained observers, and what we have called placement bias, or an assessment of the number of quadrats necessary to estimate vegetation abundance.

3. Goal three establishes a baseline for the investigation of changes in aggressive shoreline taxa along shorelines and on the outer edges of peatlands, and their relationship to water level regulation. We present these data in both the assessment of VNP peatlands (see Peatland Assessment section), and along shorelines (see Shoreline Surveys section).

4. Although there are few verifiable records, it is commonly thought that the historic populations of wild rice in the Rainy/Namakan system were more numerous and of greater size than they have been in the last 30-40 years (Monson 1986; Catton and Montgomery 2000; Kallemeyn, pers comm.). This objective provides the assessment of wild-rice response to the new rule curve (see Wild Rice Surveys section).

Intensive Sampling

Introduction

Thirty-one sites were selected for intensive monitoring using quadrats sampled on elevational contours. This was a substantial increase from the two sites per basin in the 1987 study and increases the number of sites to 10 on Rainy Lake, 10 on Lac la Croix, and 11 on the Namakan Reservoir.

Methods

Site Selection

Prior to selecting the 31 sites, a pool of potential wetland sampling sites in the Rainy Lake and Namakan Reservoir was randomly chosen from the Voyageurs vegetation database (Hop et al. 2001). The area covered by vegetation mapping includes the southeast arm of Rainy Lake, the Namakan Reservoir, and Sandpoint Lake (Figure 7).

Wetland polygons of the midwest pondweed, wild rice marsh, deep marsh mosaic, and northern water lily vegetative cover-types were pooled and potential sites were randomly chosen from this vegetation database. The potential pool was reduced to include only those polygons that were confluent with Rainy Lake or Namakan Reservoir with a minimum size of greater than one hectare.

Vegetation mapping was unavailable for Lac la Croix. Due to travel limitations in 2002, sites were selected that were in close proximity to the 1987 sampling sites based on aerial photographs and field reconnaissance. In 2005, aerial photography from Lac la Croix and Ikonos imagery were used to randomly select sites within a region approximately 10 km west of the initial Lac la Croix sites.

Potential sites were visited in the field to assess their suitability. Suitable sites had zones 1, 2 and 3 represented, were not dominated by floating mat vegetation (since this vegetation was not expected to change with the new rule curve), and were not heavily influenced by human activity (former or existing cabins, landings, etc.). The few shorelines chosen that were dominated by large cattail (*Typha* spp.) and common reed (*Phragmites australis*) stands were rejected as the behavior of these mat forming species appears to be less affected by rule curve changes.

Sampling zones or elevations were located in the field by obtaining actual water level measures (Lake of the Woods Control Board website) at the time of sampling and comparing them to mean high water level (MHW). The mean high water levels served as the datum or reference elevations used in all the sampling and were as follows: Namakan Reservoir = 340.90 m, Rainy Lake = 337.75 m, Lac la Croix = 362.00 m. For example, when we sought the 1.25 m elevation in Namakan, and the water level at the time of sampling was 340.75 m (or 0.15 m below MHW), we established the 1.25 m contour at actual water depths of 1.10 m.

Sampling of the 31 intensively studied sites took place between late July-late August 2002-2005 when the vegetation was fully developed. In 2002, water levels ranged from 10 to 30 cm above

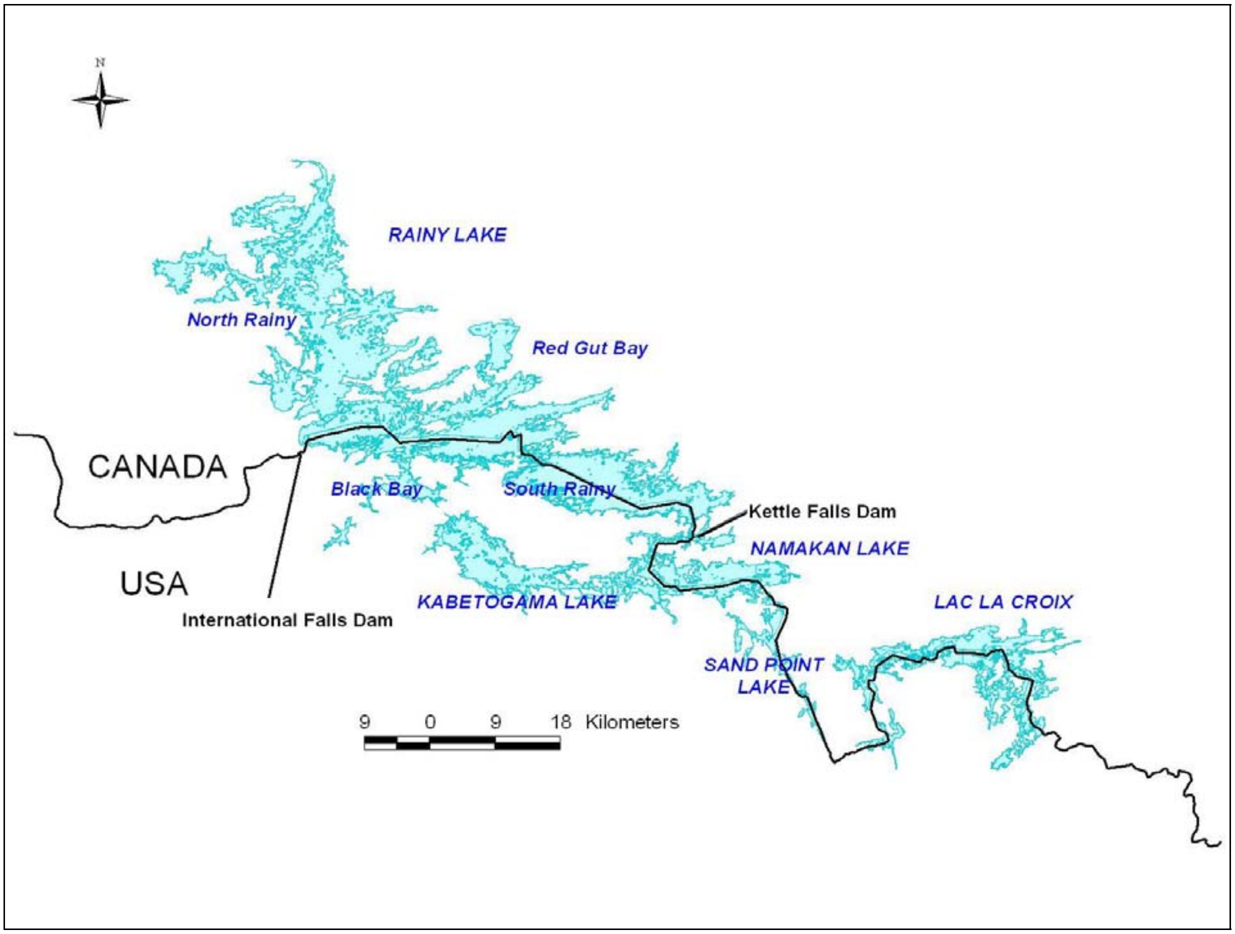


Figure 7. Map of the study area showing the dams at Kettle Falls (controlling the outflow from Namakan Lake) and International Falls (controlling the outflow from Rainy Lake).

mean high water (MHW) in the Namakan Reservoir and from 20 to 30 cm below MHW in Lac la Croix. Due to extremely high water levels in Rainy in 2002, we deferred the intensive vegetation sampling in that basin until 2003-2004; water levels in Rainy were 60 cm below MHW in 2003 and ranged from 15 to 20 cm below MHW in 2004. Sampling in Lac la Croix took place in 2002 and 2005 when water levels were 35-40 cm below MHW. All sites chosen are listed in Table 1, along with the elevations, site names, sampling dates, and labels used in the following analyses.

Field Methods

The original six sites were established in 1987, and on repeated visits, these sites were sampled along transects at five water elevations relative to MHW: 0.0 m, 0.5 m, 1.25 m, 1.75 m, and 2.0 m. All sites established after 1987 were only sampled at three water level elevations: 0.0 m, 1.25 m, and 2.0 m. We elected to eliminate the 0.5 m and 1.75 m elevations during the 2002-2005 sampling efforts to reduce field time required to monitor the site into the future, without, we believe, restricting the ability to detect change.

Table 1. Intensive sampling sites.

Site Name	Date	Location	1987 Site	Transect Depths (m)				
				0	0.5	1.25	1.75	2
LLC01	07/17/2005	West end		X		X		X
LLC02	07/17/2005	South of Wilkins Bay		X		X		X
LLC03	07/18/2005	Wilkins Bay Narrows		X		X		X
LLC04	07/18/2005	North side of Wilkins Bay		X		X		X
LLC05	07/19/2005	North side of Wilkins Bay		X		X		X
LLC06	07/15/2002	Lady Boot Bay East	X	X	X	X	X	X
LLC07	07/16/2002	Lady Boot Bay North		X		X		X
LLC08	07/16/2002	Lady Boot Bay South		X		X		X
LLC09	07/15/2002	Lady Boot Bay West	X	X	X	X	X	X
LLC10	07/16/2002	Lady Boot Bay Southeast		X		X		X
NAM01	08/13/2002	Moxie Island		X		X		X
NAM02	08/13/2002	Lost Bay		X		X		X
NAM03	07/10/2002	McManus Island		X		X		X
NAM04	07/12/2002	Canadian Mainland South of Mica I.		X		X		X
NAM05	08/14/2002	Sheen Pt	X	X	X	X	X	X
NAM06	07/10/2002	Canadian Mainland W. of Blackstone I.		X		X		X
NAM07	07/07/2002	Deep Slu	X	X	X	X	X	X
NAM08	07/12/2002	Canadian Mainland E. of Blackstone I.		X		X		X
NAM09	07/11/2002	Hammer Bay		X		X		X
NAM10	07/11/2002	Sand Point Lake		X		X		X
NAM11	07/11/2002	Swanson's Bay		X		X		X
Rainy01	08/24/2004	Brown's Inlet		X		X		X
Rainy02	08/26/2004	Canoe Channel		X		X		X
Rainy03	08/23/2004	Cape Horn		X		X		X
Rainy04	08/25/2004	Cormorant Bay		X		X		X
Rainy05	08/25/2004	Little Brule		X		X		X
Rainy06	08/15/2003	Dove Bay	X	X	X	X	X	X
Rainy07	08/15/2003	Alder Creek	X	X	X	X	X	X
Rainy08	08/15/2005	Lost Bay		X		X		X
Rainy09	08/15/2005	Hallelujah Point		X		X		X
Rainy10	08/17/2003	Sandpoint Island		X		X		X

Twenty 1 m x 1 m quadrats were sampled on each transect, which were distributed by first estimating the length of each transect, then dividing it into 20 equal segments. Within each of the 20 segments, a quadrat location was randomly chosen. In the aquatic zones (i.e. 1.25, 1.75 and 2.0 m depths) each random quadrat location was marked with a foam float attached to a sinker, and along the shoreline transect with a temporary flag. Transects at 0.0 m and 0.5 m were sampled by walking, and snorkeling gear was used to sample the 1.25, 1.75 m and 2.0 m depths. At each of the three elevations, we had 200, 220 and 200 quadrats for Lac la Croix, Namakan, and Rainy, respectively (i.e., 20 quadrats per site per basin).

At each quadrat we first made a single estimate of vegetative cover, and the values of this "estimated cover" fell between 0 and 100%. Following that, species identifications and individual percent cover per taxon were recorded. We estimated, by taxa, the cover of all foliage directly above the quadrats that was less than two meters tall (i.e., did not include the cover of any overhanging tall tree or shrub branches greater than that height). Taxa covering less than 1% of a quadrat were systematically recorded as 0.1%. As plants may occupy space at different strata, the sum of individual cover estimates could exceed 100%. Nomenclature follows Gleason and Cronquist (1991).

Data analyses

By design, we treated each elevational transect at each site as the experiment unit, and hence the quadrats as subsamples. We believe that VNP will be able to sample in the same site and at the same elevation relative to mean high water, but re-locating the quadrats will not be possible. In addition, in the analyses and reporting of results that follows, we will focus on how the basins differ at specific elevations relative to mean high water. That is, we have focused on looking at similarities and differences among the three basins at similar elevations, as this reflects the differences in water level management over time and space.

Four main metrics were calculated from the quadrat data. These include **estimated cover** for the whole quadrat**, summed percent cover** for all taxa per quadrat, **frequency of occurrence**, and **relative importance value**, each described in more detail below. Species richness and total cover by plant life form were also calculated.

Total **estimated cover** for each quadrat can be analyzed at the quadrat level and higher (e.g. transect, basin), but it does not have a taxonomic component.

Summed percent cover (also called raw cover) was summed at the transect level; 1) for each taxon, 2) by life forms, and 3) summed for all taxa.

Another metric was calculated from the field data, and we refer to it as **frequency of occurrence** (sometimes referred to as raw frequency or frequency). This value can only be used at the transect scale and above (e.g. basin). For example, a taxon has a frequency of 5 if it was found in 5 of the 20 quadrats along an elevation at a particular site. (It can also be reported as a percent, as 5/20 = 25%, but in order to minimize confusion with other percentile metrics, we will refer to it primarily as the number of times seen in a transect.)

Both cover and frequency metrics are measures of abundance and can be quite different for a given taxon. For example, a given species may be present at only two quadrats along a transect at a given site but with 90% cover each time. In this case the species total percent cover value along the transect may be high (180%), whereas the frequency is low, 2 of 20. This is an example of a species that has a clumped distribution, in contrast to a species that was scattered frequently about but never with much cover. To capture both of these distribution types, we have chosen to analyze both frequency and cover, as well as a composite measure, relative importance value, described next.

Two other metrics were calculated as intermediate steps in calculating **relative importance value**, namely relative cover and relative frequency. Relative cover is calculated for each taxon as its percent cover divided by (or relative to) the sum of all other taxa found *in that transect*. Relative frequency is calculated for each taxon as its frequency of occurrence relative to the total frequency of all taxa at a given transect. Since each of these metrics is a measure of an individual taxon's abundance relative to all other taxa, the sum of all taxa's relative cover and the sum of all taxa's relative frequency will each be 100%. Finally, to calculate **relative importance value** (a composite of cover and frequency), each taxon's relative cover and relative frequency is averaged, and it, too, will result in a total of 100% for all taxa at each transect. Since we have sampled at 31 sites the total relative importance for all taxa at each of the three elevations will be 3100 (100 x 31).

All quadrat data was entered into databases, printed out, and error checked with field notebooks. It is available on CD, and in Meeker and Harris (2008) along with maps of each site.

Each sampling elevation was determined in the field relative to mean high water and will be referred to as either **shoreline** (0.0m), **1.25 m** or mid deep, and **2.0 m** or deep. Each elevation is analyzed separately below. Analyses include a non-parametric single factor ANOVA equivalent, the Kruskal-Wallis test, where the variable factor is basin at three categorical levels (Lac la Croix, Namakan, Rainy). These Kruskal-Wallis comparisons are based on medians, but means are depicted in figures for ease of comparsion. On other metrics, the Kruskal-Wallis test was used with the addition of life form as a variable, which grouped taxa into six, five, or four categories for the shoreline, 1.25 m, and 2.0 m elevations respectively. Tables 2 to 4 list all taxa recorded and their life form grouping, including aquatic, emergent, graminoid (grasslike), facultative wetland herb, tree/shrub, and upland herb for the shoreline; tall submergent, low submergent, isoetid, floating leaf, and emergent for the 1.25 m transects; and tall submergent, low submergent, isoetid, and floating leaf for the 2.0 m transects.

In order to summarize the floristic as well as the abundance differences among the three basins, we created taxa x transect matrices and calculated non-dimensional scaling (NMS) ordinations. These calculations were performed in PCORD (McCune and Mefford 1999) using the importance value (IV) metric on all taxa occurring in three or more quadrats across all basins.

Multi-response Permutation Procedure (MRPP) (McCune and Mefford 1999) pair wise comparison of vegetation data was conducted on importance values to test for significant differences in vegetation composition.

Table 2. Taxa recorded in 620 1 m x 1 m quadrats at the shoreline (0 m depth) along with placement into one of four life form categories.

	Taxa	Life form category	Taxa abbrev.	LF abbrev.
1	*Abies balsamea*	tree/shrub	ABIBAL	TRSHRUB
2	*Acer rubrum*	tree/shrub	ACERUB	TRSHRUB
3	*Acer saccharinum*	tree/shrub	ACESAC	TRSHRUB
4	*Acorus calamus*	emergent	ACOCAL	EMERG
5	*Agalinis tenuifolia*	upland herb	AGATEN	UPHERB
6	*Agrostis hyemalis*	graminoid	AGRHYM	GRAMIN
7	*Alisma plantago-aquatica*	emergent	ALIPLA	EMERG
8	*Alnus incana*	tree/shrub	ALNINC	TRSHRUB
9	*Apocynum androsaemifolium*	upland herb	APOAND	UPHERB
10	*Asclepias incarnata*	facultative wetland herb	ASCINC	FACWET
11	*Aster sp_*	facultative wetland herb	ASTESP	FACWET
12	*Betula papyrifera*	tree/shrub	BETPAP	TRSHRUB
13	*Bidens sp_*	facultative wetland herb	BIDESP	FACWET
14	*Calamagrostis canadensis*	graminoid	CALCAN	GRAMIN
15	*Calla palustris*	facultative wetland herb	CALPAL	FACWET
16	*Campanula aparinoides*	facultative wetland herb	CAMAPA	FACWET
17	*Cardamine sp_*	facultative wetland herb	CARDSP	FACWET
18	*Carex acutae group*	graminoid	CARACU	GRAMIN
19	*Carex atherodes*	graminoid	CARATH	GRAMIN
20	*Carex canescens*	graminoid	CARCAN	GRAMIN
21	*Carex chordorrhiza*	graminoid	CARCHO	GRAMIN
22	*Carex crinita*	graminoid	CARCRI	GRAMIN
23	*Carex diandra*	graminoid	CARDIA	GRAMIN
24	*Carex lacustris*	graminoid	CARLAC	GRAMIN
25	*Carex lasiocarpa*	graminoid	CARLAS	GRAMIN
26	*Carex ovales group*	graminoid	CAROVA	GRAMIN
27	*Carex pellita*	graminoid	CARPEL	GRAMIN
28	*Carex praegracilis*	graminoid	CARPRA	GRAMIN
29	*Carex sp_*	graminoid	CARESP	GRAMIN
30	*Carex utriculata*	graminoid	CARUTR	GRAMIN
31	*Carex viridula*	graminoid	CARVIR	GRAMIN
32	*Ceratophyllum demersum*	aquatic	CERDEM	AQUATIC
33	*Chamaedaphne calyculata*	tree/shrub	CHACAL	TRSHRUB
34	*Cicuta sp_*	facultative wetland herb	CICUSP	FACWET
35	*Cirsium sp_*	upland herb	CIRSSP	UPHERB
36	*Cornus sericea*	tree/shrub	CORSER	TRSHRUB
37	*Cuscuta sp_*	facultative wetland herb	CUSCSP	FACWET
38	*Cyperus squarrosus*	graminoid	CYPSQU	GRAMIN
39	*Cyperus strigosus*	graminoid	CYPSTR	GRAMIN
40	*Deschampsia cespitosa*	graminoid	DESCES	GRAMIN
41	*Dulichium arundinaceum*	graminoid	DULARU	GRAMIN

	Taxa	Life form category	Taxa abbrev.	LF abbrev.
42	*Elatine minima*	aquatic	ELAMIN	AQUATIC
43	*Eleocharis acicularis*	graminoid	ELEACI	GRAMIN
44	*Eleocharis ovata*	facultative wetland herb	ELEOVA	FACWET
45	*Eleocharis palustris*	emergent	ELEPAL	EMERG
46	*Epilobium coloratum*	facultative wetland herb	EPICOL	FACWET
47	*Equisetum sp_*	facultative wetland herb	EQUISP	FACWET
48	*Euthamia graminifolia*	facultative wetland herb	EUTGRA	FACWET
49	*Fragaria sp_*	upland herb	FRAGSP	UPHERB
50	*Fraxinus sp_*	tree/shrub	FRAXSP	TRSHRUB
51	*Galium sp_*	facultative wetland herb	GALISP	FACWET
52	*Geranium bicknellii*	upland herb	GERBIC	UPHERB
53	*Glyceria borealis*	graminoid	GLYBOR	GRAMIN
54	*Glyceria sp_*	graminoid	GLYCSP	GRAMIN
55	*graminoid seedling*	graminoid	GRAMSD	GRAMIN
56	*Hypericum majus*	facultative wetland herb	HYPMAJ	FACWET
57	*Impatiens capensis*	facultative wetland herb	IMPCAP	FACWET
58	*Iris versicolor*	emergent	IRIVER	EMERG
59	*Juncus filiformis*	graminoid	JUNFIL	GRAMIN
60	*Juncus pelocarpus*	graminoid	JUNPEL	GRAMIN
61	*Juncus sp_*	graminoid	JUNCSP	GRAMIN
62	*Juncus tenuis*	graminoid	JUNTEN	GRAMIN
63	*Lathyrus sp_*	facultative wetland herb	LATHSP	FACWET
64	*Leersia oryzoides*	graminoid	LEEORY	GRAMIN
65	*Lemna minor*	aquatic	LEMMIN	AQUATIC
66	*Lemna trisulca*	aquatic	LEMTRI	AQUATIC
67	*Lycopodium sp_*	upland herb	LYCOPO	UPHERB
68	*Lycopus sp_*	facultative wetland herb	LYCOSP	FACWET
69	*Lysimachia ciliata*	facultative wetland herb	LYSCIL	FACWET
70	*Lysimachia sp_*	facultative wetland herb	LYSISP	FACWET
71	*Maianthemum canadense*	upland herb	MAICAN	UPHERB
72	*Mentha arvensis*	facultative wetland herb	MENARV	FACWET
73	*moss sp_*	facultative wetland herb	MOSSSP	FACWET
74	*Myrica gale*	tree/shrub	MYRGAL	TRSHRUB
75	*Myriophyllum sp_*	aquatic	MYRISP	AQUATIC
76	*Onoclea sensibilis*	facultative wetland herb	ONOSEN	FACWET
77	*Osmunda regalis*	facultative wetland herb	OSMREG	FACWET
78	*Oxalis sp_*	upland herb	OXALSP	UPHERB
79	*Panicum sp_*	graminoid	PANISP	GRAMIN
80	*Parthenocissus inserta*	tree/shrub	PARINS	TRSHRUB
81	*Petasites frigidus*	upland herb	PETSAG	UPHERB
82	*Phalaris arundinacea*	graminoid	PHAARU	GRAMIN
83	*Phragmites australis*	emergent	PHRAUS	EMERG
84	*Pinus strobus*	tree/shrub	PINSTR	TRSHRUB
85	*Poa sp_*	graminoid	POASPP	GRAMIN

	Taxa	Life form category	Taxa abbrev.	LF abbrev.
86	*Polygonum amphibium*	facultative wetland herb	POLAMP	FACWET
87	*Polygonum sagittatum*	facultative wetland herb	POLSAG	FACWET
88	*Polygonum sp_*	facultative wetland herb	POLYSP	FACWET
89	*Populus sp_*	tree/shrub	POPUSP	TRSHRUB
90	*Potentilla norvegica*	facultative wetland herb	POTNOR	FACWET
91	*Potentilla palustris*	facultative wetland herb	POTPAL	FACWET
92	*Prunella vulgaris*	upland herb	PRUVUL	UPHERB
93	*Prunus pumila*	tree/shrub	PRUPUM	TRSHRUB
94	*Prunus virginiana*	tree/shrub	PRUVIR	TRSHRUB
95	*Ranunculus flammula*	facultative wetland herb	RANFLA	FACWET
96	*Ranunculus pensylvanicus*	facultative wetland herb	RANPEN	FACWET
97	*Rorippa sp_*	facultative wetland herb	RORISP	FACWET
98	*Rosa sp_*	tree/shrub	ROSASP	TRSHRUB
99	*Rubus sp_*	tree/shrub	RUBUSP	TRSHRUB
100	*Rumex sp_*	facultative wetland herb	RUMESP	FACWET
101	*Sagittaria sp_*	emergent	SAGISP	EMERG
102	*Salix spp_*	tree/shrub	SALISP	TRSHRUB
103	*Scirpus cyperinus*	graminoid	SCICYP	GRAMIN
104	*Scirpus fluviatilis*	emergent	SCIFLU	EMERG
105	*Scutellaria sp_*	facultative wetland herb	SCUTSP	FACWET
106	*Sium suave*	facultative wetland herb	SIUSUA	FACWET
107	*Solidago sp_*	upland herb	SOLISP	UPHERB
108	*Sparganium erect*	emergent	SPAERE	EMERG
109	*Spartina pectinata*	graminoid	SPAPEC	GRAMIN
110	*Sphagnum sp_*	facultative wetland herb	SPHASP	FACWET
111	*Spiraea alba*	tree/shrub	SPIALB	TRSHRUB
112	*Spirodela polyrhiza*	aquatic	SPIPOL	AQUATIC
113	*Stachys palustris*	facultative wetland herb	STAPAL	FACWET
114	*Thelypteris palustris*	facultative wetland herb	THEPAL	FACWET
115	*Thuja occidentalis*	tree/shrub	THUOCC	TRSHRUB
116	*Toxicodendron radicans*	tree/shrub	TOXRAD	TRSHRUB
117	*Triadenum fraseri*	facultative wetland herb	TRIFRA	FACWET
118	*Trifolium sp_*	upland herb	TRIFSP	UPHERB
119	*Typha latifolia*	emergent	TYPLAT	EMERG
120	*Typha x glauca*	emergent	TYPXGL	EMERG
121	*Ulmus americana*	tree/shrub	ULMAME	TRSHRUB
122	*Utricularia intermedia*	aquatic	UTRINT	AQUATIC
123	*Utricularia vulgaris*	aquatic	UTRVUL	AQUATIC
124	*Verbena hastata*	facultative wetland herb	VERHAS	FACWET
125	*Veronica scutellata*	facultative wetland herb	VERSCU	FACWET
126	*Viburnum lentago*	tree/shrub	VIBLEN	TRSHRUB
127	*Viola sp_*	upland herb	VIOLSP	UPHERB

Table 3. Taxa recorded in 620 1 m x 1 m quadrats at the 1.25 m depth along with placement into one of four life form categories.

	Taxa	Life form category	Taxa abbrev.	LF abbrev.
1	*Bidens beckii*	tall submergent	BIDBEC	SUBTALL
2	*Bidens sp_*	emergent	BIDESP	EMERG
3	*Callitriche hermaphroditica*	low submergent	CALHER	SUBLOW
4	*Ceratophyllum demersum*	tall submergent	CERDEM	SUBTALL
5	*Chara sp_*	low submergent	CHARSP	SUBLOW
6	*Crassula aquatica*	isoetid	CRAAQU	ISOETID
7	*Elatine minima*	low submergent	ELAMIN	SUBLOW
8	*Eleocharis acicularis*	low submergent	ELEACI	SUBLOW
9	*Eleocharis ovata*	emergent	ELEOVA	EMERG
10	*Eleocharis palustris*	emergent	ELEPAL	EMERG
11	*Elodea canadensis*	tall submergent	ELOCAN	SUBTALL
12	*Equisetum sp_*	emergent	EQUISP	EMERG
13	*Eriocaulon aquaticum*	isoetid	ERIAQU	ISOETID
14	*Glyceria borealis*	emergent	GLYBOR	EMERG
15	*Hippuris vulgaris*	tall submergent	HIPVUL	SUBTALL
16	*Isoetes sp_*	isoetid	ISOESP	ISOETID
17	*Juncus pelocarpus*	isoetid	JUNPEL	ISOETID
18	*Lemna minor*	floating leaf	LEMMIN	FLOATLF
19	*Lemna trisulca*	low submergent	LEMTRI	SUBLOW
20	*Littorella uniflora*	isoetid	LITUNI	ISOETID
21	*moss sp_*	low submergent	MOSSSP	SUBLOW
22	*Myriophyllum sp_*	tall submergent	MYRISP	SUBTALL
23	*Najas flexilis*	low submergent	NAJFLE	SUBLOW
24	*Nuphar sp_*	floating leaf	NUPHSP	FLOATLF
25	*Nymphaea odorata*	floating leaf	NYMODO	FLOATLF
26	*Potamogeton amplifolius*	tall submergent	POTAMP	SUBTALL
27	*Potamogeton epihydrus*	floating leaf	POTEPI	FLOATLF
28	*Potamogeton gramineus*	tall submergent	POTGRA	SUBTALL
29	*Potamogeton narrow leaved*	tall submergent	POTNAR	SUBTALL
30	*Potamogeton natans*	floating leaf	POTNAT	FLOATLF
31	*Potamogeton obtusifolius*	tall submergent	POTOBT	SUBTALL
32	*Potamogeton richardsonii*	tall submergent	POTRIC	SUBTALL
33	*Potamogeton robbinsii*	low submergent	POTROB	SUBLOW
34	*Potamogeton zosteriformis*	tall submergent	POTZOS	SUBTALL
35	*Ranunculus flammula*	low submergent	RANFLA	SUBLOW
36	*Ranunculus longirostris*	tall submergent	RANLON	SUBTALL
37	*Sagittaria rosette*	isoetid	SAGROS	ISOETID
38	*Sagittaria sp_*	emergent	SAGISP	EMERG
39	*Scirpus acutus*	emergent	SCIACU	EMERG
40	*Scirpus subterminalis*	low submergent	SCISUB	SUBLOW
41	*Scirpus validus*	emergent	SCIVAL	EMERG

	Taxa	Life form category	Taxa abbrev.	LF abbrev.
42	*Sium suave*	emergent	SIUSUA	EMERG
43	*Sparganium sp_*	floating leaf	SPARSP	FLOATLF
44	*Spirodela polyrhiza*	floating leaf	SPIPOL	FLOATLF
45	*Subularia aquatica*	isoetid	SUBAQU	ISOETID
46	*Utricularia intermedia*	low submergent	UTRINT	SUBLOW
47	*Utricularia minor*	low submergent	UTRMIN	SUBLOW
48	*Utricularia vulgaris*	tall submergent	UTRVUL	SUBTALL
49	*Vallisneria americana*	tall submergent	VALAME	SUBTALL
50	*Zizania palustris*	emergent	ZIZPAL	EMERG
51	*Zosterella dubia*	tall submergent	ZOSDUB	SUBTALL

Table 4. Taxa recorded in 620 1 m x 1 m quadrats at the 2.0 m depth along with placement into one of four life form categories.

	Taxa	Life form category	Taxa abbrev.	LF abbrev.
1	*Bidens beckii*	tall submergent	BIDBEC	SUBTALL
2	*Callitriche hermaphroditica*	low submergent	CALHER	SUBLOW
3	*Ceratophyllum demersum*	tall submergent	CERDEM	SUBTALL
4	*Chara sp_*	low submergent	CHARSP	SUBLOW
5	*Elatine minima*	low submergent	ELAMIN	SUBLOW
6	*Eleocharis acicularis*	low submergent	ELEACI	SUBLOW
7	*Elodea canadensis*	tall submergent	ELOCAN	SUBTALL
8	*Isoetes sp_*	isoetid	ISOESP	ISOETID
9	*Juncus pelocarpus*	isoetid	JUNPEL	ISOETID
10	*Lemna trisulca*	low submergent	LEMTRI	SUBLOW
11	*Littorella uniflora*	isoetid	LITUNI	ISOETID
12	*Myriophyllum sp_*	tall submergent	MYRISP	SUBTALL
13	*Najas flexilis*	low submergent	NAJFLE	SUBLOW
14	*Nuphar sp_*	floating leaf	NUPHSP	FLOATLF
15	*Nymphaea odorata*	floating leaf	NYMODO	FLOATLF
16	*Potamogeton amplifolius*	tall submergent	POTAMP	SUBTALL
17	*Potamogeton epihydrus*	floating leaf	POTEPI	FLOATLF
18	*Potamogeton gramineus*	tall submergent	POTGRA	SUBTALL
19	*Potamogeton narrow leaved*	tall submergent	POTNAR	SUBTALL
20	*Potamogeton richardsonii*	tall submergent	POTRIC	SUBTALL
21	*Potamogeton robbinsii*	low submergent	POTROB	SUBLOW
22	*Potamogeton zosteriformis*	tall submergent	POTZOS	SUBTALL
23	*Ranunculus longirostris*	tall submergent	RANLON	SUBTALL
24	*Sagittaria rosette*	isoetid	SAGROS	ISOETID
25	*Scirpus subterminalis*	low submergent	SCISUB	SUBLOW
26	*Sparganium sp_*	floating leaf	SPARSP	FLOATLF
27	*Utricularia intermedia*	low submergent	UTRINT	SUBLOW
28	*Utricularia minor*	low submergent	UTRMIN	SUBLOW

	Taxa	Life form category	Taxa abbrev.	LF abbrev.
29	*Utricularia vulgaris*	tall submergent	UTRVUL	SUBTALL
30	*Vallisneria americana*	tall submergent	VALAME	SUBTALL
31	*Zosterella dubia*	tall submergent	ZOSDUB	SUBTALL

Results

Shoreline

One hundred and twenty-seven taxa were recognized in all the shoreline transects and are listed in alphabetical order (along with taxa abbreviations) in Table 5 to Table 7 for percent cover, frequency, and importance values (IV). Mean summed cover was greatest at Rainy (78.6%), followed by Lac la Croix (78.4%) and Namakan (65.8%), but the differences were not significant (Chi^2 = 5.037 df = 2 p = 0.081) (Figure 8, Table 5). Namakan has significantly fewer species per quadrat (lower richness) than Rainy, but there are no significant differences between the other basins (Chi^2 = 10.957, df = 2, p = 0.004) (Table 6, Figure 9).

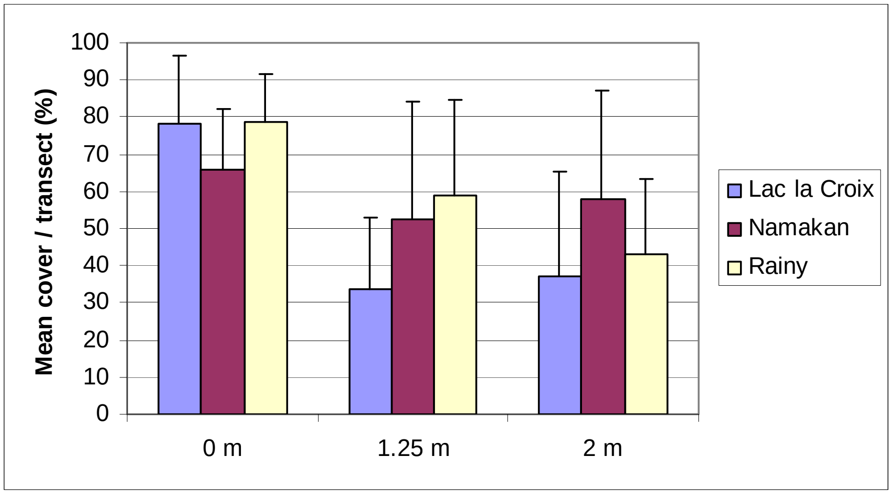


Figure 8. Mean cover (%) recorded at three depths across all three basins. Error bars represent one standard deviation.

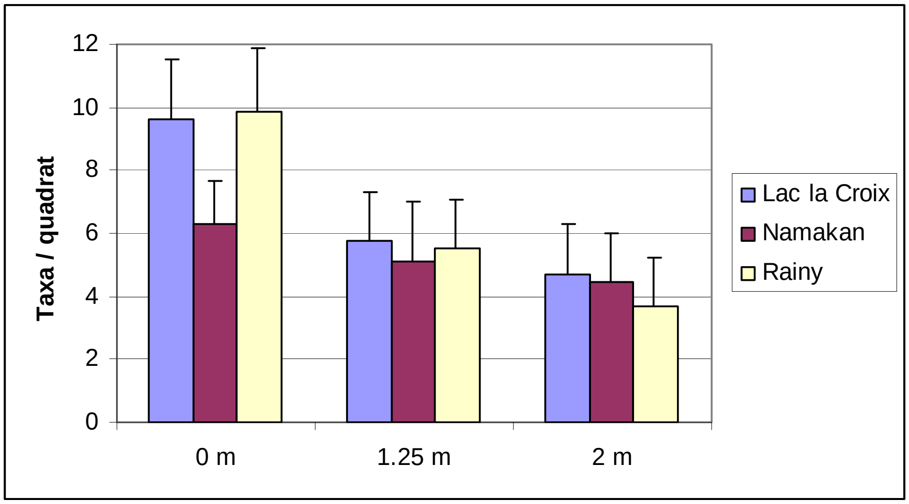


Figure 9. Mean number of taxa per 1 m x 1 m quadrat recorded at three depths across all three basins. Error bars represent one standard deviation.

Table 5. Total percent summed cover in 1 m x 1 m quadrats for all taxa recorded in the shoreline transects across all three basins. Lac la Croix was sampled with 10 transects comprising 200 quadrats, Namakan with 11 transects and 220 quadrats, and Rainy with 10 transects and 200 quadrats.

		Lac la Croix		Namakan		Rainy		Total all basins	
		Total Cover	% of total	Total Cover	% of total	Total Cover	% of total	Total Cover	% of total
1	*Abies balsamea*	0.0	0.0	0.0	0.0	0.1	0.0	0.1	0.0
2	*Acer rubrum*	34.8	0.2	17.2	0.1	6.1	0.0	58.1	0.1
3	*Acer saccharinum*	2.0	0.0	0.0	0.0	0.0	0.0	2.0	0.0
4	*Acorus calamus*	2.0	0.0	229.0	1.6	5.4	0.0	236.4	0.5
5	*Agalinis tenuifolia*	0.0	0.0	0.0	0.0	0.3	0.0	0.3	0.0
6	*Agrostis hyemalis*	53.1	0.3	3.1	0.0	28.7	0.2	84.9	0.2
7	*Alisma plantago-aquatica*	6.0	0.0	0.0	0.0	0.0	0.0	6.0	0.0
8	*Alnus incana*	76.0	0.5	632.0	4.4	70.1	0.4	778.1	1.7
9	*Apocynum androsaemifolium*	4.0	0.0	0.0	0.0	0.0	0.0	4.0	0.0
10	*Asclepias incarnata*	0.0	0.0	1.0	0.0	0.0	0.0	1.0	0.0
11	*Aster spp.*	202.9	1.3	68.4	0.5	261.6	1.7	532.9	1.2
12	*Betula papyrifera*	0.0	0.0	7.0	0.0	1.1	0.0	8.1	0.0
13	*Bidens spp.*	0.1	0.0	0.0	0.0	3.5	0.0	3.6	0.0
14	*Calamagrostis canadensis*	2382.5	15.2	2411.2	16.6	5678.1	36.1	10471.8	22.8
15	*Calla palustris*	0.0	0.0	0.1	0.0	0.0	0.0	0.1	0.0
16	*Campanula aparinoides*	103.5	0.7	48.1	0.3	316.0	2.0	467.6	1.0
17	*Cardamine spp.*	0.1	0.0	5.9	0.0	0.0	0.0	6.0	0.0
18	*Carex acutae group*	6.1	0.0	0.0	0.0	50.3	0.3	56.4	0.1
19	*Carex atherodes*	0.0	0.0	760.0	5.2	53.3	0.3	813.3	1.8
20	*Carex canescens*	45.4	0.3	3.4	0.0	0.1	0.0	48.9	0.1
21	*Carex chordorrhiza*	4.0	0.0	0.0	0.0	0.0	0.0	4.0	0.0

		Lac la Croix		Namakan		Rainy		Total all basins	
		Total Cover	% of total	Total Cover	% of total	Total Cover	% of total	Total Cover	% of total
22	*Carex crinita*	0.0	0.0	7.0	0.0	0.0	0.0	7.0	0.0
23	*Carex diandra*	0.0	0.0	0.1	0.0	0.0	0.0	0.1	0.0
24	*Carex lacustris*	0.0	0.0	307.0	2.1	206.6	1.3	513.6	1.1
25	*Carex lasiocarpa*	109.1	0.7	183.3	1.3	56.1	0.4	348.5	0.8
26	*Carex ovales group*	4.1	0.0	0.2	0.0	63.3	0.4	67.6	0.1
27	*Carex pellita*	5.0	0.0	0.0	0.0	20.5	0.1	25.5	0.1
28	*Carex praegracilis*	23.1	0.1	0.0	0.0	0.0	0.0	23.1	0.1
29	*Carex spp.*	11.4	0.1	0.1	0.0	52.0	0.3	63.5	0.1
30	*Carex utriculata*	1529.9	9.8	1522.3	10.5	226.2	1.4	3278.4	7.1
31	*Carex viridula*	26.0	0.2	20.0	0.1	0.0	0.0	46.0	0.1
32	*Ceratophyllum demersum*	0.0	0.0	0.2	0.0	0.0	0.0	0.2	0.0
33	*Chamaedaphne calyculata*	181.0	1.2	0.0	0.0	0.0	0.0	181.0	0.4
34	*Cicuta spp.*	0.1	0.0	8.7	0.1	1.6	0.0	10.4	0.0
35	*Cirsium spp.*	0.0	0.0	0.0	0.0	9.1	0.1	9.1	0.0
36	*Cornus sericea*	223.0	1.4	333.0	2.3	209.0	1.3	765.0	1.7
37	*Cuscuta sp_*	0.2	0.0	0.0	0.0	0.0	0.0	0.2	0.0
38	*Cyperus squarrosus*	0.0	0.0	0.0	0.0	0.1	0.0	0.1	0.0
39	*Cyperus strigosus*	0.0	0.0	0.0	0.0	0.3	0.0	0.3	0.0
40	*Deschampsia cespitosa*	0.1	0.0	0.0	0.0	0.0	0.0	0.1	0.0
41	*Dulichium arundinaceum*	381.3	2.4	0.0	0.0	0.0	0.0	381.3	0.8
42	*Elatine minima*	0.0	0.0	0.1	0.0	0.0	0.0	0.1	0.0
43	*Eleocharis acicularis*	2.1	0.0	56.4	0.4	0.0	0.0	58.5	0.1
44	*Eleocharis ovata*	0.0	0.0	0.0	0.0	2.3	0.0	2.3	0.0
45	*Eleocharis palustris*	1.1	0.0	46.2	0.3	0.2	0.0	47.5	0.1
46	*Epilobium coloratum*	0.0	0.0	0.0	0.0	2.0	0.0	2.0	0.0
47	*Equisetum spp.*	5.6	0.0	233.0	1.6	69.7	0.4	308.3	0.7
48	*Euthamia graminifolia*	109.3	0.7	11.1	0.1	3.1	0.0	123.5	0.3
49	*Fragaria sp.*	0.2	0.0	0.0	0.0	0.0	0.0	0.2	0.0
50	*Fraxinus spp.*	1069.1	6.8	175.1	1.2	47.0	0.3	1291.2	2.8
51	*Galium spp.*	79.5	0.5	3.1	0.0	97.4	0.6	180.0	0.4
52	*Geranium bicknellii*	0.0	0.0	0.0	0.0	0.1	0.0	0.1	0.0
53	*Glyceria borealis*	0.0	0.0	20.0	0.1	0.1	0.0	20.1	0.0
54	*Glyceria spp.*	2.1	0.0	3.0	0.0	2.0	0.0	7.1	0.0
55	*graminoid seedling*	2.4	0.0	0.0	0.0	0.0	0.0	2.4	0.0
56	*Hypericum majus*	0.1	0.0	0.0	0.0	109.0	0.7	109.1	0.2
57	*Impatiens capensis*	0.0	0.0	0.0	0.0	7.0	0.0	7.0	0.0
58	*Iris versicolor*	181.8	1.2	33.0	0.2	38.2	0.2	253.0	0.6
59	*Juncus filiformis*	130.0	0.8	25.0	0.2	0.0	0.0	155.0	0.3
60	*Juncus pelocarpus*	8.4	0.1	33.0	0.2	0.0	0.0	41.4	0.1
61	*Juncus spp.*	0.1	0.0	0.0	0.0	0.0	0.0	0.1	0.0
62	*Juncus tenuis*	0.0	0.0	0.1	0.0	0.1	0.0	0.2	0.0
63	*Lathyrus spp.*	0.0	0.0	6.1	0.0	40.5	0.3	46.6	0.1
64	*Leersia oryzoides*	0.0	0.0	0.0	0.0	9.2	0.1	9.2	0.0
65	*Lemna minor*	0.0	0.0	0.3	0.0	0.0	0.0	0.3	0.0
66	*Lemna trisulca*	0.0	0.0	133.6	0.9	0.0	0.0	133.6	0.3

		Lac la Croix		Namakan		Rainy		Total all basins	
		Total Cover	% of total	Total Cover	% of total	Total Cover	% of total	Total Cover	% of total
67	*Lycopodium spp.*	5.1	0.0	0.3	0.0	0.0	0.0	5.4	0.0
68	*Lycopus spp.*	73.1	0.5	43.0	0.3	257.7	1.6	373.8	0.8
69	*Lysimachia ciliata*	36.4	0.2	0.1	0.0	0.0	0.0	36.5	0.1
70	*Lysimachia spp.*	361.4	2.3	250.3	1.7	179.8	1.1	791.5	1.7
71	*Maianthemum canadense*	2.1	0.0	0.0	0.0	2.3	0.0	4.4	0.0
72	*Mentha arvensis*	36.9	0.2	17.2	0.1	0.6	0.0	54.7	0.1
73	*moss spp.*	411.5	2.6	121.3	0.8	326.8	2.1	859.6	1.9
74	*Myrica gale*	3946.0	25.2	3564.1	24.6	4045.0	25.7	11555.1	25.2
75	*Myriophyllum sp_*	0.0	0.0	0.1	0.0	0.0	0.0	0.1	0.0
76	*Onoclea sensibilis*	27.0	0.2	53.0	0.4	0.0	0.0	80.0	0.2
77	*Osmunda regalis*	380.1	2.4	0.0	0.0	0.0	0.0	380.1	0.8
78	*Oxalis sp.*	0.0	0.0	0.0	0.0	0.1	0.0	0.1	0.0
79	*Panicum spp.*	33.0	0.2	0.0	0.0	9.7	0.1	42.7	0.1
80	*Parthenocissus inserta*	0.0	0.0	0.0	0.0	4.0	0.0	4.0	0.0
81	*Petasites frigidus*	0.0	0.0	3.0	0.0	0.0	0.0	3.0	0.0
82	*Phalaris arundinacea*	2.1	0.0	122.0	0.8	154.5	1.0	278.6	0.6
83	*Phragmites australis*	22.0	0.1	76.0	0.5	213.1	1.4	311.1	0.7
84	*Pinus strobus*	0.0	0.0	275.0	1.9	51.9	0.3	326.9	0.7
85	*Poa spp.*	0.0	0.0	0.2	0.0	40.5	0.3	40.7	0.1
86	*Polygonum amphibium*	310.9	2.0	52.6	0.4	214.8	1.4	578.3	1.3
87	*Polygonum sagittatum*	0.1	0.0	66.0	0.5	260.8	1.7	326.9	0.7
88	*Polygonum spp.*	0.0	0.0	0.0	0.0	37.1	0.2	37.1	0.1
89	*Populus spp.*	0.0	0.0	3.0	0.0	12.2	0.1	15.2	0.0
90	*Potentilla norvegica*	0.1	0.0	0.0	0.0	101.8	0.6	101.9	0.2
91	*Potentilla palustris*	313.3	2.0	110.4	0.8	180.2	1.1	603.9	1.3
92	*Prunella vulgaris*	10.0	0.1	2.0	0.0	0.0	0.0	12.0	0.0
93	*Prunus pumila*	0.0	0.0	0.0	0.0	1.0	0.0	1.0	0.0
94	*Prunus virginiana*	0.0	0.0	0.0	0.0	3.0	0.0	3.0	0.0
95	*Ranunculus flammula*	9.6	0.1	0.0	0.0	0.3	0.0	9.9	0.0
96	*Ranunculus pensylvanicus*	0.3	0.0	0.0	0.0	1.2	0.0	1.5	0.0
97	*Rorippa spp.*	0.0	0.0	2.0	0.0	2.0	0.0	4.0	0.0
98	*Rosa spp.*	127.2	0.8	35.0	0.2	82.8	0.5	245.0	0.5
99	*Rubus spp.*	2.0	0.0	2.0	0.0	33.3	0.2	37.3	0.1
100	*Rumex spp.*	0.0	0.0	0.0	0.0	7.0	0.0	7.0	0.0
101	*Sagittaria spp.*	22.4	0.1	9.0	0.1	0.0	0.0	31.4	0.1
102	*Salix spp.*	316.1	2.0	159.0	1.1	345.0	2.2	820.1	1.8
103	*Scirpus cyperinus*	143.1	0.9	540.4	3.7	68.5	0.4	752.0	1.6
104	*Scirpus fluviatilis*	0.0	0.0	172.0	1.2	12.0	0.1	184.0	0.4
105	*Scutellaria spp.*	11.2	0.1	11.2	0.1	0.4	0.0	22.8	0.0
106	*Sium suave*	23.4	0.1	70.1	0.5	50.6	0.3	144.1	0.3
107	*Solidago spp.*	6.0	0.0	5.1	0.0	0.0	0.0	11.1	0.0
108	*Sparganium erect*	5.2	0.0	15.1	0.1	2.1	0.0	22.4	0.0
109	*Spartina pectinata*	38.0	0.2	0.0	0.0	0.0	0.0	38.0	0.1
110	*Sphagnum spp.*	98.6	0.6	0.0	0.0	19.1	0.1	117.7	0.3
111	*Spiraea alba*	999.4	6.4	1017.1	7.0	933.5	5.9	2950.0	6.4

		Lac la Croix		Namakan		Rainy		Total all basins	
		Total Cover	% of total	Total Cover	% of total	Total Cover	% of total	Total Cover	% of total
112	*Spirodela polyrhiza*	0.0	0.0	26.3	0.2	0.0	0.0	26.3	0.1
113	*Stachys palustris*	0.0	0.0	1.0	0.0	22.7	0.1	23.7	0.1
114	*Thelypteris palustris*	624.4	4.0	7.0	0.0	34.2	0.2	665.6	1.5
115	*Thuja occidentalis*	0.0	0.0	5.0	0.0	0.0	0.0	5.0	0.0
116	*Toxicodendron radicans*	59.4	0.4	8.0	0.1	0.0	0.0	67.4	0.1
117	*Triadenum fraseri*	187.1	1.2	26.5	0.2	2.4	0.0	216.0	0.5
118	*Trifolium sp.*	0.0	0.0	0.0	0.0	0.1	0.0	0.1	0.0
119	*Typha latifolia*	0.0	0.0	11.0	0.1	34.4	0.2	45.4	0.1
120	*Typha x glauca*	0.0	0.0	157.1	1.1	200.1	1.3	357.2	0.8
121	*Ulmus americana*	0.0	0.0	2.0	0.0	0.0	0.0	2.0	0.0
122	*Utricularia intermedia*	0.2	0.0	1.8	0.0	0.0	0.0	2.0	0.0
123	*Utricularia vulgaris*	0.0	0.0	0.1	0.0	0.0	0.0	0.1	0.0
124	*Verbena hastata*	0.0	0.0	0.0	0.0	0.2	0.0	0.2	0.0
125	*Veronica scutellata*	23.4	0.1	0.0	0.0	0.0	0.0	23.4	0.1
126	*Viburnum lentago*	0.0	0.0	91.0	0.6	0.0	0.0	91.0	0.2
127	*Viola spp.*	4.3	0.0	0.0	0.0	16.8	0.1	21.1	0.0
	Mean cover per quadrat	**78.4**	**100.0**	**65.8**	**100.0**	**78.6**	**100.0**	**74.0**	**100.0**

Table 6. Total frequency of occurrence in 1 m x 1 m quadrats for all taxa recorded in the shoreline transects across all three basins. Lac la Croix was sampled with 10 transects comprising 200 quadrats, Namakan with 11 transects and 220 quadrats, and Rainy with 10 transects and 200 quadrats.

	Lac la Croix		Namakan		Rainy		Total all basins	
Taxa	Total Freq.	% of total	Total Freq.	% of total	Total Freq.	% of total	Total Cover	% of total
Abies balsamea	0	0.0	0	0.0	1	0.1	1	0.0
Acer rubrum	32	1.7	4	0.3	4	0.2	40	0.8
Acer saccharinum	1	0.1	0	0.0	0	0.0	1	0.0
Acorus calamus	1	0.1	29	2.1	7	0.4	37	0.7
Agalinis tenuifolia	0	0.0	0	0.0	3	0.2	3	0.1
Agrostis hyemalis	7	0.4	3	0.2	20	1.0	30	0.6
Alisma plantago-aquatica	2	0.1	0	0.0	0	0.0	2	0.0
Alnus incana	7	0.4	34	2.5	9	0.5	50	1.0
Apocynum androsaemifolium	2	0.1	0	0.0	0	0.0	2	0.0
Asclepias incarnata	0	0.0	1	0.1	0	0.0	1	0.0
Aster spp.	55	2.9	16	1.2	78	4.0	149	2.8
Betula papyrifera	0	0.0	2	0.1	11	0.6	13	0.2
Bidens spp.	1	0.1	0	0.0	6	0.3	7	0.1
Calamagrostis canadensis	182	9.5	163	11.8	192	9.9	537	10.2
Calla palustris	0	0.0	1	0.1	0	0.0	1	0.0
Campanula aparinoides	69	3.6	42	3.0	68	3.5	179	3.4
Cardamine spp.	1	0.1	13	0.9	0	0.0	14	0.3

Taxa	Lac la Croix Total Freq.	Lac la Croix % of total	Namakan Total Freq.	Namakan % of total	Rainy Total Freq.	Rainy % of total	Total all basins Total Cover	Total all basins % of total
Carex acutae group	5	0.3	0	0.0	10	0.5	15	0.3
Carex atherodes	0	0.0	41	3.0	12	0.6	53	1.0
Carex canescens	31	1.6	6	0.4	1	0.1	38	0.7
Carex chordorrhiza	1	0.1	0	0.0	0	0.0	1	0.0
Carex crinita	0	0.0	1	0.1	0	0.0	1	0.0
Carex diandra	0	0.0	1	0.1	0	0.0	1	0.0
Carex lacustris	0	0.0	23	1.7	42	2.2	65	1.2
Carex lasiocarpa	11	0.6	19	1.4	4	0.2	34	0.6
Carex ovales group	2	0.1	2	0.1	11	0.6	15	0.3
Carex pellita	2	0.1	0	0.0	15	0.8	17	0.3
Carex praegracilis	6	0.3	0	0.0	0	0.0	6	0.1
Carex spp.	8	0.4	1	0.1	3	0.2	12	0.2
Carex utriculata	141	7.4	114	8.2	63	3.2	318	6.1
Carex viridula	6	0.3	1	0.1	0	0.0	7	0.1
Ceratophyllum demersum	0	0.0	2	0.1	0	0.0	2	0.0
Chamaedaphne calyculata	20	1.0	0	0.0	0	0.0	20	0.4
Cicuta spp.	1	0.1	20	1.4	7	0.4	28	0.5
Cirsium spp.	0	0.0	0	0.0	2	0.1	2	0.0
Cornus sericea	17	0.9	17	1.2	23	1.2	57	1.1
*Cuscuta sp_*	2	0.1	0	0.0	0	0.0	2	0.0
Cyperus squarrosus	0	0.0	0	0.0	1	0.1	1	0.0
Cyperus strigosus	0	0.0	0	0.0	3	0.2	3	0.1
Deschampsia cespitosa	1	0.1	0	0.0	0	0.0	1	0.0
Dulichium arundinaceum	29	1.5	0	0.0	0	0.0	29	0.6
Elatine minima	0	0.0	1	0.1	0	0.0	1	0.0
Eleocharis acicularis	2	0.1	9	0.6	0	0.0	11	0.2
Eleocharis ovata	0	0.0	0	0.0	5	0.3	5	0.1
Eleocharis palustris	2	0.1	9	0.6	2	0.1	13	0.2
Epilobium coloratum	0	0.0	0	0.0	1	0.1	1	0.0
Equisetum spp.	10	0.5	77	5.6	24	1.2	111	2.1
Euthamia graminifolia	10	0.5	5	0.4	3	0.2	18	0.3
Fragaria sp.	2	0.1	0	0.0	0	0.0	2	0.0
Fraxinus spp.	64	3.3	15	1.1	10	0.5	89	1.7
Galium spp.	55	2.9	3	0.2	51	2.6	109	2.1
Geranium bicknellii	0	0.0	0	0.0	1	0.1	1	0.0
Glyceria borealis	0	0.0	3	0.2	1	0.1	4	0.1
Glyceria spp.	2	0.1	1	0.1	1	0.1	4	0.1
graminoid seedling	6	0.3	0	0.0	0	0.0	6	0.1
Hypericum majus	1	0.1	0	0.0	76	3.9	77	1.5
Impatiens capensis	0	0.0	0	0.0	13	0.7	13	0.2
Iris versicolor	38	2.0	7	0.5	13	0.7	58	1.1
Juncus filiformis	60	3.1	1	0.1	0	0.0	61	1.2

Taxa	Lac la Croix		Namakan		Rainy		Total all basins	
	Total Freq.	% of total	Total Freq.	% of total	Total Freq.	% of total	Total Cover	% of total
Juncus pelocarpus	7	0.4	2	0.1	0	0.0	9	0.2
Juncus spp.	1	0.1	0	0.0	0	0.0	1	0.0
Juncus tenuis	0	0.0	1	0.1	1	0.1	2	0.0
Lathyrus spp.	0	0.0	5	0.4	18	0.9	23	0.4
Leersia oryzoides	0	0.0	0	0.0	7	0.4	7	0.1
Lemna minor	0	0.0	3	0.2	0	0.0	3	0.1
Lemna trisulca	0	0.0	19	1.4	0	0.0	19	0.4
Lycopodium spp.	4	0.2	3	0.2	0	0.0	7	0.1
Lycopus spp.	33	1.7	31	2.2	62	3.2	126	2.4
Lysimachia ciliata	12	0.6	1	0.1	0	0.0	13	0.2
Lysimachia spp.	145	7.6	108	7.8	124	6.4	377	7.2
Maianthemum canadense	2	0.1	0	0.0	4	0.2	6	0.1
Mentha arvensis	21	1.1	6	0.4	6	0.3	33	0.6
moss spp.	66	3.5	18	1.3	76	3.9	160	3.0
Myrica gale	146	7.6	89	6.4	147	7.5	382	7.3
*Myriophyllum sp_*	0	0.0	1	0.1	0	0.0	1	0.0
Onoclea sensibilis	4	0.2	5	0.4	0	0.0	9	0.2
Osmunda regalis	12	0.6	0	0.0	0	0.0	12	0.2
Oxalis sp.	0	0.0	0	0.0	1	0.1	1	0.0
Panicum spp.	2	0.1	0	0.0	11	0.6	13	0.2
Parthenocissus inserta	0	0.0	0	0.0	3	0.2	3	0.1
Petasites frigidus	0	0.0	1	0.1	0	0.0	1	0.0
Phalaris arundinacea	2	0.1	19	1.4	26	1.3	47	0.9
Phragmites australis	3	0.2	7	0.5	9	0.5	19	0.4
Pinus strobus	0	0.0	4	0.3	14	0.7	18	0.3
Poa spp.	0	0.0	2	0.1	18	0.9	20	0.4
Polygonum amphibium	75	3.9	25	1.8	52	2.7	152	2.9
Polygonum sagittatum	1	0.1	12	0.9	57	2.9	70	1.3
Polygonum spp.	0	0.0	0	0.0	47	2.4	47	0.9
Populus spp.	0	0.0	1	0.1	3	0.2	4	0.1
Potentilla norvegica	1	0.1	0	0.0	85	4.4	86	1.6
Potentilla palustris	50	2.6	29	2.1	27	1.4	106	2.0
Prunella vulgaris	2	0.1	1	0.1	0	0.0	3	0.1
Prunus pumila	0	0.0	0	0.0	1	0.1	1	0.0
Prunus virginiana	0	0.0	0	0.0	1	0.1	1	0.0
Ranunculus flammula	8	0.4	0	0.0	3	0.2	11	0.2
Ranunculus pensylvanicus	3	0.2	0	0.0	3	0.2	6	0.1
Rorippa spp.	0	0.0	2	0.1	1	0.1	3	0.1
Rosa spp.	21	1.1	6	0.4	29	1.5	56	1.1
Rubus spp.	1	0.1	1	0.1	30	1.5	32	0.6
Rumex spp.	0	0.0	0	0.0	3	0.2	3	0.1
Sagittaria spp.	12	0.6	4	0.3	0	0.0	16	0.3

Taxa	Lac la Croix			Namakan			Rainy			Total all basins	
	Total Freq.	% of total		Total Freq.	% of total		Total Freq.	% of total		Total Cover	% of total
Salix spp.	30	1.6		11	0.8		33	1.7		74	1.4
Scirpus cyperinus	37	1.9		60	4.3		20	1.0		117	2.2
Scirpus fluviatilis	0	0.0		15	1.1		5	0.3		20	0.4
Scutellaria spp.	5	0.3		8	0.6		4	0.2		17	0.3
Sium suave	25	1.3		41	3.0		35	1.8		101	1.9
Solidago spp.	3	0.2		2	0.1		0	0.0		5	0.1
Sparganium erect	5	0.3		6	0.4		2	0.1		13	0.2
Spartina pectinata	3	0.2		0	0.0		0	0.0		3	0.1
Sphagnum spp.	20	1.0		0	0.0		7	0.4		27	0.5
Spiraea alba	101	5.3		55	4.0		97	5.0		253	4.8
Spirodela polyrhiza	0	0.0		17	1.2		0	0.0		17	0.3
Stachys palustris	0	0.0		1	0.1		17	0.9		18	0.3
Thelypteris palustris	53	2.8		4	0.3		10	0.5		67	1.3
Thuja occidentalis	0	0.0		1	0.1		0	0.0		1	0.0
Toxicodendron radicans	15	0.8		4	0.3		0	0.0		19	0.4
Triadenum fraseri	68	3.6		16	1.2		5	0.3		89	1.7
Trifolium sp.	0	0.0		0	0.0		1	0.1		1	0.0
Typha latifolia	0	0.0		5	0.4		15	0.8		20	0.4
Typha x glauca	0	0.0		31	2.2		15	0.8		46	0.9
Ulmus americana	0	0.0		1	0.1		0	0.0		1	0.0
Utricularia intermedia	2	0.1		9	0.6		0	0.0		11	0.2
Utricularia vulgaris	0	0.0		1	0.1		0	0.0		1	0.0
Verbena hastata	0	0.0		0	0.0		2	0.1		2	0.0
Veronica scutellata	10	0.5		0	0.0		0	0.0		10	0.2
Viburnum lentago	0	0.0		4	0.3		0	0.0		4	0.1
Viola spp.	6	0.3		0	0.0		15	0.8		21	0.4
Totals per basin	1912			1385			1949			5246	
Mean richness per quadrat	9.6			6.3			9.7			8.5	
Number of taxa recorded per basin	80			83			84				

Table 7. Total relative importance value for all taxa recorded in the shoreline quadrats across all three basins. Lac la Croix was sampled with 10 transects comprising 200 quadrats, Namakan with 11 transects and 220 quadrats, and Rainy with 10 transects and 200 quadrats. Relative importance was calculated by averaging relative cover and relative frequency.

	Lac la Croix		Namakan		Rainy		Total all basins	
Taxa	Total Rel. IV	% of total	Total Rel. IV	% of total	Total Rel. IV	% of total	Total Rel. IV	% of total
Abies balsamea	0.0	0.0	0.0	0.0	0.3	0.0	0.3	0.0
Acer rubrum	8.8	0.9	2.6	0.2	1.1	0.1	13.6	0.4
Acer saccharinum	0.3	0.0	0.0	0.0	0.0	0.0	0.3	0.0
Acorus calamus	0.3	0.0	18.9	1.7	2.2	0.2	23.1	0.7
Agalinis tenuifolia	0.0	0.0	0.0	0.0	0.9	0.1	0.9	0.0
Agrostis hyemalis	3.4	0.3	1.4	0.1	6.7	0.7	12.0	0.4
Alisma plantago-aquatica	0.6	0.1	0.0	0.0	0.0	0.0	0.7	0.0
Alnus incana	4.5	0.5	38.7	3.5	4.2	0.4	51.4	1.6
Apocynum androsaemifolium	0.6	0.1	0.0	0.0	0.0	0.0	0.7	0.0
Asclepias incarnata	0.0	0.0	0.4	0.0	0.0	0.0	0.5	0.0
Aster spp.	21.1	2.1	8.0	0.7	25.5	2.6	57.4	1.7
Betula papyrifera	0.0	0.0	1.2	0.1	3.2	0.3	4.5	0.1
Bidens spp.	0.3	0.0	0.0	0.0	1.8	0.2	2.1	0.1
Calamagrostis canadensis	121.0	12.1	160.9	14.6	233.5	23.4	542.2	16.4
Calla palustris	0.0	0.0	0.3	0.0	0.0	0.0	0.3	0.0
Campanula aparinoides	19.9	2.0	18.6	1.7	25.0	2.5	67.2	2.0
Cardamine spp.	0.4	0.0	5.6	0.5	0.0	0.0	6.5	0.2
Carex acutae group	1.5	0.1	0.0	0.0	4.5	0.5	6.1	0.2
Carex atherodes	0.0	0.0	46.3	4.2	5.4	0.5	55.9	1.7
Carex canescens	9.2	0.9	2.1	0.2	0.3	0.0	12.7	0.4
Carex chordorrhiza	0.3	0.0	0.0	0.0	0.0	0.0	0.4	0.0
Carex crinita	0.0	0.0	0.8	0.1	0.0	0.0	0.8	0.0
Carex diandra	0.0	0.0	0.4	0.0	0.0	0.0	0.4	0.0
Carex lacustris	0.0	0.0	21.4	1.9	18.0	1.8	41.3	1.3
Carex lasiocarpa	6.3	0.6	15.8	1.4	3.1	0.3	27.2	0.8
Carex ovales group	0.5	0.1	0.7	0.1	4.1	0.4	5.5	0.2
Carex pellita	0.6	0.1	0.0	0.0	4.5	0.4	5.2	0.2
Carex praegracilis	2.2	0.2	0.0	0.0	0.0	0.0	2.4	0.1
Carex spp.	2.0	0.2	0.4	0.0	3.1	0.3	5.7	0.2
Carex utriculata	89.2	8.9	103.4	9.4	25.1	2.5	236.1	7.2
Carex viridula	2.5	0.2	1.3	0.1	0.0	0.0	4.1	0.1
Ceratophyllum demersum	0.0	0.0	0.8	0.1	0.0	0.0	0.9	0.0
Chamaedaphne calyculata	11.1	1.1	0.0	0.0	0.0	0.0	12.2	0.4
Cicuta spp.	0.2	0.0	6.6	0.6	1.6	0.2	9.0	0.3
Cirsium spp.	0.0	0.0	0.0	0.0	0.8	0.1	0.8	0.0
Cornus sericea	12.8	1.3	19.9	1.8	11.5	1.1	47.3	1.4
Cuscuta sp.	0.4	0.0	0.0	0.0	0.0	0.0	0.5	0.0

Taxa	Lac la Croix Total Rel. IV	Lac la Croix % of total	Namakan Total Rel. IV	Namakan % of total	Rainy Total Rel. IV	Rainy % of total	Total all basins Total Rel. IV	Total all basins % of total
Cyperus squarrosus	0.0	0.0	0.0	0.0	0.4	0.0	0.4	0.0
Cyperus strigosus	0.0	0.0	0.0	0.0	0.9	0.1	0.9	0.0
Deschampsia cespitosa	0.2	0.0	0.0	0.0	0.0	0.0	0.3	0.0
Dulichium arundinaceum	20.6	2.1	0.0	0.0	0.0	0.0	22.7	0.7
Elatine minima	0.0	0.0	0.5	0.0	0.0	0.0	0.5	0.0
Eleocharis acicularis	0.8	0.1	5.9	0.5	0.0	0.0	7.2	0.2
Eleocharis ovata	0.0	0.0	0.0	0.0	1.5	0.1	1.5	0.0
Eleocharis palustris	0.6	0.1	5.1	0.5	0.5	0.0	6.7	0.2
Epilobium coloratum	0.0	0.0	0.0	0.0	0.4	0.0	0.4	0.0
Equisetum spp.	3.1	0.3	38.6	3.5	8.1	0.8	53.6	1.6
Euthamia graminifolia	6.1	0.6	2.8	0.3	1.0	0.1	10.8	0.3
Fragaria sp.	0.6	0.1	0.0	0.0	0.0	0.0	0.6	0.0
Fraxinus spp.	47.3	4.7	13.2	1.2	4.1	0.4	70.6	2.1
Galium spp.	16.0	1.6	1.3	0.1	15.4	1.5	34.5	1.0
Geranium bicknellii	0.0	0.0	0.0	0.0	0.2	0.0	0.2	0.0
Glyceria borealis	0.0	0.0	2.3	0.2	0.3	0.0	2.8	0.1
Glyceria spp.	0.5	0.0	0.6	0.1	0.3	0.0	1.4	0.0
graminoid seedling	1.6	0.2	0.0	0.0	0.0	0.0	1.7	0.1
Hypericum majus	0.2	0.0	0.0	0.0	22.0	2.2	22.2	0.7
Impatiens capensis	0.0	0.0	0.0	0.0	3.3	0.3	3.3	0.1
Iris versicolor	15.6	1.6	4.0	0.4	5.0	0.5	26.6	0.8
Juncus filiformis	20.9	2.1	1.5	0.1	0.0	0.0	24.7	0.7
Juncus pelocarpus	1.9	0.2	2.3	0.2	0.0	0.0	4.6	0.1
Juncus spp.	0.2	0.0	0.0	0.0	0.0	0.0	0.2	0.0
Juncus tenuis	0.0	0.0	0.5	0.0	0.2	0.0	0.8	0.0
Lathyrus spp.	0.0	0.0	2.6	0.2	4.9	0.5	7.8	0.2
Leersia oryzoides	0.0	0.0	0.0	0.0	2.2	0.2	2.2	0.1
Lemna minor	0.0	0.0	1.1	0.1	0.0	0.0	1.2	0.0
Lemna trisulca	0.0	0.0	11.5	1.0	0.0	0.0	12.6	0.4
Lycopodium spp.	1.2	0.1	1.3	0.1	0.0	0.0	2.8	0.1
Lycopus spp.	10.4	1.0	13.8	1.3	22.2	2.2	48.6	1.5
Lysimachia ciliata	4.1	0.4	0.6	0.1	0.0	0.0	5.1	0.2
Lysimachia spp.	50.6	5.1	51.2	4.7	37.7	3.8	149.2	4.5
Maianthemum canadense	0.7	0.1	0.0	0.0	1.0	0.1	1.7	0.1
Mentha arvensis	6.5	0.6	2.2	0.2	1.5	0.2	11.0	0.3
moss spp.	29.4	2.9	9.8	0.9	29.0	2.9	72.0	2.2
Myrica gale	165.3	16.5	168.3	15.3	163.7	16.4	529.0	16.0
Myriophyllum spp.	0.0	0.0	0.4	0.0	0.0	0.0	0.4	0.0
Onoclea sensibilis	1.8	0.2	3.7	0.3	0.0	0.0	6.0	0.2
Osmunda regalis	15.7	1.6	0.0	0.0	0.0	0.0	17.2	0.5
Oxalis sp.	0.0	0.0	0.0	0.0	0.2	0.0	0.2	0.0
Panicum spp.	1.5	0.2	0.0	0.0	3.2	0.3	4.9	0.1

Taxa	Lac la Croix		Namakan		Rainy		Total all basins	
	Total Rel. IV	% of total	Total Rel. IV	% of total	Total Rel. IV	% of total	Total Rel. IV	% of total
Parthenocissus inserta	0.0	0.0	0.0	0.0	1.2	0.1	1.2	0.0
Petasites frigidus	0.0	0.0	0.4	0.0	0.0	0.0	0.4	0.0
Phalaris arundinacea	0.6	0.1	12.6	1.1	14.4	1.4	28.7	0.9
Phragmites australis	1.6	0.2	6.4	0.6	9.4	0.9	18.1	0.5
Pinus strobus	0.0	0.0	8.6	0.8	5.1	0.5	14.5	0.4
Poa spp.	0.0	0.0	0.9	0.1	4.8	0.5	5.7	0.2
Polygonum amphibium	31.4	3.1	12.1	1.1	20.5	2.0	68.2	2.1
Polygonum sagittatum	0.2	0.0	7.9	0.7	23.5	2.3	32.3	1.0
Polygonum spp.	0.0	0.0	0.0	0.0	13.8	1.4	13.8	0.4
Populus spp.	0.0	0.0	0.7	0.1	1.3	0.1	2.1	0.1
Potentilla norvegica	0.3	0.0	0.0	0.0	24.3	2.4	24.6	0.7
Potentilla palustris	24.0	2.4	16.0	1.5	11.9	1.2	55.8	1.7
Prunella vulgaris	0.9	0.1	0.5	0.0	0.0	0.0	1.5	0.0
Prunus pumila	0.0	0.0	0.0	0.0	0.4	0.0	0.4	0.0
Prunus virginiana	0.0	0.0	0.0	0.0	0.3	0.0	0.3	0.0
Ranunculus flammula	2.4	0.2	0.0	0.0	0.8	0.1	3.4	0.1
Ranunculus pensylvanicus	0.7	0.1	0.0	0.0	0.9	0.1	1.6	0.0
Rorippa spp.	0.0	0.0	0.8	0.1	0.4	0.0	1.3	0.0
Rosa spp.	8.8	0.9	3.0	0.3	10.2	1.0	23.2	0.7
Rubus spp.	0.3	0.0	0.4	0.0	7.7	0.8	8.5	0.3
Rumex spp.	0.0	0.0	0.0	0.0	1.1	0.1	1.1	0.0
Sagittaria spp.	4.0	0.4	1.4	0.1	0.0	0.0	5.9	0.2
Salix spp.	19.6	2.0	11.6	1.1	19.5	2.0	53.7	1.6
Scirpus cyperinus	13.8	1.4	45.6	4.1	7.4	0.7	72.3	2.2
Scirpus fluviatilis	0.0	0.0	10.9	1.0	1.3	0.1	13.2	0.4
Scutellaria spp.	1.6	0.2	3.2	0.3	1.2	0.1	6.4	0.2
Sium suave	6.7	0.7	18.4	1.7	9.8	1.0	37.2	1.1
Solidago spp.	0.9	0.1	1.1	0.1	0.0	0.0	2.2	0.1
Sparganium erect	1.4	0.1	3.0	0.3	0.6	0.1	5.3	0.2
Spartina pectinata	2.5	0.2	0.0	0.0	0.0	0.0	2.7	0.1
Sphagnum spp.	8.3	0.8	0.0	0.0	2.7	0.3	11.8	0.4
Spiraea alba	62.8	6.3	64.8	5.9	57.6	5.8	197.3	6.0
Spirodela polyrhiza	0.0	0.0	7.1	0.6	0.0	0.0	7.7	0.2
Stachys palustris	0.0	0.0	0.6	0.1	4.2	0.4	4.9	0.1
Thelypteris palustris	29.7	3.0	2.2	0.2	3.4	0.3	38.5	1.2
Thuja occidentalis	0.0	0.0	0.7	0.1	0.0	0.0	0.7	0.0
Toxicodendron radicans	5.9	0.6	1.8	0.2	0.0	0.0	8.4	0.3
Triadenum fraseri	23.0	2.3	7.2	0.7	1.4	0.1	34.6	1.0
Trifolium sp.	0.0	0.0	0.0	0.0	0.2	0.0	0.2	0.0
Typha latifolia	0.0	0.0	2.7	0.2	4.6	0.5	7.5	0.2
Typha x glauca	0.0	0.0	18.1	1.6	13.8	1.4	33.5	1.0
Ulmus americana	0.0	0.0	0.7	0.1	0.0	0.0	0.7	0.0

Taxa	Lac la Croix			Namakan			Rainy			Total all basins	
	Total Rel. IV	% of total		Total Rel. IV	% of total		Total Rel. IV	% of total		Total Rel. IV	% of total
Utricularia intermedia	0.5	0.0		3.5	0.3		0.0	0.0		4.4	0.1
Utricularia vulgaris	0.0	0.0		0.4	0.0		0.0	0.0		0.4	0.0
Verbena hastata	0.0	0.0		0.0	0.0		0.5	0.0		0.5	0.0
Veronica scutellata	3.5	0.3		0.0	0.0		0.0	0.0		3.8	0.1
Viburnum lentago	0.0	0.0		3.9	0.4		0.0	0.0		4.3	0.1
Viola spp.	1.4	0.1		0.0	0.0		4.3	0.4		5.9	0.2
	1000.0	100.0		1100.0	100.0		1000.0	100.0		3300.0	100.0

Total cover
The twenty most abundant taxa by cover for each basin are listed inTable 8. Three taxa, *Myrica gale*, *Calamagrostis canadensis*, and *Spirea alba* were among the top five taxa in all basins. In addition the top five taxa by cover accounted for between 63.3% (Lac la Croix) and 72.1% (Rainy) of total cover of all taxa. The floristic composition begins to diverge thereafter as only four of the top 10 taxa are shared among the basins (with the addition of *Carex utriculata*). The ten taxa with the most cover in Lac la Croix accounted for 77.1% of the total cover of all 80 taxa found in shoreline transects in that basin. In Namakan the top ten accounted for 78.5% of the 83 taxa's total cover, and the top ten in Rainy accounted for 80.5% of the 84 taxa total. In general, a few taxa accounted for most of the cover in all basins.

Frequency
A similar analysis of frequency of occurrence shows a more balanced flora, as the top five taxa as measured by frequency in each basin accounted for only 37.4, 39.8, and 33.1% of the total frequency in Lac la Croix, Namakan, and Rainy respectively (Table 9). As with cover, three taxa were in the top five for frequency in all three basins, including *Myrica gale*, *Calamagrostis canadensis*, and *Lysimachia* spp. There were six shared taxa in the top ten in frequency, with the addition of *Carex utriculata*, *Spirea alba*, and *Campanula aparinoides*. Compared to the cover metric, the top ten taxa by frequency for each basin accounted for much less of the relative total at 55.3, 57.0, and 51.6% for Lac la Croix, Namakan, and Rainy respectively.

Importance values
The top five taxa in relative importance value accounted for 48.9, 49.9, and 52.1% of total IV in Lac la Croix, Namakan, and Rainy respectively (Table 10). This was expected as IV is a composite of the cover and frequency. Four taxa of the top five were in common (*Myrica gale*, *Calamagrostis canadensis*, *Spirea alba* and *Lysimachia* spp.).

Table 8. Most abundant taxa by percent cover in 1 m x 1 m quadrats recorded in the shoreline quadrats across all three basins. Lac la Croix was sampled with 10 transects comprising 200 quadrats, Namakan with 11 transects and 220 quadrats, and Rainy with 10 transects and 200 quadrats.

Lac la Croix				**Namakan**					**Rainy**					
Taxa	**Total Cover**	**% of total**	**Cum. %**		**Taxa**	**Total Cover**	**% of total**	**Cum. %**		**Taxa**	**Total Cover**	**% of total**	**Cum. %**	
Myrica gale	3946.0	25.2	25.2	1	Myrica gale	3564.1	24.6	24.6	1	Calamagrostis canadensis	5678.1	36.1	36.1	
Calamagrostis canadensis	2382.5	15.2	40.4	2	Calamagrostis canadensis	2411.2	16.6	41.3	2	Myrica gale	4045.0	25.7	61.9	
Carex utriculata	1529.9	9.8	50.1	3	Carex utriculata	1522.3	10.5	51.8	3	Spiraea alba	933.5	5.9	67.8	
Fraxinus spp.	1069.1	6.8	56.9	4	Spiraea alba	1017.1	7.0	58.8	4	Salix spp.	345.0	2.2	70.0	
Spiraea alba	999.4	6.4	63.3	5	Carex atherodes	760.0	5.2	64.0	5	moss spp.	326.8	2.1	72.1	
Thelypteris palustris	624.4	4.0	67.3	6	Alnus incana	632.0	4.4	68.4	6	Campanula aparinoides	316.0	2.0	74.1	
moss spp.	411.5	2.6	69.9	7	Scirpus cyperinus	540.4	3.7	72.1	7	Aster spp.	261.6	1.7	75.8	
Dulichium arundinaceum	381.3	2.4	72.3	8	Cornus sericea	333.0	2.3	74.4	8	Polygonum sagittatum	260.8	1.7	77.4	
Osmunda regalis	380.1	2.4	74.8	9	Carex lacustris	307.0	2.1	76.6	9	Lycopus spp.	257.7	1.6	79.1	
Lysimachia spp.	361.4	2.3	77.1	10	Pinus strobus	275.0	1.9	78.5	10	Carex utriculata	226.2	1.4	80.5	
Salix spp.	316.1	2.0	79.1	11	Lysimachia spp.	250.3	1.7	80.2	11	Polygonum amphibium	214.8	1.4	81.9	
Potentilla palustris	313.3	2.0	81.1	12	Equisetum spp.	233.0	1.6	81.8	12	Phragmites australis	213.1	1.4	83.2	
Polygonum amphibium	310.9	2.0	83.1	13	Acorus calamus	229.0	1.6	83.4	13	Cornus sericea	209.0	1.3	84.6	
Cornus sericea	223.0	1.4	84.5	14	Carex lasiocarpa	183.3	1.3	84.6	14	Carex lacustris	206.6	1.3	85.9	
Aster spp.	202.9	1.3	85.8	15	Fraxinus spp.	175.1	1.2	85.9	15	Typha x glauca	200.1	1.3	87.2	
Triadenum fraseri	187.1	1.2	87.0	16	Scirpus fluviatilis	172.0	1.2	87.0	16	Potentilla palustris	180.2	1.1	88.3	
Iris versicolor	181.8	1.2	88.1	17	Salix spp_	159.0	1.1	88.1	17	Lysimachia spp.	179.8	1.1	89.4	
Chamaedaphne calyculata	181.0	1.2	89.3	18	Typha x glauca	157.1	1.1	89.2	18	Phalaris arundinacea	154.5	1.0	90.4	
Scirpus cyperinus	143.1	0.9	90.2	19	Lemna trisulca	133.6	0.9	90.1	19	Hypericum majus	109.0	0.7	91.1	
Juncus filiformis	130.0	0.8	91.0	20	Phalaris arundinacea	122.0	0.8	91.0	20	Potentilla norvegica	101.8	0.6	91.8	

Table 9. Most abundant taxa by frequency of occurrence in 1 m x 1 m quadrats recorded in the shoreline quadrats across all three basins. Lac la Croix was sampled with 10 transects comprising 200 quadrats, Namakan with 11 transects and 220 quadrats, and Rainy with 10 transects and 200 quadrats.

		Lac la Croix					**Namakan**					**Rainy**		
	Taxa	**Total Freq.**	**% of total**	**Cum. %**			**Total Freq.**	**% of total**	**Cum. %**			**Total Freq.**	**% of total**	**Cum. %**
1	Calamagrostis canadensis	182	9.5	9.5	1	Calamagrostis canadensis	163	11.8	11.8	1	Calamagrostis canadensis	192	9.9	9.9
2	Myrica gale	146	7.6	17.2	2	Carex utriculata	114	8.2	20.0	2	Myrica gale	147	7.5	17.4
3	Lysimachia spp.	145	7.6	24.7	3	Lysimachia spp.	108	7.8	27.8	3	Lysimachia spp.	124	6.4	23.8
4	Carex utriculata	141	7.4	32.1	4	Myrica gale	89	6.4	34.2	4	Spiraea alba	97	5.0	28.7
5	Spiraea alba	101	5.3	37.4	5	Equisetum spp.	77	5.6	39.8	5	Potentilla norvegica	85	4.4	33.1
6	Polygonum amphibium	75	3.9	41.3	6	Scirpus cyperinus	60	4.3	44.1	6	Aster spp.	78	4.0	37.1
7	Campanula aparinoides	69	3.6	44.9	7	Spiraea alba	55	4.0	48.1	7	Hypericum majus	76	3.9	41.0
8	Triadenum fraseri	68	3.6	48.5	8	Campanula aparinoides	42	3.0	51.1	8	moss spp.	76	3.9	44.9
9	moss spp.	66	3.5	51.9	9	Carex atherodes	41	3.0	54.1	9	Campanula aparinoides	68	3.5	48.4
10	Fraxinus spp.	64	3.3	55.3	10	Sium suave	41	3.0	57.0	10	Carex utriculata	63	3.2	51.6
11	Juncus filiformis	60	3.1	58.4	11	Alnus incana	34	2.5	59.5	11	Lycopus spp.	62	3.2	54.8
12	Aster spp.	55	2.9	61.3	12	Lycopus spp.	31	2.2	61.7	12	Polygonum sagittatum	57	2.9	57.7
13	Galium spp.	55	2.9	64.2	13	Typha x glauca	31	2.2	64.0	13	Polygonum amphibium	52	2.7	60.4
14	Thelypteris palustris	53	2.8	66.9	14	Acorus calamus	29	2.1	66.1	14	Galium spp.	51	2.6	63.0
15	Potentilla palustris	50	2.6	69.6	15	Potentilla palustris	29	2.1	68.2	15	Polygonum spp.	47	2.4	65.4
16	Iris versicolor	38	2.0	71.5	16	Polygonum amphibium	25	1.8	70.0	16	Carex lacustris	42	2.2	67.6
17	Scirpus cyperinus	37	1.9	73.5	17	Carex lacustris	23	1.7	71.6	17	Sium suave	35	1.8	69.4
18	Lycopus spp.	33	1.7	75.2	18	Cicuta spp.	20	1.4	73.1	18	Salix spp.	33	1.7	71.1
19	Acer rubrum	32	1.7	76.9	19	Carex lasiocarpa	19	1.4	74.4	19	Rubus spp.	30	1.5	72.6
20	Carex canescens	31	1.6	78.5	20	Phalaris arundinacea	19	1.4	75.8	20	Rosa spp.	29	1.5	74.1

Table 10. Most abundant taxa by relative importance value (IV) in 1 m x 1 m quadrats recorded in the shoreline quadrats across all three basins. Lac la Croix was sampled with 10 transects comprising 200 quadrats, Namakan with 11 transects and 220 quadrats, and Rainy with 10 transects and 200 quadrats.

		Lac la Croix					**Namakan**					**Rainy**		
		Total	**% of**	**Cum.**			**Total**	**% of**	**Cum.**			**Total**	**% of**	**Cum.**
	Taxa	**Rel. IV**	**total**	**%**			**Rel. IV**	**total**	**%**			**Rel. IV**	**total**	**%**
1	Myrica gale	165.3	16.5	16.5	1	Myrica gale	168.3	15.3	15.3	1	Calamagrostis canadensis	233.5	23.4	23.4
2	Calamagrostis canadensis	121.0	12.1	28.6	2	Calamagrostis canadensis	160.9	14.6	29.9	2	Myrica gale	163.7	16.4	39.7
3	Carex utriculata	89.2	8.9	37.6	3	Carex utriculata	103.4	9.4	39.3	3	Spiraea alba	57.6	5.8	45.5
4	Spiraea alba	62.8	6.3	43.8	4	Spiraea alba	64.8	5.9	45.2	4	Lysimachia spp.	37.7	3.8	49.2
5	Lysimachia spp.	50.6	5.1	48.9	5	Lysimachia spp.	51.2	4.7	49.9	5	moss spp.	29.0	2.9	52.1
6	Fraxinus spp.	47.3	4.7	53.6	6	Carex atherodes	46.3	4.2	54.1	6	Aster spp.	25.5	2.6	54.7
7	Polygonum amphibium	31.4	3.1	56.8	7	Scirpus cyperinus	45.6	4.1	58.2	7	Carex utriculata	25.1	2.5	57.2
8	Thelypteris palustris	29.7	3.0	59.7	8	Alnus incana	38.7	3.5	61.7	8	Campanula aparinoides	25.0	2.5	59.7
9	moss spp.	29.4	2.9	62.7	9	Equisetum spp.	38.6	3.5	65.2	9	Potentilla norvegica	24.3	2.4	62.1
10	Potentilla palustris	24.0	2.4	65.1	10	Carex lacustris	21.4	1.9	67.2	10	Polygonum sagittatum	23.5	2.3	64.5
11	Triadenum fraseri	23.0	2.3	67.4	11	Cornus sericea	19.9	1.8	69.0	11	Lycopus spp.	22.2	2.2	66.7
12	Aster spp.	21.1	2.1	69.5	12	Acorus calamus	18.9	1.7	70.7	12	Hypericum majus	22.0	2.2	68.9
13	Juncus filiformis	20.9	2.1	71.6	13	Campanula aparinoides	18.6	1.7	72.4	13	Polygonum amphibium	20.5	2.0	71.0
14	Dulichium arundinaceum	20.6	2.1	73.6	14	Sium suave	18.4	1.7	74.1	14	Salix spp.	19.5	2.0	72.9
15	Campanula aparinoides	19.9	2.0	75.6	15	Typha x glauca	18.1	1.6	75.7	15	Carex lacustris	18.0	1.8	74.7
16	Salix spp.	19.6	2.0	77.6	16	Potentilla palustris	16.0	1.5	77.2	16	Galium spp.	15.4	1.5	76.3
17	Galium spp.	16.0	1.6	79.2	17	Carex lasiocarpa	15.8	1.4	78.6	17	Phalaris arundinacea	14.4	1.4	77.7
18	Osmunda regalis	15.7	1.6	80.8	18	Lycopus spp.	13.8	1.3	79.9	18	Typha x glauca	13.8	1.4	79.1
19	Iris versicolor	15.6	1.6	82.3	19	Fraxinus spp.	13.2	1.2	81.1	19	Polygonum spp.	13.8	1.4	80.4
20	Scirpus cyperinus	13.8	1.4	83.7	20	Phalaris arundinacea	12.6	1.1	82.2	20	Potentilla palustris	11.9	1.2	81.6

Unique Taxa

Taxa recorded in the 620 total shoreline quadrats were designated as unique in two ways: some were unique to a particular basin, while others were uniquely absent from one of the three basins. Table 11 indicates those taxa with overall frequencies of occurrence of 10 or greater across all basins that were uniquely either absent or present at one basin. Without thorough analysis of distributional data, it is difficult to explain most of these differences. However, some taxonomic distributions are easily noted in the different basins, such as the absence of the aggressive taxa *Typha* x *glauca* and *Scirpus fluviatile* in Lac la Croix. Some taxa that appear rather routinely in one basin (e.g. *Juncus filiformis* n=60 in Lac la Croix) may be replaced in other basins by other taxa that occur routinely in those basins (e.g. *Carex atherodes* or *Carex lacustris* n=53 and 65 in Namakan and Rainy respectively). The taxa unique to a particular basin include poor fen taxa in Lac la Croix (*Osmunda regalis*, *Chamaedaphne calyculata*, and *Dulichium arundinaceum*) and annuals in Rainy (*Polygonum* spp.).

Ordinations

Exploratory analysis indicated that at the 0.0 m depth one transect appeared as an outlier (Namakan Site 1) due, in part, to having considerable cover of *Lemna trisulca* and *Spirodela polyrhiza*. Namakan Site 1 is the only shoreline site for these typically aquatic taxa. After deleting the rare taxa and Namakan Site 1, the ordination discussed below was calculated on a matrix of 30 transects and 95 taxa.

The strongest factor influencing the ordination (Figure 10) appeared to be an elevational gradient along axis one, with the tree and shrub taxa better represented at sites with higher axis one scores (r= 0.730), and sites dominated by the graminoid taxa (grasses and sedges, r=-0.848) and aquatic taxa (r=-0.627) plotting lower on axis one.

In addition six of the Lac la Croix shoreline transects were loosely clustered higher on axis two, above the bulk of the Rainy sites. These Lac la Croix sites were better represented by the facultative wetland taxa (r=0.558; not shown), which may be related to the non-regulated nature of the Lac la Croix shoreline.

Multi-response Permutation Procedure

A pairwise comparison of vegetation data suggests that shoreline vegetation at Rainy Lake is significantly different from that at Lac la Croix and Namakan Lake (Table 12).

Comparison of Life Forms Among Basins

In addition to the above-mentioned ordinations and analyses of unique taxa that suggested differences among basins, we categorized taxa into different life forms (Table 2) and compared the differences in percentage of life form for a number of measures, including summed cover, frequency, and importance value (IV). Looking first at cover (Table 13, Figure 11) Namakan has slightly greater contributions from the aquatic and emergent life forms combined (6.3%) when compared to both Rainy (3.2%) and Lac la Croix (1.5%), although the difference is only statistically significant for the emergent category. The total contribution of facultative wetland taxa was greatest in Lac la Croix (21.9%) and least in Namakan (8.4%) with Rainy intermediate (16.6%).

Table 11. Taxa unique to one or two basins as sampled in 620 quadrats along the shoreline transects. Only those with overall frequencies of occurrence of 10 or greater are included.

	Frequency			
Taxa uniquely absent from LLC	**Lac la Croix**	**Namakan**	**Rainy**	**Total**
Betula papyrifera	0	2	11	13
Carex atherodes	0	41	12	53
Carex lacustris	0	23	42	65
Lathyrus sp.	0	5	18	23
Pinus strobus	0	4	14	18
Poa spp.	0	2	18	20
Scirpus fluviatilis	0	15	5	20
Stachys palustris	0	1	17	18
Typha latifolia	0	5	15	20
Typha x glauca	0	31	15	46
Uniquely absent from Namakan				
Hypericum majus	1	0	76	77
Potentilla norvegica	1	0	85	86
Carex pellita	2	0	15	17
Panicum spp.	2	0	11	13
Carex acutae group	5	0	10	15
Viola spp.	6	0	15	21
Ranunculus flammula	8	0	3	11
Sphagnum spp,	20	0	7	27
Uniquely absent from Rainy				
Lysimachia ciliata	12	1	0	13
Juncus filiformis	60	1	0	61
Sagittaria spp.	12	4	0	16
Toxicodendron radicans	15	4	0	19
Onoclea sensibilis	4	5	0	9
Eleocharis acicularis	2	9	0	11
Utricularia intermedia	2	9	0	11
Cardamine sp.	1	13	0	14
Unique to Rainy				
Impatiens capensis	0	0	13	13
Polygonum spp.	0	0	47	47
Unique to Namakan				
Lemna trisulca	0	19	0	19
Spirodela polyrhiza	0	17	0	17
Unique to Lac la Croix				
Veronica scutellata	10	0	0	10
Osmunda regalis	12	0	0	12
Chamaedaphne calyculata	20	0	0	20
Dulichium arundinaceum	29	0	0	29

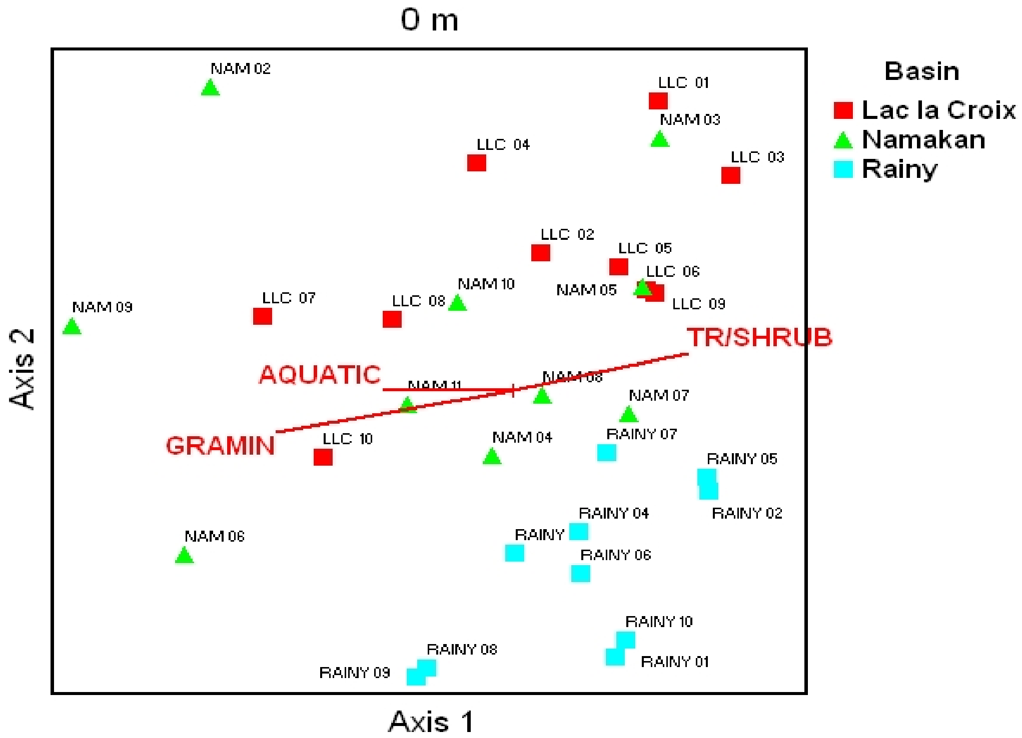


Figure 10. Non-metric multidimensional scaling (NMS) ordination of 30 shoreline transects and 95 taxa using importance values. Vectors represent taxonomic groups that are correlated with axis scores, GRAMIN = graminoids, TR/SHRUB = trees and shrubs, and AQUATIC = normally aquatic taxa (see text for values).

Table 12. Multi-response Permutation Procedure (MRPP) pairwise comparison of intensive vegetation data (importance values) for shoreline, 1.25 m, and 2.0 m depths. "*" indicates significant difference at p=0.01 level.

	Namakan	**Rainy**
0 m		
Lac la Croix	A = 0.02250232 p = 0.07157318	A = 0.08451903 p = 0.00023342 *
Namakan	-	A = 0.05081891 p = 0.00487472 *
1.25 m		
Lac la Croix	A = 0.07877460 p = 0.00085236 *	A = 0.08871650 p = 0.00032949 *
Namakan	-	A = 0.01314639 p = 0.13457373
2 m		
Lac la Croix	A = 0.09761999 p = 0.00015713 *	A = 0.14477111 p = 0.00000225 *
Namakan	-	A = 0.06174513 p = 0.00459030 *

Table 13. Comparison of life form proportions among basins at shoreline transects across three metrics: total cover, frequency of occurrence, and relative importance value (IV). Significant differences expressed at p=0.05, Kruskal-Wallis test on medians. Means are presented for clarity of interpretation for the reader.

Total Cover	**Lac la Croix**		**Namakan**		**Rainy**		
	Total	**% of**	**Total**	**% of**	**Total**	**% of**	**Significant differences**
Life Form	**Cover**	**total**	**Cover**	**total**	**Cover**	**total**	
aquatic	0.2	0.0	162.5	1.1	0.0	0.0	
emergent	240.5	1.5	748.4	5.2	505.5	3.2	NAM>LLC
facultative wetland herb	3430.2	21.9	1217.2	8.4	2613.4	16.6	LLC>NAM
graminoid	4942.4	31.5	6017.8	41.6	6720.2	42.8	
tree/shrub	7036.0	44.9	6325.5	43.7	5845.1	37.2	
upland herb	31.7	0.2	10.4	0.1	28.8	0.2	
		100		100.0		100.0	
Frequency	**Lac la Croix**		**Namakan**		**Rainy**		
	Total	**% of**	**Total**	**% of**	**Total**	**% of**	
Life Form	**Frequency**	**total**	**Frequency**	**total**	**Frequency**	**total**	
aquatic	2	0.1	53	3.8	0	0.0	
emergent	63	3.3	113	8.2	68	3.5	NAM>LLC, RNY
facultative wetland herb	817	42.7	490	35.4	976	50.1	
graminoid	554	29.0	473	34.2	462	23.7	
tree/shrub	455	23.8	249	18.0	416	21.3	
upland herb	21	1.1	7	0.5	27	1.4	
	1912	100.0	1385	100.0	1949	100.0	
Importance Value	**Lac la Croix**		**Namakan**		**Rainy**		
	Total	**% of**	**Total**	**% of**	**Total**	**% of**	
Life Form	**Rel. IV**	**total**	**Rel. IV**	**total**	**Rel. IV**	**total**	
aquatic	0.5	0.0	25.2	2.3	0.0	0.0	
emergent	24.1	2.4	70.4	6.4	37.4	3.7	
facultative wetland herb	317.8	31.8	234.2	21.3	321.2	32.1	
graminoid	303.7	30.4	427.0	38.8	342.4	34.2	
tree/shrub	347.4	34.7	340.0	30.9	291.4	29.1	
upland herb	6.4	0.6	3.2	0.3	7.6	0.8	
	1000.0	100.0	1100.0	100.0	1000.0	100.0	

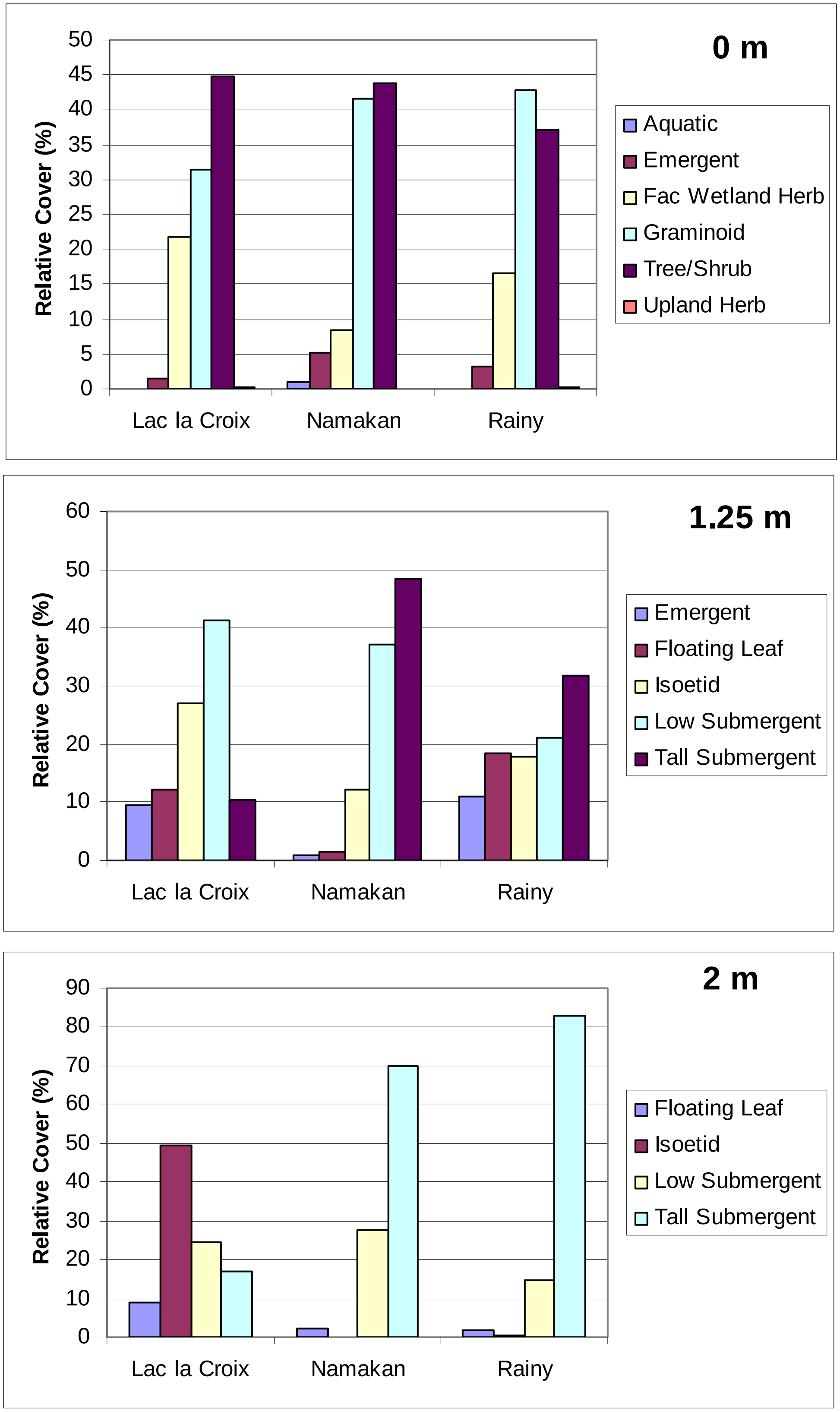


Figure 11. Comparison of percent total cover of vegetation life forms within basins for Lac la Croix, Namakan, and Rainy basins.

There were fewer differences among the basins in the contributions by tree and shrub taxa, as this group was strongly represented in all three basins (44.9, 43.7, and 37.2% at Lac la Croix, Namakan, and Rainy respectively).

As with cover, the combined aquatic and emergent frequency percentages showed Namakan with greater contributions (12.0%) compared to Lac la Croix (3.4%) and Rainy (3.5%), although again only the emergent group was statistically significant. The percent of total frequency showed less differences among basins in the facultative herb category (when compared to using cover as a metric). For example, whereas the percent cover metric suggested Lac la Croix was better represented by the facultative wetland group (21.9%), when comparing frequency, Rainy (at 50.1%) was highest. In general, the results in comparing IV were intermediate between cover and frequency.

1.25 m Depth

Fifty-one taxa were recorded in the 31 transects that were placed 1.25 m below MHW. These taxa are listed in alphabetical order (along with taxa abbreviations) in Tables 14 to 16 for percent cover, frequency and importance values (IV). Namakan has significantly fewer species per quadrat (lower richness) than Lac la Croix, but there are no significant differences between the other basins (Chi^2 = 6.426, df = 2, p = 0.040) (Table 15, Figure 9). Total number of mid-deep taxa was highest in Lac la Croix (42 taxa, Table 3) followed by Rainy (38) and Namakan (32). Mean cover per quadrat (Table 14, Figure 8) was greatest at Rainy (58.8%) followed by Namakan (52.4%), and Lac la Croix (33.7%), but the differences were not significant (Chi^2 = 3.958, df = 2, p = 0.138).

Total Cover

The fifteen most abundant taxa by cover for each basin are listed inTable 17. *Najas flexilis* was the only taxon in the top five across all basins, and it was the most abundant taxon by cover in each basin. The top five taxa by cover accounted for 73.5% (Lac la Croix), 82.4% (Namakan) and 62.4% (Rainy) of total cover in each basin respectively. Unlike the shoreline transects where three or four taxa dominated the top five values in all three metrics, here the floristic composition is more diverse. Only three of the top 10 taxa are shared among the basins (*Najas flexilis*, *Sagittaria* spp. rosette, and *Potamogeton gramineus*). The ten taxa with the most cover in Lac la Croix accounted for 86.5% of the total cover of all 42 taxa found in 1.25 m depth transects in that basin. In Namakan the top ten accounted for 94.6% of the 32 taxa’s total cover, and the top ten in Rainy accounted for 90.5% of the 38 taxa total. Even more so than in the shoreline transects, few taxa accounted for most of the cover in the 1.25 m transects.

Frequency

A similar analysis of frequency of occurrence (Table 18) shows that two taxa (*Najas flexilis* and the combined narrow leaved *Potamogeton* spp.) were in the top five for frequency in all three basins, and that the top five taxa accounted for 47.2, 54.1, and 50.3% of the total frequency in Lac la Croix, Namakan, and Rainy respectively. There were four shared taxa in the top ten in frequency, with the addition of *Isoetes* spp. and *Potamogeton gramineus*. As expected, when there are many taxa occurring frequently but at low cover, the top ten taxa by frequency for each

Table 14. Total percent cover in 1 m x 1 m quadrats for all taxa recorded in the 1.25 m depth transects across all three basins. Lac la Croix was sampled with 10 transects comprising 200 quadrats, Namakan with 11 transects and 220 quadrats, and Rainy with 10 transects and 200 quadrats.

Taxa	Species Code	Lac la Croix		Namakan		Rainy		Total all basins	
		Total Cover	% of total	Total Cover	% of total	Total Cover	% of total	Total Cover	% of total
Bidens beckii	BIDBEC	50.4	0.7	131.6	1.1	6.1	0.0	188.1	0.6
Bidens spp.	BIDESP	0.0	0.0	0.1	0.0	4.0	0.0	4.1	0.0
Callitriche hermaphroditica	CALHER	49.6	0.7	0.6	0.0	0.1	0.0	50.3	0.2
Ceratophyllum demersum	CERDEM	0.3	0.0	107.9	0.9	103.6	0.8	211.8	0.7
Chara spp.	CHARSP	46.9	0.6	505.3	4.4	64.3	0.5	616.5	1.9
Crassula aquatica	CRAAQU	0.0	0.0	0.1	0.0	0.0	0.0	0.1	0.0
Elatine minima	ELAMIN	0.0	0.0	5.2	0.0	12.2	0.1	17.4	0.1
Eleocharis acicularis	ELEACI	7.4	0.1	55.5	0.5	603.1	4.7	666.0	2.1
Eleocharis ovata	ELEOVA	0.0	0.0	0.0	0.0	0.1	0.0	0.1	0.0
Eleocharis palustris	ELEPAL	500.3	6.8	0.0	0.0	194.1	1.5	694.4	2.2
Elodea canadensis	ELOCAN	17.2	0.2	89.0	0.8	443.1	3.4	549.3	1.7
Equisetum spp.	EQUISP	2.1	0.0	0.0	0.0	0.0	0.0	2.1	0.0
Eriocaulon aquaticum	ERIAQU	171.5	2.3	0.0	0.0	0.0	0.0	171.5	0.5
Glyceria borealis	GLYBOR	178.3	2.4	20.4	0.2	0.1	0.0	198.8	0.6
Hippuris vulgaris	HIPVUL	41.0	0.6	0.0	0.0	0.0	0.0	41.0	0.1
Isoetes spp.	ISOESP	129.7	1.8	498.6	4.3	1698.3	13.1	2326.6	7.3
Juncus pelocarpus	JUNPEL	50.1	0.7	0.0	0.0	36.0	0.3	86.1	0.3
Lemna minor	LEMMIN	0.0	0.0	0.0	0.0	0.4	0.0	0.4	0.0
Lemna trisulca	LEMTRI	0.0	0.0	196.4	1.7	0.0	0.0	196.4	0.6
Littorella uniflora	LITUNI	40.3	0.5	6.9	0.1	43.0	0.3	90.2	0.3
moss spp.	MOSSSP	0.1	0.0	93.1	0.8	0.0	0.0	93.2	0.3
Myriophyllum spp.	MYRISP	111.3	1.5	19.1	0.2	38.2	0.3	168.6	0.5
Najas flexilis	NAJFLE	2601.6	35.1	3397.5	29.5	1981.2	15.3	7980.3	25.0
Nuphar spp.	NUPHSP	57.0	0.8	0.0	0.0	80.0	0.6	137.0	0.4
Nymphaea odorata	NYMODO	489.4	6.6	169.5	1.5	5.2	0.0	664.1	2.1
Potamogeton amplifolius	POTAMP	3.0	0.0	0.0	0.0	1.0	0.0	4.0	0.0
Potamogeton epihydrus	POTEPI	96.3	1.3	0.0	0.0	1.2	0.0	97.5	0.3
Potamogeton gramineus	POTGRA	157.3	2.1	411.1	3.6	1094.3	8.5	1662.7	5.2
Potamogeton narrow leaved	POTNAR	204.9	2.8	1395.8	12.1	349.8	2.7	1950.5	6.1
Potamogeton natans	POTNAT	4.0	0.1	0.0	0.0	977.1	7.6	981.1	3.1
Potamogeton obtusifolius	POTOBT	3.0	0.0	0.0	0.0	0.0	0.0	3.0	0.0
Potamogeton richardsonii	POTRIC	6.1	0.1	31.3	0.3	93.7	0.7	131.1	0.4
Potamogeton robbinsii	POTROB	8.3	0.1	0.0	0.0	53.4	0.4	61.7	0.2
Potamogeton zosteriformis	POTZOS	15.3	0.2	52.8	0.5	6.2	0.0	74.3	0.2
Ranunculus flammula	RANFLA	56.4	0.8	3.8	0.0	0.0	0.0	60.2	0.2
Ranunculus longirostris	RANLON	2.8	0.0	0.3	0.0	18.8	0.1	21.9	0.1

Taxa	Species Code	Lac la Croix			Namakan			Rainy			Total all basins	
		Total Cover	% of total		Total Cover	% of total		Total Cover	% of total		Total Cover	% of total
Sagittaria rosette	SAGROS	1599.5	21.6		907.8	7.9		519.3	4.0		3026.6	9.5
Sagittaria spp.	SAGISP	6.2	0.1		70.3	0.6		1115.2	8.6		1191.7	3.7
Scirpus acutus	SCIACU	5.1	0.1		0.0	0.0		0.0	0.0		5.1	0.0
Scirpus subterminalis	SCISUB	255.3	3.4		3.2	0.0		0.0	0.0		258.5	0.8
Scirpus validus	SCIVAL	0.0	0.0		0.1	0.0		0.2	0.0		0.3	0.0
Sium suave	SIUSUA	0.2	0.0		0.0	0.0		0.0	0.0		0.2	0.0
Sparganium spp.	SPARSP	246.5	3.3		12.5	0.1		1326.5	10.3		1585.5	5.0
Spirodela polyrhiza	SPIPOL	0.0	0.0		0.0	0.0		0.1	0.0		0.1	0.0
Subularia aquatica	SUBAQU	0.1	0.0		0.0	0.0		0.0	0.0		0.1	0.0
Utricularia intermedia	UTRINT	23.1	0.3		0.1	0.0		0.1	0.0		23.3	0.1
Utricularia minor	UTRMIN	0.3	0.0		2.1	0.0		0.0	0.0		2.4	0.0
Utricularia vulgaris	UTRVUL	85.1	1.1		52.0	0.5		4.0	0.0		141.1	0.4
Vallisneria americana	VALAME	69.2	0.9		3293.3	28.6		1941.9	15.0		5304.4	16.6
Zizania palustris	ZIZPAL	14.2	0.2		0.0	0.0		113.1	0.9		127.3	0.4
Zosterella dubia	ZOSDUB	0.0	0.0		0.0	0.0		1.3	0.0		1.3	0.0
Totals per basin		7406.7			11533.3			12930.3			31870.3	
Mean cover per quadrat		33.7			52.4			58.8			51.4	

Table 15. Total frequency of occurrence in 1 m x 1 m quadrats for all taxa recorded in the 1.25 m depth transects across all three basins. Lac la Croix was sampled with 10 transects comprising 200 quadrats, Namakan with 11 transects and 220 quadrats and Rainy with 10 transects and 200 quadrats.

	Taxa	Abbrev.	Lac la Croix			Namakan			Rainy			Total all basins	
			Total Freq.	% of total		Total Freq.	% of total		Total Freq.	% of total		Total Freq.	% of total
1	Bidens beckii	BIDBEC	27	2.4		20	1.8		15	1.4		62	1.9
2	Bidens spp.	BIDESP	0	0.0		1	0.1		2	0.2		3	0.1
3	Callitriche hermaphroditica	CALHER	21	1.9		6	0.5		1	0.1		28	0.8
4	Ceratophyllum demersum	CERDEM	3	0.3		52	4.7		23	2.1		78	2.3
5	Chara spp.	CHARSP	52	4.6		38	3.4		25	2.3		115	3.5
6	Crassula aquatica	CRAAQU	0	0.0		1	0.1		0	0.0		1	0.0
7	Elatine minima	ELAMIN	0	0.0		43	3.8		59	5.4		102	3.1
8	Eleocharis acicularis	ELEACI	8	0.7		15	1.3		58	5.4		81	2.4
9	Eleocharis ovata	ELEOVA	0	0.0		0	0.0		1	0.1		1	0.0
10	Eleocharis palustris	ELEPAL	30	2.7		0	0.0		16	1.5		46	1.4
11	Elodea canadensis	ELOCAN	11	1.0		42	3.8		35	3.2		88	2.6
12	Equisetum spp.	EQUISP	3	0.3		0	0.0		0	0.0		3	0.1
13	Eriocaulon aquaticum	ERIAQU	29	2.6		0	0.0		0	0.0		29	0.9
14	Glyceria borealis	GLYBOR	34	3.0		12	1.1		1	0.1		47	1.4
15	Hippuris vulgaris	HIPVUL	3	0.3		0	0.0		0	0.0		3	0.1

	Taxa	Abbrev.	Lac la Croix		Namakan		Rainy		Total all basins	
			Total Freq.	% of total	Total Freq.	% of total	Total Freq.	% of total	Total Freq.	% of total
16	Isoetes spp.	ISOESP	55	4.9	80	7.2	109	10.1	244	7.3
17	Juncus pelocarpus	JUNPEL	10	0.9	0	0.0	13	1.2	23	0.7
18	Lemna minor	LEMMIN	0	0.0	0	0.0	4	0.4	4	0.1
19	Lemna trisulca	LEMTRI	0	0.0	33	3.0	0	0.0	33	1.0
20	Littorella uniflora	LITUNI	4	0.4	13	1.2	15	1.4	32	1.0
21	moss spp.	MOSSSP	1	0.1	4	0.4	0	0.0	5	0.2
22	Myriophyllum spp.	MYRISP	55	4.9	20	1.8	23	2.1	98	2.9
23	Najas flexilis	NAJFLE	139	12.4	163	14.6	144	13.3	446	13.4
24	Nuphar spp.	NUPHSP	10	0.9	0	0.0	7	0.6	17	0.5
25	Nymphaea odorata	NYMODO	115	10.2	48	4.3	3	0.3	166	5.0
26	Potamogeton amplifolius	POTAMP	1	0.1	0	0.0	1	0.1	2	0.1
27	Potamogeton epihydrus	POTEPI	12	1.1	0	0.0	3	0.3	15	0.5
28	Potamogeton gramineus	POTGRA	38	3.4	91	8.1	61	5.6	190	5.7
29	Potamogeton narrow leaved	POTNAR	109	9.7	131	11.7	107	9.9	347	10.4
30	Potamogeton natans	POTNAT	2	0.2	0	0.0	24	2.2	26	0.8
31	Potamogeton obtusifolius	POTOBT	1	0.1	0	0.0	0	0.0	1	0.0
32	Potamogeton richardsonii	POTRIC	7	0.6	12	1.1	23	2.1	42	1.3
33	Potamogeton robbinsii	POTROB	8	0.7	0	0.0	23	2.1	31	0.9
34	Potamogeton zosteriformis	POTZOS	13	1.2	22	2.0	6	0.6	41	1.2
35	Ranunculus flammula	RANFLA	13	1.2	10	0.9	0	0.0	23	0.7
36	Ranunculus longirostris	RANLON	9	0.8	3	0.3	15	1.4	27	0.8
37	Sagittaria rosette	SAGROS	113	10.0	81	7.3	24	2.2	218	6.6
38	Sagittaria spp.	SAGISP	6	0.5	9	0.8	51	4.7	66	2.0
39	Scirpus acutus	SCIACU	4	0.4	0	0.0	0	0.0	4	0.1
40	Scirpus subterminalis	SCISUB	33	2.9	4	0.4	0	0.0	37	1.1
41	Scirpus validus	SCIVAL	0	0.0	1	0.1	2	0.2	3	0.1
42	Sium suave	SIUSUA	2	0.2	0	0.0	0	0.0	2	0.1
43	Sparganium spp.	SPARSP	52	4.6	7	0.6	48	4.4	107	3.2
44	Spirodela polyrhiza	SPIPOL	0	0.0	0	0.0	1	0.1	1	0.0
45	Subularia aquatica	SUBAQU	1	0.1	0	0.0	0	0.0	1	0.0
46	Utricularia intermedia	UTRINT	14	1.2	1	0.1	1	0.1	16	0.5
47	Utricularia minor	UTRMIN	3	0.3	2	0.2	0	0.0	5	0.2
48	Utricularia vulgaris	UTRVUL	38	3.4	14	1.3	2	0.2	54	1.6
49	Vallisneria americana	VALAME	27	2.4	138	12.4	124	11.4	289	8.7
50	Zizania palustris	ZIZPAL	9	0.8	0	0.0	10	0.9	19	0.6
51	Zosterella dubia	ZOSDUB	0	0.0	0	0.0	4	0.4	4	0.1
	Totals per basin		1125		1117		1084		3326	
	Mean richness per quadrat		5.63		5.08		5.42		5.36	
	Number of taxa recorded per basin		42		32		38			

Table 16. Total relative importance value for all taxa recorded in the 1.25 m depth quadrats across all three basins. Lac la Croix was sampled with 10 transects comprising 200 quadrats, Namakan with 11 transects and 220 quadrats, and Rainy with 10 transects and 200 quadrats. Relative importance was calculated by averaging relative cover and relative frequency.

			Lac la Croix		Namakan		Rainy		Total all basins	
	Taxa	Abbrev.	Total Rel. IV	% of total	Total Rel. IV	% of total	Total Rel. IV	% of total	Total Rel. IV	% of total
1	Bidens beckii	BIDBEC	23.2	2.3	13.0	1.2	6.0	0.6	42.2	1.4
2	Bidens spp.	BIDESP	0.0	0.0	0.4	0.0	0.9	0.1	1.3	0.0
3	Callitriche hermaphroditica	CALHER	20.0	2.0	2.5	0.2	0.4	0.0	22.8	0.7
4	Ceratophyllum demersum	CERDEM	1.3	0.1	25.4	2.3	12.0	1.2	38.6	1.2
5	Chara spp.	CHARSP	24.2	2.4	26.9	2.4	13.8	1.4	64.9	2.1
6	Crassula aquatica	CRAAQU	0.0	0.0	0.8	0.1	0.0	0.0	0.8	0.0
7	Elatine minima	ELAMIN	0.0	0.0	17.6	1.6	26.4	2.6	44.0	1.4
8	Eleocharis acicularis	ELEACI	3.5	0.3	18.6	1.7	53.1	5.3	75.2	2.4
9	Eleocharis ovata	ELEOVA	0.0	0.0	0.0	0.0	0.4	0.0	0.4	0.0
10	Eleocharis palustris	ELEPAL	65.0	6.5	0.0	0.0	13.6	1.4	78.7	2.5
11	Elodea canadensis	ELOCAN	5.1	0.5	21.9	2.0	32.3	3.2	59.4	1.9
12	Equisetum spp.	EQUISP	1.7	0.2	0.0	0.0	0.0	0.0	1.7	0.1
13	Eriocaulon aquaticum	ERIAQU	21.1	2.1	0.0	0.0	0.0	0.0	21.1	0.7
14	Glyceria borealis	GLYBOR	25.3	2.5	8.5	0.8	0.4	0.0	34.2	1.1
15	Hippuris vulgaris	HIPVUL	5.5	0.5	0.0	0.0	0.0	0.0	5.5	0.2
16	Isoetes spp.	ISOESP	32.9	3.3	83.8	7.6	118.3	11.8	235.0	7.6
17	Juncus pelocarpus	JUNPEL	6.4	0.6	0.0	0.0	10.8	1.1	17.3	0.6
18	Lemna minor	LEMMIN	0.0	0.0	0.0	0.0	1.5	0.2	1.5	0.0
19	Lemna trisulca	LEMTRI	0.0	0.0	19.4	1.8	0.0	0.0	19.4	0.6
20	Littorella uniflora	LITUNI	3.4	0.3	5.8	0.5	7.4	0.7	16.6	0.5
21	moss spp.	MOSSSP	0.3	0.0	14.0	1.3	0.0	0.0	14.3	0.5
22	Myriophyllum spp.	MYRISP	39.7	4.0	8.5	0.8	10.9	1.1	59.1	1.9
23	Najas flexilis	NAJFLE	203.6	20.4	230.6	21.0	145.6	14.6	579.8	18.7
24	Nuphar spp.	NUPHSP	9.1	0.9	0.0	0.0	5.5	0.6	14.6	0.5
25	Nymphaea odorata	NYMODO	85.7	8.6	38.3	3.5	1.7	0.2	125.6	4.1
26	Potamogeton amplifolius	POTAMP	0.5	0.0	0.0	0.0	0.4	0.0	0.9	0.0
27	Potamogeton epihydrus	POTEPI	9.9	1.0	0.0	0.0	1.2	0.1	11.1	0.4
28	Potamogeton gramineus	POTGRA	25.0	2.5	70.9	6.4	65.4	6.5	161.3	5.2
29	Potamogeton narrow leaved	POTNAR	60.2	6.0	124.1	11.3	61.8	6.2	246.1	7.9
30	Potamogeton natans	POTNAT	1.5	0.2	0.0	0.0	36.6	3.7	38.2	1.2
31	Potamogeton obtusifolius	POTOBT	0.5	0.1	0.0	0.0	0.0	0.0	0.5	0.0
32	Potamogeton richardsonii	POTRIC	4.1	0.4	10.5	1.0	13.6	1.4	28.2	0.9
33	Potamogeton robbinsii	POTROB	3.8	0.4	0.0	0.0	29.4	2.9	33.2	1.1
34	Potamogeton zosteriformis	POTZOS	6.4	0.6	15.8	1.4	2.8	0.3	25.0	0.8
35	Ranunculus flammula	RANFLA	7.7	0.8	8.2	0.7	0.0	0.0	16.0	0.5
36	Ranunculus longirostris	RANLON	4.2	0.4	1.3	0.1	7.2	0.7	12.6	0.4

37	Sagittaria rosette	SAGROS	143.6	14.4	67.5	6.1	30.6	3.1	241.8	7.8
38	Sagittaria spp.	SAGISP	3.9	0.4	7.2	0.7	55.7	5.6	66.9	2.2
39	Scirpus acutus	SCIACU	1.8	0.2	0.0	0.0	0.0	0.0	1.8	0.1
40	Scirpus subterminalis	SCISUB	32.9	3.3	3.4	0.3	0.0	0.0	36.3	1.2
41	Scirpus validus	SCIVAL	0.0	0.0	0.4	0.0	0.8	0.1	1.1	0.0
42	Sium suave	SIUSUA	1.1	0.1	0.0	0.0	0.0	0.0	1.1	0.0
43	Sparganium spp.	SPARSP	52.8	5.3	6.5	0.6	61.3	6.1	120.6	3.9
44	Spirodela polyrhiza	SPIPOL	0.0	0.0	0.0	0.0	0.4	0.0	0.4	0.0
45	Subularia aquatica	SUBAQU	0.4	0.0	0.0	0.0	0.0	0.0	0.4	0.0
46	Utricularia intermedia	UTRINT	11.1	1.1	0.8	0.1	0.5	0.0	12.4	0.4
47	Utricularia minor	UTRMIN	1.3	0.1	1.8	0.2	0.0	0.0	3.0	0.1
48	Utricularia vulgaris	UTRVUL	27.8	2.8	15.1	1.4	0.9	0.1	43.8	1.4
49	Vallisneria americana	VALAME	15.6	1.6	230.5	21.0	160.4	16.0	406.6	13.1
50	Zizania palustris	ZIZPAL	6.5	0.6	0.0	0.0	8.5	0.8	14.9	0.5
51	Zosterella dubia	ZOSDUB	0.0	0.0	0.0	0.0	1.7	0.2	1.7	0.1

Table 17. Most abundant taxa by percent cover in 1 m x 1 m quadrats recorded in the 1.25 m depth quadrats across all three basins. Lac la Croix was sampled with 10 transects comprising 200 quadrats, Namakan with 11 transects and 220 quadrats, and Rainy with 10 transects and 200 quadrats.

		Lac la Croix					**Namakan**					**Rainy**		
	Taxa	**Total Cover**	**% of total**	**Cum. %**		**Taxa**	**Total Cover**	**% of total**	**Cum. %**		**Taxa**	**Total Cover**	**% of total**	**Cum. %**
1	Najas flexilis	2601.6	35.1	35.1	1	Najas flexilis	3397.5	29.5	29.5	1	Najas flexilis	1981.2	15.3	15.3
2	Sagittaria rosette	1599.5	21.6	56.7	2	Vallisneria americana	3293.3	28.6	58.0	2	Vallisneria americana	1941.9	15.0	30.3
3	Eleocharis palustris	500.3	6.8	63.5	3	Potamogeton narrow lvd	1395.8	12.1	70.1	3	Isoetes spp.	1698.3	13.1	43.5
4	Nymphaea odorata	489.4	6.6	70.1	4	Sagittaria rosette	907.8	7.9	78.0	4	Sparganium spp.	1326.5	10.3	53.7
5	Scirpus subterminalis	255.3	3.4	73.5	5	Chara spp.	505.3	4.4	82.4	5	Sagittaria spp.	1115.2	8.6	62.4
6	Sparganium spp.	246.5	3.3	76.9	6	Isoetes spp.	498.6	4.3	86.7	6	Potamogeton gramineus	1094.3	8.5	70.8
7	Potamogeton narrow lvd	204.9	2.8	79.6	7	Potamogeton gramineus	411.1	3.6	90.3	7	Potamogeton natans	977.1	7.6	78.4
8	Glyceria borealis	178.3	2.4	82.0	8	Lemna trisulca	196.4	1.7	92.0	8	Eleocharis acicularis	603.1	4.7	83.0
9	Eriocaulon aquaticum	171.5	2.3	84.3	9	Nymphaea odorata	169.5	1.5	93.4	9	Sagittaria rosette	519.3	4.0	87.1
10	Potamogeton gramineus	157.3	2.1	86.5	10	Bidens beckii	131.6	1.1	94.6	10	Elodea canadensis	443.1	3.4	90.5
11	Isoetes spp.	129.7	1.8	88.2	11	Ceratophyllum demersum	107.9	0.9	95.5	11	Potamogeton narrow lvd	349.8	2.7	93.2
12	Myriophyllum spp.	111.3	1.5	89.7	12	moss spp.	93.1	0.8	96.3	12	Eleocharis palustris	194.1	1.5	94.7
13	Potamogeton epihydrus	96.3	1.3	91.0	13	Elodea canadensis	89.0	0.8	97.1	13	Zizania palustris	113.1	0.9	95.6
14	Utricularia vulgaris	85.1	1.1	92.2	14	Sagittaria spp.	70.3	0.6	97.7	14	Ceratophyllum demersum	103.6	0.8	96.4
15	Vallisneria americana	69.2	0.9	93.1	15	Eleocharis acicularis	55.5	0.5	98.2	15	Potamogeton richardsonii	93.7	0.7	97.1

Table 18. Total frequency of occurrence in 1 m x 1 m quadrats for most abundant taxa recorded in the 1.25 m depth transects across all three basins. Lac la Croix was sampled with 10 transects comprising 200 quadrats, Namakan with 11 transects and 220 quadrats and Rainy with 10 transects and 200 quadrats.

Lac la Croix					Namakan					Rainy				
	Taxa	Total Freq.	% of total	Cum. %		Taxa	Total Freq.	% of total	Cum. %		Taxa	Total Freq.	% of total	Cum. %
1	Najas flexilis	139	12.4	12.4	1	Najas flexilis	163	14.6	14.6	1	Najas flexilis	144	13.3	13.3
2	Nymphaea odorata	115	10.2	22.6	2	Vallisneria americana	138	12.4	26.9	2	Vallisneria americana	124	11.4	24.7
3	Sagittaria rosette	113	10.0	32.6	3	Potamogeton narrow lvd	131	11.7	38.7	3	Isoetes spp.	109	10.1	34.8
4	Potamogeton narrow lvd	109	9.7	42.3	4	Potamogeton gramineus	91	8.1	46.8	4	Potamogeton narrow lvd	107	9.9	44.6
5	Isoetes spp.	55	4.9	47.2	5	Sagittaria rosette	81	7.3	54.1	5	Potamogeton gramineus	61	5.6	50.3
6	Myriophyllum spp.	55	4.9	52.1	6	Isoetes spp.	80	7.2	61.2	6	Elatine minima	59	5.4	55.7
7	Chara spp.	52	4.6	56.7	7	Ceratophyllum demersum	52	4.7	65.9	7	Eleocharis acicularis	58	5.4	61.1
8	Sparganium spp.	52	4.6	61.3	8	Nymphaea odorata	48	4.3	70.2	8	Sagittaria spp.	51	4.7	65.8
9	Potamogeton gramineus	38	3.4	64.7	9	Elatine minima	43	3.8	74.0	9	Sparganium spp.	48	4.4	70.2
10	Utricularia vulgaris	38	3.4	68.1	10	Elodea canadensis	42	3.8	77.8	10	Elodea canadensis	35	3.2	73.4
11	Glyceria borealis	34	3.0	71.1	11	Chara spp.	38	3.4	81.2	11	Chara spp.	25	2.3	75.7
12	Scirpus subterminalis	33	2.9	74.0	12	Lemna trisulca	33	3.0	84.2	12	Potamogeton natans	24	2.2	78.0
13	Eleocharis palustris	30	2.7	76.7	13	Potamogeton zosteriformis	22	2.0	86.1	13	Sagittaria rosette	24	2.2	80.2
14	Eriocaulon aquaticum	29	2.6	79.3	14	Bidens beckii	20	1.8	87.9	14	Ceratophyllum demersum	23	2.1	82.3
15	Vallisneria americana	27	2.4	81.7	15	Myriophyllum spp.	20	1.8	89.7	15	Myriophyllum spp.	23	2.1	84.4

basin accounted for much less of the relative total at 68.1, 77.8.0, and 73.4% for Lac la Croix, Namakan, and Rainy respectively.

Importance Values
The top five taxa in relative importance value (Table 19) accounted for 55.8%, 67.3%, and 55.1% of total IV, values in between that of cover and frequency. Two taxa of the top five in each basin were in common (*Najas flexilis, and Potamogeton* narrow leaf spp.).

Unique Taxa
Table 20 indicates those taxa with overall frequencies of occurrence across all basins of five or greater that were uniquely either absent or present at one basin. Of particular interest are those taxa not observed in the 620 mid-deep quadrats in Namakan, including *Potamogeton natans, P. robbinsii*, *P. epihydrus*, and *Nuphar* spp. occurring with slight regularity in the other basins. This may be an indication that the initial 1 to 2 m inundation (dam building 1914-15) and subsequent extreme reservoir type management of the Namakan water levels have all but eliminated these taxa from most of the basin. Alternatively, Table 20 also indicates that *Zizania palustris* was not reported in our Namakan transects, yet it was reported in the Namakan Reservoir in other aspects of this project and by chance was not recorded in any of our sites.

Other notable, likely distributional, differences include the presence of *Eriocaulon aquaticum* in the non-regulated basin only and the absence of *Scirpus subterminalis* and *Ranunculus flammula* in Rainy. What cannot be ascertained without further investigation is whether these patterns are 1) artifacts of our random sampling (as with the case of *Zizania),* 2) indicators of long term pre-disturbance distributions, or 3) as suspected with *Potamogeton natans* et al., as a result of the dam building.

Table 19. Most abundant taxa by relative importance value (IV) in 1 m x 1 m quadrats recorded in the 1.25 m depth quadrats across all three basins. Lac la Croix was sampled with 10 transects comprising 200 quadrats, Namakan with 11 transects and 220 quadrats and Rainy with 10 transects and 200 quadrats.

Lac la Croix					**Namakan**					**Rainy**				
	Taxa	**Total Rel. IV**	**% of total**	**Cum. %**		**Taxa**	**Total Rel. IV**	**% of total**	**Cum. %**		**Taxa**	**Total Rel. IV**	**% of total**	**Cum. %**
1	Najas flexilis	203.6	20.4	20.4	1	Najas flexilis	230.6	21.0	21.0	1	Vallisneria americana	160.4	16.0	16.0
2	Sagittaria rosette	143.6	14.4	34.7	2	Vallisneria americana	230.5	21.0	41.9	2	Najas flexilis	145.6	14.6	30.6
3	Nymphaea odorata	85.7	8.6	43.3	3	Potamogeton narrow lvd	124.1	11.3	53.2	3	Isoetes spp.	118.3	11.8	42.4
4	Eleocharis palustris	65.0	6.5	49.8	4	Isoetes spp.	83.8	7.6	60.8	4	Potamogeton gramineus	65.4	6.5	49.0
5	Potamogeton narrow lvd	60.2	6.0	55.8	5	Potamogeton gramineus	70.9	6.4	67.3	5	Potamogeton narrow lvd	61.8	6.2	55.1
6	Sparganium spp.	52.8	5.3	61.1	6	Sagittaria rosette	67.5	6.1	73.4	6	Sparganium spp.	61.3	6.1	61.3
7	Myriophyllum spp.	39.7	4.0	65.1	7	Nymphaea odorata	38.3	3.5	76.9	7	Sagittaria spp.	55.7	5.6	66.8
8	Isoetes spp.	32.9	3.3	68.4	8	Chara spp.	26.9	2.4	79.3	8	Eleocharis acicularis	53.1	5.3	72.2
9	Scirpus subterminalis	32.9	3.3	71.6	9	Ceratophyllum demersum	25.4	2.3	81.7	9	Potamogeton natans	36.6	3.7	75.8
10	Utricularia vulgaris	27.8	2.8	74.4	10	Elodea canadensis	21.9	2.0	83.6	10	Elodea canadensis	32.3	3.2	79.0
11	Glyceria borealis	25.3	2.5	77.0	11	Lemna trisulca	19.4	1.8	85.4	11	Sagittaria rosette	30.6	3.1	82.1
12	Potamogeton gramineus	25.0	2.5	79.5	12	Eleocharis acicularis	18.6	1.7	87.1	12	Potamogeton robbinsii	29.4	2.9	85.0
13	Chara spp.	24.2	2.4	81.9	13	Elatine minima	17.6	1.6	88.7	13	Elatine minima	26.4	2.6	87.7
14	Bidens beckii	23.2	2.3	84.2	14	Potamogeton zosteriformis	15.8	1.4	90.1	14	Chara spp.	13.8	1.4	89.1
15	Eriocaulon aquaticum	21.1	2.1	86.3	15	Utricularia vulgaris	15.1	1.4	91.5	15	Eleocharis palustris	13.6	1.4	90.4

Table 20. Taxa unique to one or two basins as sampled in 620 quadrats along the 1.25 m depth transects. Only those with overall frequencies of occurrence of 10 or greater are included.

Uniquely absent in Lac la Croix quadrats (but with a total frequency of 3 and greater in other basins).

		Frequency Namakan	Frequency Rainy
Elatine minima	ELAMIN	43	59

Uniquely absent in Namakan quadrats (but with a total frequency of 3 and greater in other basins).

		Frequency Lac la Croix	Frequency Rainy
Potamogeton natans	POTNAT	2	24
Potamogeton robbinsii	POTROB	8	23
Zizania palustris	ZIZPAL	9	10
Juncus pelocarpus	JUNPEL	10	13
Nuphar spp.	NUPHSP	10	7
Potamogeton epihydrus	POTEPI	12	3

Uniquely absent in Rainy quadrats (but with a total frequency of 3 and greater in other basins).

		Frequency Lac la Croix	Frequency Namakan
Utricularia minor	UTRMIN	3	2
moss spp.	MOSSSP	1	4
Scirpus subterminalis	SCISUB	33	4
Ranunculus flammula	RANFLA	13	10

Uniquely present in Lac la Croix quadrats (with a total frequency of 5 and greater).

Eriocaulon aquaticum	ERIAQU	29

Uniquely present in Rainy quadrats (with a total frequency of 4 and greater).

Zosterella dubia	ZOSDUB	4
Lemna minor	LEMMIN	4

Uniquely present in Namakan quadrats (with a total frequency of 5 and greater).

Lemna trisulca	LEMTRI	33

Ordinations

A NMS ordination of importance values was also performed on the 1.25 m transects in order to view floristic differences among the remaining sites. LLC site 7 was eliminated as an outlier, as the only site uniquely dominated by *Eleocharis palustris*. This resulted in a matrix of 30 transects and 51 taxa (Table 3, Figure 12). A number of the nine remaining Lac la Croix mid-deep transects were loosely clustered lower on axis two, below the bulk of the Rainy and Namakan sites, whereas most of the Namakan sites were intermediate on axis two between the Lac la Croix and Rainy sites. It appears, then, that axis two reflects some of the floristic differences suggested above by looking at unique taxa.

To observe the relationships between life form and the ordinational results, each taxon was assigned to one of five life form categories, and correlations between these life forms and the transect axis scores were calculated. The strongest factor influencing the ordination appeared to be a factor separating the distribution of the low submergent taxa (r=0.522) from the floating leaf taxa (r=-0.529) along axis one. Correlation with tall submergent taxa was weaker (r=0.181).

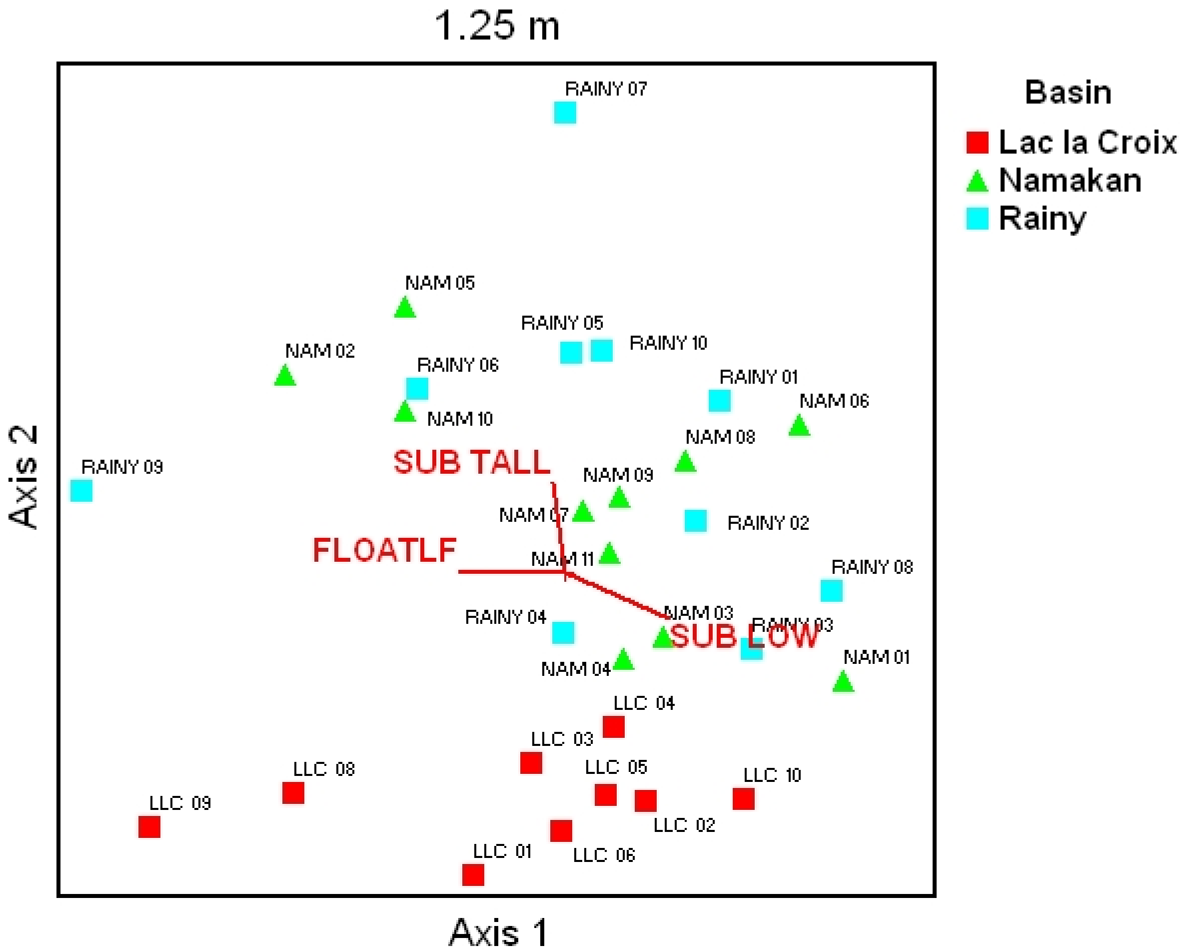


Figure 12. Non-metric multidimensional scaling (NMS) ordination of 30 1.25 m depth transects and 51 taxa (importance values). Vectors represent taxonomic groups that are correlated with axis scores, FLOATLF = floating leaf taxa, SUBLOW = low lying submergent taxa, SUBTALL = tall submergent taxa (see text for values).

Multi-response Permutation Procedure
A pairwise comparison of vegetation data suggests that at the 1.25 m depth, the vegetation of Lac la Croix is significantly different from Rainy and Namakan (Table 12). No significant difference was detected between the Rainy and Namakan basins.

Comparison of Life Forms Among Basins
Both Lac la Croix and Rainy had greater contributions (in percent of total cover) from the emergent life forms combined (9.5 and 11.0%) when compared to Namakan (0.8%) (Table 21, Figure 11) Similarly, floating leaf taxa also were significantly less represented in Namakan (1.6%) when compared to both Lac la Croix (12.1%) and Rainy (18.5%). Tall submergents were better represented in the Namakan Reservoir (48.4%) when compared to Lac la Croix (10.7%), with Rainy being intermediate (31.7%).

Analyses of the frequency metric showed similar trends in the emergent and floating leaf life forms, but here only Lac la Croix had significantly greater values than Namakan in the emergent life form (7.8% to 2.1%) (Table 21). In the floating leaf comparisons, Lac la Croix had significantly greater contributions (17.0%) than both Namakan (4.9%) and Rainy (8.3%). Using frequency as the metric, there were no significant differences in the isoetid, low, and tall submergent categories.

Importance values, being a composite of frequency and cover, show differences among basins that are intermediate in magnitude compared to the differences among basins shown by either frequency or cover alone. Both Lac la Croix (10.5%) and Rainy (8.0%) had significantly greater contributions compared to Namakan (1.5%) in the emergent life form, and Lac la Croix was better represented in floating leaf taxa (15.9%) when compared to Namakan (4.1%).

In summary, some differences were robust to the type of metric used, i.e., they were consistent across metrics (the differences in emergent and floating leaf proportions, for example), whereas other differences were metric dependent. For example, it appears that the tall submergents had greater cover in Namakan but were not more frequent.

Table 21. Comparison of life form proportions among basins at 1.25 m depth transects across three metrics: total cover, frequency of occurrence, and relative importance value (IV). Significant differences expressed at p=0.05, Kruskal-Wallis test on medians.

	Lac la Croix		**Namakan**		**Rainy**		
	Total Cover	**% of Total**	**Total Cover**	**% of Total**	**Total Cover**	**% of Total**	**Significant differences**
emergent	706.4	9.5	90.9	0.8	1426.8	11.0	LLC>NAM, NAM<RNY
floating leaf	893.2	12.1	182.0	1.6	2390.5	18.5	LLC>NAM, RNY>NAM
isoetid	1991.2	26.9	1413.4	12.3	2296.6	17.8	
low submergent	3049.0	41.2	4262.8	37.0	2714.4	21.0	
tall submergent	766.9	10.4	5584.2	48.4	4102.0	31.7	LLC<NAM
Total	7406.7	100.0	11533.3	100.0	12930.3	100.0	
	Total	**% of**	**Total**	**% of**	**Total**	**% of**	
	Frequency	**Total**	**Frequency**	**Total**	**Frequency**	**Total**	
emergent	88	7.8	23	2.1	83	7.7	LLC>NAM
floating leaf	191	17.0	55	4.9	90	8.3	LLC>NAM, LLC>RNY
isoetid	212	18.8	175	15.7	161	14.9	
low submergent	292	26.0	319	28.6	311	28.7	
tall submergent	342	30.4	545	48.8	439	40.5	
Total	1125	100.0	1117	100.0	1084	100.0	
	Total	**% of**	**Total**	**% of**	**Total**	**% of**	
	Rel. IV.	**Total**	**Rel. IV.**	**Total**	**Rel. IV.**	**Total**	
emergent	105.4	10.5	16.5	1.5	80.2	8.0	LLC>NAM, NAM<RNY
floating leaf	159.0	15.9	44.8	4.1	108.2	10.8	LLC>NAM
isoetid	208.0	20.8	157.9	14.4	167.1	16.7	
low submergent	308.4	30.8	343.9	31.3	269.1	26.9	
tall submergent	219.2	21.9	536.8	48.8	375.4	37.5	LLC<NAM
Total	1000.0	100.0	1100.0	100.0	1000.0	100.0	

2.0 m Depth

Thirty-one taxa were recognized in all the 2.0 m deep transects and are listed in alphabetical order (along with taxa abbreviations) in Tables 22 to 25 for percent cover, frequency, and importance values (IV). Mean number of taxa per quadrat was greatest in Lac la Croix (4.64) followed by Namakan (4.08) and Rainy (3.62), but there is no significant difference in species richness per quadrat between the basins ($Chi^2 = 6.426$, df = 2, p = 0.040) (Table 23, Figure 9). Mean summed cover per quadrat was greatest at Namakan (56.2%) followed by Rainy (43.0%) Lac la Croix (37.1%), but there is no significant difference in cover between the basins ($Chi^2 = 2.189$, df = 2, p = 0.335) (Table 22, Figure 8). Total number of deep transect taxa was highest in Rainy (28 taxa) followed by Lac la Croix (25) and, as in the mid-deep transects, Namakan (23) (Table 23).

Total Cover

The fifteen most abundant taxa by percent cover for each basin are listed in Table 25. Only one species, *Vallisneria americana*, was among the top five taxa abundant by cover in all basins. Even though the basins only shared one species in the top five, these five in each basin accounted for 76.5, 84.2 and 86.2% of the total cover in Lac la Croix, Namakan, and Rainy respectively. Overall, these cumulative percents were comparatively more than the top five in the shoreline and mid-deep, as is usually the case as the species pool narrows with depth. The floristic composition does not appear to converge in the top ten taxa by cover, as only *Najas flexilis* is added (common in the top ten of all basins). In sum, few taxa share a high level of cover across basins.

Frequency

A similar analysis of frequency of occurrence shows a more balanced flora as the top five taxa, as measured by frequency, in each basin accounted for 46.3, 61.0, and 57.6% of the total frequency in Lac la Croix, Namakan, and Rainy respectively (Table 26). As with cover, only *Vallisneria americana* taxa was in the top five for frequency in all three basins. There were four shared taxa in the top ten in frequency, with the addition of *Najas flexilis*, *Potamogeton* narrow-leaf, and *Bidens beckii*.

Importance Value (IV)

As with cover and frequency only *Vallisneria americana* was in the top five for IV in all three basins, and there were four shared taxa in the top ten with the addition of *Najas flexilis*, *Potamogeton* narrow-leaf, and *Bidens beckii* (Table 27).

Table 22. Total percent cover in 1 m x 1 m quadrats for all taxa recorded in the 2 m depth transects across all three basins. Lac la Croix was sampled with 10 transects comprising 200 quadrats, Namakan with 11 transects and 220 quadrats, and Rainy with 10 transects and 200 quadrats.

		Lac la Croix		Namakan		Rainy		Total all basins	
Taxa	Abbrev.	Total Cover	% of total	Total Cover	% of total	Total Cover	% of total	Total Cover	% of total
Bidens beckii	BIDBEC	72.5	1.0	418.3	3.4	343.5	4.0	834.3	2.9
Callitriche hermaphroditica	CALHER	0.1	0.0	0.0	0.0	0.3	0.0	0.4	0.0
Ceratophyllum demersum	CERDEM	9.3	0.1	523.4	4.2	17.2	0.2	549.9	1.9
*Chara sp_*	CHARSP	337.9	4.6	2366.4	19.2	3.9	0.0	2708.2	9.5
Elatine minima	ELAMIN	0.0	0.0	0.8	0.0	0.5	0.0	1.3	0.0
Eleocharis acicularis	ELEACI	0.0	0.0	0.1	0.0	0.3	0.0	0.4	0.0
Elodea canadensis	ELOCAN	3.5	0.0	134.5	1.1	19.4	0.2	157.4	0.6
Isoetes spp.	ISOESP	2907.5	39.2	3.9	0.0	9.1	0.1	2920.5	10.3
Juncus pelocarpus	JUNPEL	180.1	2.4	0.1	0.0	1.0	0.0	181.2	0.6
Lemna trisulca	LEMTRI	0.0	0.0	459.7	3.7	0.3	0.0	460.0	1.6
Littorella uniflora	LITUNI	0.0	0.0	0.2	0.0	0.4	0.0	0.6	0.0
Myriophyllum spp.	MYRISP	12.6	0.2	119.0	1.0	431.4	5.0	563.0	2.0
Najas flexilis	NAJFLE	674.1	9.1	584.8	4.7	110.1	1.3	1369.0	4.8
Nuphar sp.	NUPHSP	0.0	0.0	3.2	0.0	1.0	0.0	4.2	0.0
Nymphaea odorata	NYMODO	578.0	7.8	257.5	2.1	7.2	0.1	842.7	3.0
Potamogeton amplifolius	POTAMP	1.1	0.0	0.0	0.0	0.1	0.0	1.2	0.0
Potamogeton epihydrus	POTEPI	65.1	0.9	0.0	0.0	58.0	0.7	123.1	0.4
Potamogeton gramineus	POTGRA	118.2	1.6	71.2	0.6	35.1	0.4	224.5	0.8
Potamogeton narrow leaved	POTNAR	35.0	0.5	1020.7	8.3	22.8	0.3	1078.5	3.8
Potamogeton richardsonii	POTRIC	28.9	0.4	166.8	1.3	622.3	7.2	818.0	2.9
Potamogeton robbinsii	POTROB	130.5	1.8	0.0	0.0	1159.2	13.5	1289.7	4.5
Potamogeton zosteriformis	POTZOS	13.0	0.2	286.3	2.3	11.1	0.1	310.4	1.1
Ranunculus longirostris	RANLON	6.8	0.1	0.4	0.0	431.5	5.0	438.7	1.5
Sagittaria rosette	SAGROS	591.5	8.0	24.1	0.2	32.4	0.4	648.0	2.3
Scirpus subterminalis	SCISUB	677.2	9.1	0.1	0.0	0.0	0.0	677.3	2.4
Sparganium spp.	SPARSP	35.3	0.5	0.0	0.0	78.0	0.9	113.3	0.4
Utricularia intermedia	UTRINT	0.6	0.0	0.0	0.0	0.0	0.0	0.6	0.0
Utricularia minor	UTRMIN	0.1	0.0	0.0	0.0	0.0	0.0	0.1	0.0
Utricularia vulgaris	UTRVUL	116.7	1.6	6.0	0.0	4.3	0.1	127.0	0.4
Vallisneria americana	VALAME	828.9	11.2	5908.4	47.8	4737.4	55.1	11474.7	40.4
Zosterella dubia	ZOSDUB	0.0	0.0	0.0	0.0	453.6	5.3	453.6	1.6
Totals per basin		7424.5	100.0	12355.9	100.0	8591.4	100.0	28371.8	100.0
Mean cover per quadrat		37.1		56.2		43.0		45.8	

Table 23. Total frequency of occurrence in 1 m x 1 m quadrats for all taxa recorded in the 2 m depth transects across all three basins. Lac la Croix was sampled with 10 transects comprising 200 quadrats, Namakan with 11 transects and 220 quadrats, and Rainy with 10 transects and 200 quadrats.

		Lac la Croix		Namakan		Rainy		Total all basins	
Taxa	Abbrev.	Total Freq.	% of total	Total Freq.	% of total	Total Freq.	% of total	Total Freq.	% of total
Bidens beckii	BIDBEC	67	7.2	47	5.2	62	8.6	176	6.9
Callitriche hermaphroditica	CALHER	1	0.1	0	0.0	3	0.4	4	0.2
Ceratophyllum demersum	CERDEM	4	0.4	56	6.2	15	2.1	75	2.9
Chara sp.	CHARSP	80	8.6	114	12.7	11	1.5	205	8.0
Elatine minima	ELAMIN	0	0.0	8	0.9	5	0.7	13	0.5
Eleocharis acicularis	ELEACI	0	0.0	1	0.1	3	0.4	4	0.2
Elodea canadensis	ELOCAN	6	0.6	72	8.0	20	2.8	98	3.8
Isoetes spp.	ISOESP	76	8.2	11	1.2	17	2.3	104	4.1
Juncus pelocarpus	JUNPEL	12	1.3	1	0.1	1	0.1	14	0.5
Lemna trisulca	LEMTRI	0	0.0	35	3.9	3	0.4	38	1.5
Littorella uniflora	LITUNI	0	0.0	2	0.2	4	0.6	6	0.2
Myriophyllum spp.	MYRISP	36	3.9	54	6.0	65	9.0	155	6.1
Najas flexilis	NAJFLE	96	10.4	132	14.7	51	7.0	279	10.9
Nuphar sp.	NUPHSP	0	0.0	3	0.3	1	0.1	4	0.2
Nymphaea odorata	NYMODO	82	8.8	37	4.1	5	0.7	124	4.9
Potamogeton amplifolius	POTAMP	2	0.2	0	0.0	1	0.1	3	0.1
Potamogeton epihydrus	POTEPI	3	0.3	0	0.0	7	1.0	10	0.4
Potamogeton gramineus	POTGRA	30	3.2	20	2.2	6	0.8	56	2.2
Potamogeton narrow leaved	POTNAR	78	8.4	69	7.7	40	5.5	187	7.3
Potamogeton richardsonii	POTRIC	24	2.6	42	4.7	54	7.5	120	4.7
Potamogeton robbinsii	POTROB	15	1.6	0	0.0	81	11.2	96	3.8
Potamogeton zosteriformis	POTZOS	15	1.6	17	1.9	5	0.7	37	1.5
Ranunculus longirostris	RANLON	20	2.2	4	0.4	61	8.4	85	3.3
Sagittaria rosette	SAGROS	49	5.3	6	0.7	7	1.0	62	2.4
Scirpus subterminalis	SCISUB	28	3.0	1	0.1	0	0.0	29	1.1
Sparganium sp.	SPARSP	39	4.2	0	0.0	3	0.4	42	1.6
Utricularia intermedia	UTRINT	6	0.6	0	0.0	0	0.0	6	0.2
Utricularia minor	UTRMIN	1	0.1	0	0.0	0	0.0	1	0.0
Utricularia vulgaris	UTRVUL	64	6.9	5	0.6	5	0.7	74	2.9
Vallisneria americana	VALAME	93	10.0	160	17.8	148	20.4	401	15.7
Zosterella dubia	ZOSDUB	0	0.0	0	0.0	40	5.5	40	1.6
Totals per basin		927		897		724		2548	
Mean richness per quadrat		4.64		4.08		3.62		4.11	
Number of taxa recorded per basin		25		23		28			

Table 24. Total relative importance value for all taxa recorded in the 2 m depth quadrats across all three basins. Lac la Croix was sampled with 10 transects comprising 200 quadrats, Namakan with 11 transects and 220 quadrats, and Rainy with 10 transects and 200 quadrats. Relative importance was calculated by averaging relative cover and relative frequency.

		Lac la Croix		Namakan		Rainy		Total all basins	
Taxa	**Abbrev.**	Total Rel. IV	% of total	Total Rel. IV	% of total	Total Rel. IV	% of total	Total Rel. IV	% of total
Bidens beckii	BIDBEC	49.2	4.9	37.4	3.4	60.3	6.0	155.2	4.7
Callitriche hermaphroditica	CALHER	1.0	0.1	0.0	0.0	1.4	0.1	2.6	0.1
Ceratophyllum demersum	CERDEM	6.2	0.6	55.1	5.0	9.4	0.9	76.3	2.3
Chara sp.	CHARSP	66.6	6.7	148.4	13.5	12.3	1.2	247.5	7.5
Elatine minima	ELAMIN	0.0	0.0	4.3	0.4	2.5	0.2	7.2	0.2
Eleocharis acicularis	ELEACI	0.0	0.0	1.9	0.2	2.2	0.2	4.2	0.1
Elodea canadensis	ELOCAN	2.5	0.3	55.9	5.1	16.6	1.7	80.4	2.4
Isoetes spp.	ISOESP	155.4	15.5	6.1	0.6	11.2	1.1	188.8	5.7
Juncus pelocarpus	JUNPEL	15.8	1.6	0.5	0.0	0.5	0.1	18.5	0.6
Lemna trisulca	LEMTRI	0.0	0.0	66.9	6.1	1.6	0.2	74.6	2.3
Littorella uniflora	LITUNI	0.0	0.0	1.1	0.1	3.3	0.3	4.5	0.1
Myriophyllum spp.	MYRISP	18.3	1.8	32.2	2.9	53.0	5.3	108.3	3.3
Najas flexilis	NAJFLE	109.3	10.9	102.6	9.3	39.9	4.0	272.1	8.2
Nuphar sp.	NUPHSP	0.0	0.0	1.7	0.2	0.7	0.1	2.6	0.1
Nymphaea odorata	NYMODO	90.7	9.1	38.7	3.5	3.4	0.3	145.4	4.4
Potamogeton amplifolius	POTAMP	1.1	0.1	0.0	0.0	2.4	0.2	3.6	0.1
Potamogeton epihydrus	POTEPI	3.9	0.4	0.0	0.0	9.5	0.9	13.8	0.4
Potamogeton gramineus	POTGRA	24.9	2.5	18.1	1.6	6.2	0.6	53.3	1.6
Potamogeton narrow leaved	POTNAR	51.9	5.2	69.6	6.3	28.9	2.9	161.9	4.9
Potamogeton richardsonii	POTRIC	18.3	1.8	31.7	2.9	70.6	7.1	125.3	3.8
Potamogeton robbinsii	POTROB	13.9	1.4	0.0	0.0	142.4	14.2	157.6	4.8
Potamogeton zosteriformis	POTZOS	13.0	1.3	18.2	1.7	5.0	0.5	39.2	1.2
Ranunculus longirostris	RANLON	12.0	1.2	2.1	0.2	51.6	5.2	67.1	2.0
Sagittaria rosette	SAGROS	47.1	4.7	5.7	0.5	6.7	0.7	64.9	2.0
Scirpus subterminalis	SCISUB	62.4	6.2	0.4	0.0	0.0	0.0	69.1	2.1
Sparganium sp.	SPARSP	47.2	4.7	0.0	0.0	5.6	0.6	57.4	1.7
Utricularia intermedia	UTRINT	5.1	0.5	0.0	0.0	0.0	0.0	5.6	0.2
Utricularia minor	UTRMIN	0.4	0.0	0.0	0.0	0.0	0.0	0.5	0.0
Utricularia vulgaris	UTRVUL	71.3	7.1	3.1	0.3	2.9	0.3	84.7	2.6
Vallisneria americana	VALAME	112.4	11.2	398.3	36.2	409.4	40.9	967.6	29.3
Zosterella dubia	ZOSDUB	0.0	0.0	0.0	0.0	40.4	4.0	40.4	1.2

Table 25. Most abundant taxa by percent cover in 1 m x 1 m quadrats recorded in the 2 m depth quadrats across all three basins. Lac la Croix was sampled with 10 transects comprising 200 quadrats, Namakan with 11 transects and 220 quadrats, and Rainy with 10 transects and 200 quadrats.

		Lac la Croix					**Namakan**					**Rainy**		
	Taxa	**Total Cover**	**% of total**	**Cum. %**		Taxa	**Total Cover**	**% of total**	**Cum. %**		Taxa	**Total Cover**	**% of total**	**Cum. %**
1	*Isoetes spp.*	2907.5	39.2	39.2	1	*Vallisneria americana*	5908.4	47.8	47.8	1	*Vallisneria americana*	4737.4	55.1	55.1
2	*Vallisneria americana*	828.9	11.2	50.3	2	*Chara spp.*	2366.4	19.2	67.0	2	*Potamogeton robbinsii*	1159.2	13.5	68.6
3	*Scirpus subterminalis*	677.2	9.1	59.4	3	*Potamogeton narrow lvd*	1020.7	8.3	75.2	3	*P. richardsonii*	622.3	7.2	75.9
4	*Najas flexilis*	674.1	9.1	68.5	4	*Najas flexilis*	584.8	4.7	80.0	4	*Zosterella dubia*	453.6	5.3	81.2
5	*Sagittaria rosette*	591.5	8.0	76.5	5	*Ceratophyllum demersum*	523.4	4.2	84.2	5	*Ranunculus longirostris*	431.5	5.0	86.2
6	*Nymphaea odorata*	578.0	7.8	84.3	6	*Lemna trisulca*	459.7	3.7	87.9	6	*Myriophyllum spp.*	431.4	5.0	91.2
7	*Chara spp.*	337.9	4.6	88.8	7	*Bidens beckii*	418.3	3.4	91.3	7	*Bidens beckii*	343.5	4.0	95.2
8	*Juncus pelocarpus*	180.1	2.4	91.3	8	*P. zosteriformis*	286.3	2.3	93.6	8	*Najas flexilis*	110.1	1.3	96.5
9	*Potamogeton robbinsii*	130.5	1.8	93.0	9	*Nymphaea odorata*	257.5	2.1	95.7	9	*Sparganium spp.*	78.0	0.9	97.4
10	*P. gramineus*	118.2	1.6	94.6	10	*P.richardsonii*	166.8	1.3	97.1	10	*Potamogeton epihydrus*	58.0	0.7	98.1
11	*Utricularia vulgaris*	116.7	1.6	96.2	11	*Elodea canadensis*	134.5	1.1	98.1	11	*Potamogeton gramineus*	35.1	0.4	98.5
12	*Bidens beckii*	72.5	1.0	97.2	12	*Myriophyllum spp.*	119.0	1.0	99.1	12	*Sagittaria rosette*	32.4	0.4	98.8
13	*P. epihydrus*	65.1	0.9	98.0	13	*P. gramineus*	71.2	0.6	99.7	13	*Potamogeton narrow lvd*	22.8	0.3	99.1
14	*Sparganium spp.*	35.3	0.5	98.5	14	*Sagittaria rosette*	24.1	0.2	99.9	14	*Elodea canadensis*	19.4	0.2	99.3
15	*P. narrow-lvd*	35.0	0.5	99.0	15	*Utricularia vulgaris*	6.0	0.0	99.9	15	*Ceratophyllum demersum*	17.2	0.2	99.5

Table 26. Total frequency of occurrence in 1 m x 1 m quadrats for most abundant taxa recorded in the 2 m depth transects across all three basins. Lac la Croix was sampled with 10 transects comprising 200 quadrats, Namakan with 11 transects and 220 quadrats, and Rainy with 10 transects and 200 quadrats.

Lac la Croix					**Namakan**					**Rainy**				
	Taxa	**Total Freq.**	**% of total**	**Cum. %**		**Taxa**	**Total Freq.**	**% of total**	**Cum. %**		**Taxa**	**Total Freq.**	**% of total**	**Cum. %**
1	*Najas flexilis*	96	10.4	10.4	1	*Vallisneria americana*	160	17.8	17.8	1	*Vallisneria americana*	148	20.4	20.4
2	*Vallisneria americana*	93	10.0	20.4	2	*Najas flexilis*	132	14.7	32.6	2	*Potamogeton robbinsii*	81	11.2	31.6
3	*Nymphaea odorata*	82	8.8	29.2	3	*Chara spp.*	114	12.7	45.3	3	*Myriophyllum spp.*	65	9.0	40.6
4	*Chara spp.*	80	8.6	37.9	4	*Elodea canadensis*	72	8.0	53.3	4	*Bidens beckii*	62	8.6	49.2
5	*Potamogeton narrow leaved*	78	8.4	46.3	5	*Potamogeton narrow leaved*	69	7.7	61.0	5	*Ranunculus longirostris*	61	8.4	57.6
6	*Isoetes spp.*	76	8.2	54.5	6	*Ceratophyllum demersum*	56	6.2	67.2	6	*Potamogeton richardsonii*	54	7.5	65.1
7	*Bidens beckii*	67	7.2	61.7	7	*Myriophyllum spp.*	54	6.0	73.2	7	*Najas flexilis*	51	7.0	72.1
8	*Utricularia vulgaris*	64	6.9	68.6	8	*Bidens beckii*	47	5.2	78.5	8	*Potamogeton narrow leaved*	40	5.5	77.6
9	*Sagittaria rosette*	49	5.3	73.9	9	*Potamogeton richardsonii*	42	4.7	83.2	9	*Zosterella dubia*	40	5.5	83.1
10	*Sparganium spp.*	39	4.2	78.1	10	*Nymphaea odorata*	37	4.1	87.3	10	*Elodea canadensis*	20	2.8	85.9
11	*Myriophyllum spp.*	36	3.9	82.0	11	*Lemna trisulca*	35	3.9	91.2	11	*Isoetes spp.*	17	2.3	88.3
12	*Potamogeton gramineus*	30	3.2	85.2	12	*Potamogeton gramineus*	20	2.2	93.4	12	*Ceratophyllum demersum*	15	2.1	90.3
13	*Scirpus subterminalis*	28	3.0	88.2	13	*Potamogeton zosteriformis*	17	1.9	95.3	13	*Chara spp.*	11	1.5	91.9
14	*Potamogeton richardsonii*	24	2.6	90.8	14	*Isoetes spp.*	11	1.2	96.5	14	*Potamogeton epihydrus*	7	1.0	92.8
15	*Ranunculus longirostris*	20	2.2	93.0	15	*Elatine minima*	8	0.9	97.4	15	*Sagittaria rosette*	7	1.0	93.8

Table 27. Most abundant taxa by relative importance value (IV) in 1 m x 1 m quadrats recorded in the 2 m depth quadrats across all three basins. Lac la Croix was sampled with 10 transects comprising 200 quadrats, Namakan with 11 transects and 220 quadrats, and Rainy with 10 transects and 200 quadrats.

Lac la Croix					Namakan					Rainy				
	Taxa	**Total Rel. IV**	**% of total**	**Cum. %**		**Taxa**	**Total Rel. IV**	**% of total**	**Cum. %**		**Taxa**	**Total Rel. IV**	**% of total**	**Cum. %**
1	*Isoetes spp.*	155.4	15.5	15.5	1	*Vallisneria americana*	398.3	36.2	36.2	1	*Vallisneria americana*	409.4	40.9	40.9
2	*Vallisneria americana*	112.4	11.2	26.8	2	*Chara spp.*	148.4	13.5	49.7	2	*Potamogeton robbinsii*	142.4	14.2	55.2
3	*Najas flexilis*	109.3	10.9	37.7	3	*Najas flexilis*	102.6	9.3	59.0	3	*Potamogeton richardsonii*	70.6	7.1	62.2
4	*Nymphaea odorata*	90.7	9.1	46.8	4	*Potamogeton narrow-lvd*	69.6	6.3	65.4	4	*Bidens beckii*	60.3	6.0	68.3
5	*Utricularia vulgaris*	71.3	7.1	53.9	5	*Lemna trisulca*	66.9	6.1	71.4	5	*Myriophyllum spp.*	53.0	5.3	73.6
6	*Chara spp.*	66.6	6.7	60.6	6	*Elodea canadensis*	55.9	5.1	76.5	6	*Ranunculus longirostris*	51.6	5.2	78.7
7	*Scirpus subterminalis*	62.4	6.2	66.8	7	*Ceratophyllum demersum*	55.1	5.0	81.5	7	*Zosterella dubia*	40.4	4.0	82.8
8	*Potamogeton narrow-lvd*	51.9	5.2	72.0	8	*Nymphaea odorata*	38.7	3.5	85.0	8	*Najas flexilis*	39.9	4.0	86.8
9	*Bidens beckii*	49.2	4.9	76.9	9	*Bidens beckii*	37.4	3.4	88.4	9	*Potamogeton narrow-lvd*	28.9	2.9	89.6
10	*Sparganium spp.*	47.2	4.7	81.6	10	*Myriophyllum spp.*	32.2	2.9	91.4	10	*Elodea canadensis*	16.6	1.7	91.3
11	*Sagittaria rosette*	47.1	4.7	86.4	11	*Potamogeton richardsonii*	31.7	2.9	94.3	11	*Chara spp.*	12.3	1.2	92.5
12	*Potamogeton gramineus*	24.9	2.5	88.8	12	*Potamogeton zosteriformis*	18.2	1.7	95.9	12	*Isoetes spp.*	11.2	1.1	93.7
13	*Potamogeton richardsonii*	18.3	1.8	90.7	13	*Potamogeton gramineus*	18.1	1.6	97.6	13	*Potamogeton epihydrus*	9.5	0.9	94.6
14	*Myriophyllum spp.*	18.3	1.8	92.5	14	*Isoetes spp.*	6.1	0.6	98.1	14	*Ceratophyllum demersum*	9.4	0.9	95.5
15	*Juncus pelocarpus*	15.8	1.6	94.1	15	*Sagittaria rosette*	5.7	0.5	98.6	15	*Sagittaria rosette*	6.7	0.7	96.2

Unique Taxa

Table 28 indicates those taxa with overall frequencies of occurrence across all basins of five or greater that were uniquely either absent or present at one basin. Of interest, as in the mid-deep, are those taxa not observed in the 620 mid-deep quadrats in Namakan, including *Potamogeton robbinsii*, *P. epihydrus*, and *Sparganium* spp., occurring regularly in the other basins.

Other notable differences include the absence of *Scirpus subterminalis* and the unique presence of *Zosterella dubia* in Rainy.

Table 28. Taxa unique to one or two basins as sampled in 620 quadrats along the 2 m depth transects. Only those with overall frequencies of occurrence of five or greater are included.

Uniquely absent in Lac la Croix quadrats (but with a total frequency of 5 and greater in other basins).

		Frequency Namakan	Frequency Rainy
Elatine minima	ELAMIN	8	5
Lemna trisulca	LEMTRI	35	3
Littorella uniflora	LITUNI	2	4

Uniquely absent in Namakan quadrats (but with a total frequency of 5 and greater in other basins).

		Frequency Lac la Croix	Frequency Rainy
Potamogeton epihydrus	POTEPI	3	7
Potamogeton robbinsii	POTROB	15	81
Sparganium spp.	SPARSP	39	3

Uniquely absent in Rainy quadrats (but with a total frequency of 5 and greater in other basins).

		Frequency Lac la Croix	Frequency Namakan
Scirpus subterminalis	SCISUB	28	1

Uniquely present in Lac la Croix quadrats (with a total frequency of 5 and greater).

		Frequency
Utricularia intermedia	UTRINT	6

Uniquely present in Rainy quadrats (with a total frequency of 5 and greater).

		Frequency
Zosterella dubia	ZOSDUB	40

Ordinations
NMS ordinations were performed in PCORD using the composite IV metric on all 31 taxa occurring across the 31, 2.0 m transects (Figure 13).

In general the abundance of the isoetid life form in four Lac la Croix transects heavily influenced the ordination (r= 0.778 on axis two). In addition several of the Namakan and the Lac la Croix sites had a slightly greater contribution of floating leaf taxa (r=0.557). The dominance of tall submergents mostly in Rainy Lake (plotting lower on axis two, r=-0.578) separated most of these sites from the Namakan and Lac la Croix sites. In addition, there was a slight clustering of ten Namakan sites, somewhat intermediate between Rainy and Lac la Croix.

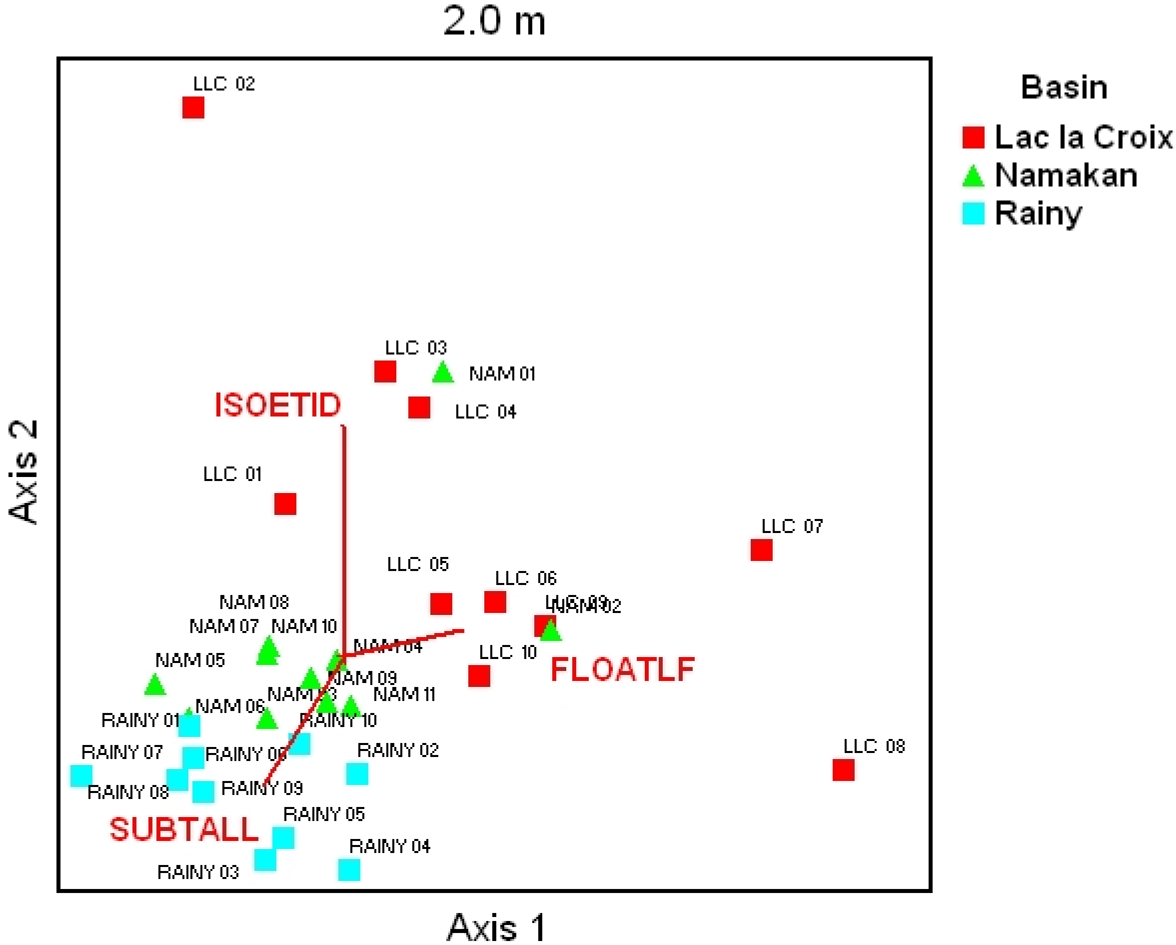


Figure 13. Non-metric multidimensional scaling (NMS) ordination of 31, 2 m depth transects and 31 taxa (importance values). Vectors represent taxonomic groups that are correlated with axis scores, ISOETID = taxa with a low rosette life form, SUBTALL = submergent taxa occupying nearly the whole water column, FLOATLF = floating leaf taxa (see text for values).

Multi-response Permutation Procedure

A pairwise comparison of vegetation data suggests that the three basins are significantly different at the 2 m depth (Table 12).

Comparison of Life Forms Among Basins

Looking first at percent cover (Table 29, Figure 11), Lac la Croix has greater contributions from the floating leaf and isoetid life forms than both Namakan and Rainy, although only significantly greater than Rainy for floating leaf and than Namakan for isoetids. Alternatively, the tall submergent category was significantly greater in both Namakan and Rainy than in Lac la Croix (with 70 and 83 vs. only 16.8% of the total cover respectively).

The frequency values indicated similar differences with the floating leaf and isoetid categories (Lac la Croix significantly greater in both), but there were no significant differences in the frequency of tall submergents as compared to cover (48.%1 in Lac la Croix compared to 60.9 at Namakan and 72.1 at Rainy).

The analyses of differences among basins using importance value showed similar results, and in the case with this metric, significant differences were apparent for three of the four categories (floating leaf, isoetid, and tall submergents), with Lac la Croix different from Namakan in each case.

Discussion

The wetland communities of Lac la Croix, Namakan Reservoir, and Rainy Lake differed from each other in species composition. Ordinations and MRPP analysis showed that (i) shoreline communities of Rainy Lake are significantly different from the other basins, (ii) at the 1.25 m depth, Lac la Croix differed from the other two basins and (iii) all three basins differed from each other at the 2.0 m depth. These findings are similar to those of Wilcox and Meeker (1991) who concluded that vegetation of the three basins differed, particularly at greater depths. However, we observed some differences from Wilcox and Meeker's 1987 study. We found no significant difference in vegetation cover between basins at any depth.

Shorelines

There was no significant difference in total cover among the basins at the shoreline elevation. As with Wilcox and Meeker (1991), a few taxa accounted for most of the cover in all basins and the most dominant taxa were similar across all three basins (*Myrica gale*, *Calamagrostis canadensis*, *Spirea alba* and *Lysimachia* spp.). Rainy Lake shorelines had greater species richness per quadrat than Namakan shorelines. We speculate that this may be due to the proliferation of annual species (*Polygonum sagittatum*, *Polygonum* spp) and seedlings of shrubs species (*Rosa* spp, *Rubus* spp., *Salix* spp.) (Table 9) that colonized exposed substrate associated with the low water levels in 2003 on Rainy Lake. These species may account for the difference in Rainy Lake shorelines as determined by the MRPP analysis.

Table 29. Comparison of life form proportions among basins at 2 m depth transects across three metrics, total cover, frequency of occurrence, and relative importance value (IV). Significant differences expressed at p=0.05, Kruskal-Wallis test on medians.

	Lac la Croix		**Namakan**		**Rainy**		
Life Form	**Total Cover**	**% of total**	**Total Cover**	**% of total**	**Total Cover**	**% of total**	**Significant differences**
floating leaf	678.4	9.1	260.7	2.1	144.2	1.7	LLC>RNY
isoetid	3679.1	49.6	28.3	0.2	42.9	0.5	LLC>NAM
low submergent	1819.8	24.5	3411.9	27.6	1274.6	14.8	
tall submergent	1247.2	16.8	8655.0	70.0	7129.7	83.0	LLC<NAM, LLC<RNY
	7424.5	100.0	12355.9	100.0	8591.4	100.0	
	Total Frequency	**% of total**	**Total Frequency**	**% of total**	**Total Frequency**	**% of total**	
floating leaf	124	13.4	40	4.5	16	2.2	LLC>NAM, LLC>RNY
isoetid	137	14.8	20	2.2	29	4.0	LLC>NAM
low submergent	220	23.7	291	32.4	157	21.7	
tall submergent	446	48.1	546	60.9	522	72.1	
	927	100.0	897	100.0	724	100.0	
	Total Rel. IV	**% of total**	**Total Rel. IV**	**% of total**	**Total Rel. IV**	**% of total**	
floating leaf	141.8	14.2	40.4	3.7	19.2	1.9	LLC>NAM, LLC>RNY
isoetid	218.3	21.8	13.5	1.2	21.8	2.2	LLC>NAM
low submergent	258.8	25.9	324.4	29.5	202.3	20.2	
tall submergent	381.1	38.1	721.7	65.6	756.8	75.7	LLC<NAM, LLC<RNY

There were enough taxa unique to particular basins to suggest that either past or present water level management does differentially influence the shoreline communities. Lac la Croix has significantly more cover of facultative wetland herb taxa than Namakan, but less cover of emergent taxa, perhaps reflecting the gradual summer drawdown occurring in Lac la Croix, but not the other basins, allowing facultative wetland species to invade the drawdown zone. We speculate that the higher proportion of fen plant species at Lac la Croix (e.g. *Osmunda regalis*, *Chamaedaphne calyculata*, *Dulichium arundinaceum*) (Tables 10 and 11) may also reflect the flooding-drawdown cycle since these species are intolerant of both prolonged flooding and high levels of competition with trees and shrubs.

1.25 m Depth

The vegetation structure at this depth appears to have changed since 1987, at least in the Namakan Reservoir. Wilcox and Meeker (1991) found that Namakan was dominated by rosette and mat-forming species at the 1.25 and 2.0 m depths, but this was not observed in the present study. They attributed the difference to the late winter drawdown in Namakan resulting in dessication and ice scour that killed or damaged perennial species inhabiting this zone. The apparent increase in low and tall submergents at the 1.25 m depth may be evidence that the aquatic community has begun to recover and responded to the higher water levels in late winter.

However, Namakan continues to have less emergent and floating leaf cover than the other basins and has a smaller species pool than Lac la Croix.

2.0 m Depth

Although there is no significant difference in total vegetation cover or species richness between the basins at the 2.0 m depth, differences in vegetation structure and composition are apparent. The 2.0 m depth ordination suggests that that the Lac la Croix sites have more vegetation diversity than the other basins (Figure 13). In addition, Lac la Croix has greater vegetation structural diversity compared to the other basins (relative cover is more evenly distributed among the life forms; Figure 11). Lac la Croix has significantly less tall submergent cover but more floating leaf and isoetid vegetation. This supports the findings of Wilcox and Meeker (1991), who attributed the difference in vegetation structure to the intermediate level of disturbance at Lac la Croix, lacking both the extreme drawdowns of the Namakan Reservoir and the unnaturally stable water levels of Rainy Lake. Rainy Lake, on the other hand, continues to be dominated by tall submergents, again supporting Wilcox and Meeker's conclusion that stable water levels promote the dominance of this life form.

Differences in species composition among basins are also evident, although few taxa dominate this depth in all basins. The absence of *Potamogeton robbinsii, P. epihydrus,* and *Sparganium* spp. in the Namakan reservoir may be evidence that the water regime has all but eliminated these taxa from the 2.0 m depth.

On the other hand, the general lack of significant difference in cover and richness may suggest that the basins are converging since the Namakan Reservoir began to be regulated closer to the middle of the rule curve in the 1980s. In particular, the shift from dominance by low mat forming species to taller submergents at 1.25 m and 2.0 m in Namakan may be evidence that the wetland communities are responding to rule curve changes. This study increases the sample size from the small pool of samples (n = 2 per basin) used by Wilcox and Meeker and should enable detection of changes in subsequent monitoring.

Changes in wetland communities between 1987 and 2002-2003 for a subset of the sites will be discussed in the following section.

Assessing Vegetative Change Over Time

In this section we assess changes in vegetation 1) over a relatively short term at two Namakan sites and 2) over a long term period (15 to 16 years) at two sites in each basin.

As presented in the Intensive Sampling section, Namakan has experienced a reduction of drawdown amplitude since the early 1970s, and this continued through the 1987 sampling (Wilcox and Meeker 1991) and into the 1990s (Figure 3). Prior to re-sampling in 2002, we expected that this gradual reduction in water level variability would affect two wetland zones. These include zone 1, the 2.0 m depth, where the protection of vegetation by insulating water cover during the winter should result in increased vegetative growth, and zone 3, the shoreline zone, where a gradual reduction of water levels during the summer should encourage facultative wetland taxa and trees and shrubs. We also predicted that the changes in vegetation should be greater between 1987 and 2002 than among the 2002, 2004, and 2006 samplings.

Namakan Variability over Four Sampling Times (1987, 2002, 2004, and 2006)

To increase the understanding of vegetation dynamics in this present monitoring effort, we conducted multiple resampling of two of the intensive sampled sites. We asked: "How much change can we expect over short time spans (two to four years) versus long intervals?" In this case we looked at two Namakan sites (NAM05 and NAM07) in 2002, 2004, and 2006. We chose these sites because they were also the two Namakan sites sampled in 1987 (Wilcox and Meeker 1991) and offered a fourth sampling time 15 years prior to 2002.

Methods

As in the intensive sampling at each site, we sampled three elevational transects relative to mean high water—0.0 m (or shoreline), 1.25 m (mid-deep), and 2.0 m (deep)—using 20 quadrats at each transect. It should again be noted that these are target elevations relative to expected responses to the new rule curve. The actual water depths sampled differed from year to year, depending on basin precipitation and upstream supply. Actual water levels at the time of sampling were as follows:

Year	Target elevation (m)	Actual Depth (m)
1987	0.0	0.20 above water level
1987	1.25	1.05
1987	2.0	1.80
2002	0.0	0.34 below water level
2002	1.25	1.59
2002	2.0	1.82
2004	0.0	0.17 above water level
2004	1.25	1.08
2004	2.0	1.83
2006	0.0	0.25 above water level
2006	1.25	1.00
2006	2.0	1.75

In general, the water levels were highest in 2002. In that year at the 1.25 m transect, observers were looking through about 1.6 meters of water as opposed to only about one meter at the other times.

In order to follow general vegetational changes, rather than what happened at a particular site, data was combined for each elevational transect. Hence, Namakan site 05 was combined with the Namakan site 07 for a total of 40 quadrats (20 for each site).

Floristic similarity indices were calculated for all possible pairings of the four time periods at each elevation using the formula similarity % = 2w/(a+ b) x 100, where w = the taxa in common between two times and a and b are the respective number of taxa at each time. Other vegetation and sampling and analysis techniques are described in the Intensive Sampling section.

A visual inspection of the NMS ordination suggests that the two Namakan repeat sample sites are reasonably representative of the Namakan sites in general (Figures 10, 12, and 13).

Results

Similarity

In general the 0.0 m elevations (shorelines) of Namakan were more species rich than the submerged aquatic habitats and varied from 42 taxa (in 2002) to 51 (in both 1987 and 2004; Table 30). Richness was lowest in the deepest aquatic habitat, varying from a low of 12 (again in 2002) to a high of 19 in 1987.

Mean similarity among the six shoreline comparisons was 68.4%, varying from a low of 60.2 to a high of 73.5%, and there appeared to be no trends among comparison years.

Comparisons among both aquatic transects suggested a trend of increasing similarity among the later years. At the 1.25 m transects, all recent year comparisons were 70.0% or greater (to a high of 83.7%), while the comparisons with 1987 ranged from 47.4 to 61.9%. The deep transect comparisons were also more similar among recent years (78.6 to 88.9%) than the values involving 1987 (58.1 to 68.6%).

Shoreline Transects

Seventy-seven taxa were recorded at the two Namakan shoreline sites over the four sampling times, and 41 were found with an overall quadrat frequency greater than five (of 160, or 4 years x 40 quadrats each year) (Table 31). Of these 41, six were uniquely absent to 1987 (or only absent in 1987). These include *Iris versicolor*, moss spp. (possibly overlooked in 1987), *Phalaris arundinacea*, and three woody taxa, *Pinus strobus*, *Salix* spp., and *Viburnum lentago*. Another six were uniquely absent in 2002, while no taxa were only absent in 2004, and only three taxa were uniquely absent in 2006.

Table 30. Floristic similarities among four sampling times for combined Namakan sites. Values are presence or absence only based on the formula: similarity % = 2w/(a+b) x 100, where w = the taxa that the two times have in common and a and b are taxa richness values for both years being compared.

Shoreline												
Comparison years	**1987**	**2002**	**1987**	**2004**	**1987**	**2006**	**2002**	**2004**	**2002**	**2006**	**2004**	**2006**
Taxa in common (w)	28		34		36		32		31		35	
Richness per year (a and b)	51	42	51	51	51	47	42	51	42	47	51	47
Similarity index value (%)	60.2		66.7		73.5		68.8		69.7		71.4	
(2w/(a + b)) x 100	mean values =	68.4										
Mid-deep (1.25m)												
Comparison years	**1987**	**2002**	**1987**	**2004**	**1987**	**2006**	**2002**	**2004**	**2002**	**2006**	**2004**	**2006**
Taxa in common (w)	9		13		12		14		15		18	
Richness per year (a and b)	20	18	20	22	20	21	18	22	18	21	22	21
Similarity index value (%)	47.4		61.9		58.5		70.0		76.9		83.7	
(2w/(a + b)) x 100	mean values =	66.4										
Deep (2.0m)												
Comparison years	**1987**	**2002**	**1987**	**2004**	**1987**	**2006**	**2002**	**2004**	**2002**	**2006**	**2004**	**2006**
Taxa in common (w)	9		11		12		12		11		13	
Richness per year (a and b)	19	12	19	15	19	16	12	15	12	16	15	16
Similarity index value (%)	58.1		64.7		68.6		88.9		78.6		83.9	
(2w/(a + b)) x 100	mean values =	73.8										

Table 31. Total cover and frequency of occurrence for forty-one taxa recorded in at least five quadrats at shoreline transects over four sampling years at two Namakan sites (NAM 05 and NAM07). Both metrics are over 40, 1 m x 1 m quadrats.

		1987		**2002**		**2004**		**2006**		**All years**	
Taxa	**Life Form**	Cover	Freq.	Cover	Freq.	Cover	Freq.	Cover	Freq.	Cover	Freq.
Acorus calamus	EMERG	2	2	0	0	2	2	10	3	7	14
Agrostis hyemalis	GRAMIN	5.1	5	1.1	2	0.1	1	0	0	8	6.3
Alnus incana	TRSHRUB	2	1	246	14	664	22	393	19	56	1305
Aster spp.	FACWET	5.1	4	0	0	8.2	7	23	11	22	36.3
Calamagrostis canadensis	GRAMIN	338	27	490	32	700	35	457	35	129	1985
Campanula aparinoides	FACWET	9	7	22.4	13	14.2	10	27.1	17	47	72.7
Carex lacustris	GRAMIN	197	14	18	5	33	11	90	15	45	338
Carex utriculata	GRAMIN	187	25	113.2	17	97.1	24	143	29	95	540
Cicuta spp.	FACWET	8.3	8	0.1	1	2.4	6	0	0	15	10.8
Cornus sericea	TRSHRUB	0.1	1	66	5	36	5	25.1	5	16	127
Eleocharis acicularis	GRAMIN	1	1	0	0	7.2	5	0.2	2	8	8.4
Equisetum spp.	FACWET	25	9	111.4	23	23.2	15	8.1	7	54	168
Fraxinus spp.	TRSHRUB	0.2	2	16	3	4	1	6	3	9	26.2
Galium spp.	FACWET	1.1	2	3	2	5.2	5	3.5	7	16	12.8
Glyceria spp.	GRAMIN	4	2	0	0	2	2	4.1	3	7	10.1
Impatiens capensis	FACWET	9.1	6	0	0	1.1	2	0	0	8	10.2
Iris versicolor	EMERG	0	0	6	3	2	1	4	2	6	12
Lathyrus spp.	FACWET	1	1	2.1	2	3	2	0	0	5	6.1
Lemna minor	AQUATIC	1.3	4	0.1	1	0	0	0	0	5	1.4
Lycopus spp.	FACWET	34.1	15	12.2	10	16.1	11	24.1	17	53	86.5
Lysimachia spp.	FACWET	42.4	26	50.1	21	55.3	28	67	32	107	215
moss spp.	FACWET	0	0	5	1	66.2	18	33	11	30	104
Myrica gale	TRSHRUB	20.3	10	1671	33	1159	30	1441	36	109	4291
Onoclea sensibilis	FACWET	5.1	4	36	2	2	1	2	1	8	45.1
Phalaris arundinacea	GRAMIN	0	0	16	2	12	3	43	3	8	71
Pinus strobus	TRSHRUB	0	0	275	4	134	5	101	5	14	510
Poa spp.	GRAMIN	1.1	2	0	0	0.1	1	4.2	5	8	5.4
Polygonum amphibium	FACWET	15	7	5.2	5	41	9	42	15	36	103
Polygonum spp.	FACWET	14.2	9	0	0	0	0	5.1	4	13	19.3
Potentilla palustris	FACWET	14	4	52	8	77	14	56.1	16	42	199
Ranunculus flammula	FACWET	5.3	8	0	0	1	1	1.4	5	14	7.7
Ranunculus pensylvanicus	FACWET	1.2	3	0	0	0	0	0.4	4	7	1.6
Salix spp.	TRSHRUB	0	0	45	2	7	2	6	1	5	58
Scirpus cyperinus	GRAMIN	79	10	6.2	5	17	2	65	11	28	167
Scutellaria spp.	FACWET	1.2	3	6	3	2	2	1.1	2	10	10.3
Sium suave	FACWET	3.2	5	2.1	2	4.2	5	8.4	9	21	17.9
Spiraea alba	TRSHRUB	1.1	2	44	5	48	5	36	3	15	129
Toxicodendron radicans	TRSHRUB	1	1	8	4	2	1	1	1	7	12
Triadenum fraseri	FACWET	23.1	11	25.2	12	12	7	23.1	10	40	83.4
Viburnum lentago	TRSHRUB	0	0	91	4	35	4	4	2	10	130
Viola spp.	UPHERB	0.7	7	0	0	0	0	1.1	2	9	1.8

A NMS ordination of the two shoreline Namakan sites at each sampling year suggests that the greatest change in species composition (i.e. longest successional vectors) occurred between 1987 and 2002 at both sites (Figure 14). Subsequent change was smaller and not in a uniform direction, especially at NAM05.

There are clear differences in taxa abundance among years (Table 32). Of the twelve most abundant taxa by percent relative cover (that comprise at least 90% of the cumulative relative cover in each year), sampling year 1987 stands out as having no woody taxa in the top five. Sampling years 2002, 2004, and 2006 all have the same top five taxa which include three woody taxa (*Myrica*, *Pinus*, and *Alnus*). In addition, it should be noted that the absolute cover in the more recent samplings is considerably greater. For example, whereas *Calamagrotis canadensis* had the greatest total cover (at 338) of all taxa in 1987 it was less than all subsequent years (at 490, 700, and 457 for 2002, 2004, and 2006 respectively; Table 32).

There were also significant differences in quadrat cover (all taxa) among years (Table 33, bottom). Whereas in 1987 the shoreline quadrat mean percent cover was 27.2%, it increased significantly to 79.8% and greater in the last three samplings ($p < .000001$, Kruskal-Wallis non-parametric analysis of variance). There were also differences in quadrat richness, as 2006 (9.2 taxa per quadrat) was significantly higher than both 1987 (6.8) and 2002 (6.5) ($p < .00002$, Kruskal-Wallis).

Shoreline taxa were grouped into six life forms for additional analyses, and these showed significant differences in mean cover per quadrat among years in the shrub/tree category, where all three recent years had greater representation by woody taxa (ranging from 50.4 to 61.8, $p < 0.00001$, Kruskal-Wallis;Table 33). These woody taxa were primarily *Myrica gale*, *Pinus strobus*, and *Alnus incana* (Table 32). Graminoid (grasses and sedges) cover showed no significant differences among years (ranging from 16.1 to 21.7%), suggesting that the overall increase over time in mean quadrat cover is best explained by increases in shrub encroachment and not by losses in the raw cover of other taxa.

1.25 m Depth

Thirty-three taxa were recorded over all sampling times at the 1.25 m elevation (Table 34). Of these, five taxa were not recorded in 1987, but seen at all the later times; these include *Bidens beckii*, *Ceratophyllum demersum, Elodea canadensis*, *Myriophyllum spp*., and *Potamogeton zosteriformis,* and all taller submergent aquatics. Although *Bidens* and *Potamogeton zosteriformis* were only infrequently seen in 2002-2006, the other three taxa mentioned above were quite common in the later three samplings, suggesting real change from 1987 to 2002-2006. These differences were reflected in the low similarity index values comparing 1987 to 2002-2006 as mentioned above (Table 30). In addition, the 2002 sampling did not include *Chara* spp., *Isoetes* spp., and *Sagittaria* spp. Rosettes, while they were found at all other times (Table 34). This may be related to the greater water depth in 2002, as observer visibility would be greatly reduced by an extra 0.50 m of water. Even though samplers dove down to 'hover' over quadrats to record observations, the increased depth would result in less observation time.

A NMS ordination of the Namakan 1.25 m sites over time suggests that the greatest change in species composition (i.e. longest successional vectors) occurred between 1987 and 2002 at NAM07, but between 2002 and 2006 at NAM05 (Figure 15).

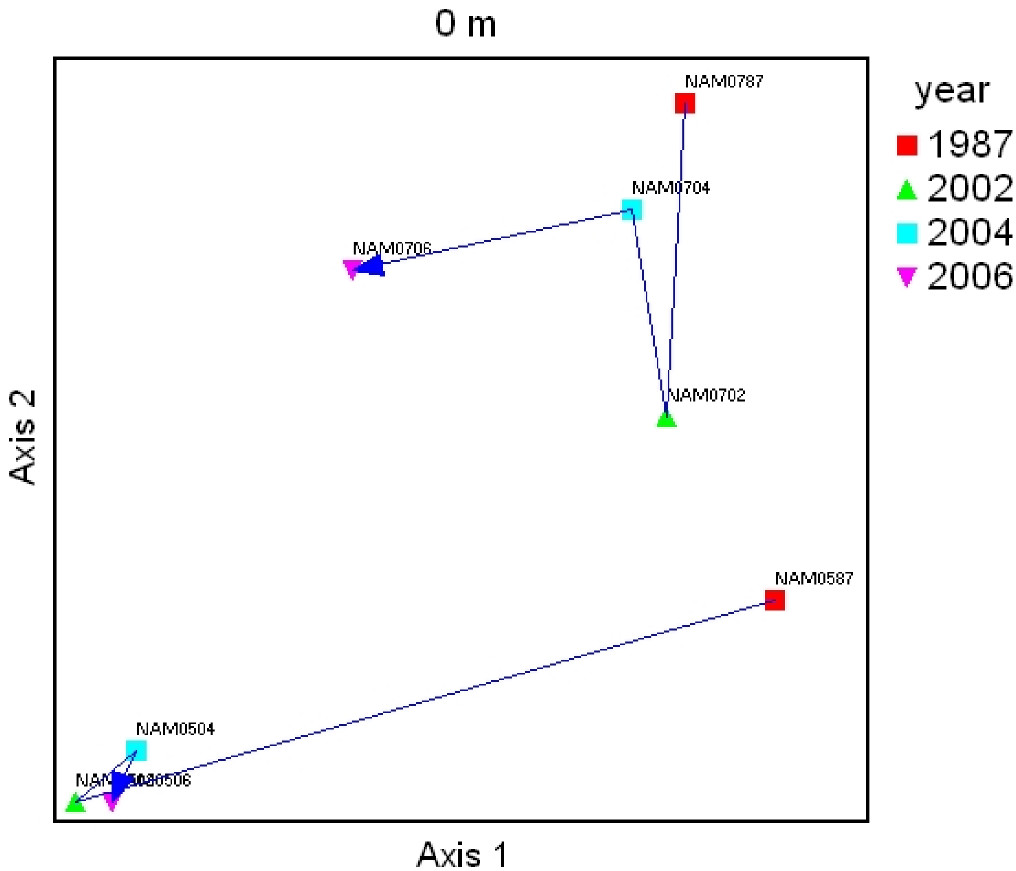


Figure 14. Non-metric multidimensional scaling (NMS) ordination of shoreline transects at two Namakan Reservoir sites 1987 to 2006. Importance Value data used in the ordination. Successional vectors join the series of repeated samples on the transect.

Table 32. The twelve most abundant shoreline taxa by cover for each sampling year. Metrics listed are total cover and frequency over 40 quadrats for each year, relative cover (relative to all cover for each year), and cumulative relative cover.

1987					2002				
Taxa	**Cover**	**Freq.**	**% Rel. Cover**	**Cum.% Rel. Cover**	**Taxa**	**Cover**	**Freq.**	**% Rel. Cover**	**Cum.% Rel. Cover**
Calamagrostis canadensis	338	27	31.1	31.1	*Myrica gale*	1671	33	48.2	48.2
Carex lacustris	197	14	18.1	49.2	*Calamagrostis canadensis*	490	32	14.1	62.4
Carex utriculata	187	25	17.2	66.5	*Pinus strobus*	275	4	7.9	70.3
Scirpus cyperinus	79	10	7.3	73.7	*Alnus incana*	246	14	7.1	77.4
Lysimachia spp.	42.4	26	3.9	77.6	*Carex utriculata*	113.2	17	3.3	80.7
Lycopus spp.	34.1	15	3.1	80.8	*Equisetum spp.*	111.4	23	3.2	83.9
Equisetum spp.	25	9	2.3	83.1	*Viburnum lentago*	91	4	2.6	86.5
Triadenum fraseri	23.1	11	2.1	85.2	*Cornus sericea*	66	5	1.9	88.4
Myrica gale	20.3	10	1.9	87.1	*Potentilla palustris*	52	8	1.5	89.9
Polygonum amphibium	15	7	1.4	88.5	*Lysimachia spp.*	50.1	21	1.4	91.3
Polygonum spp.	14.2	9	1.3	89.8	*Salix spp.*	45	2	1.3	92.6
Potentilla palustris	14	4	1.3	91.1	*Spiraea alba*	44	5	1.3	93.9
2004					**2006**				
Taxa	**Cover**	**Freq.**	**% Rel. Cover**	**Cum.% Rel. Cover**	**Taxa**	**Cover**	**Freq.**	**% Rel. Cover**	**Cum.% Rel. Cover**
Myrica gale	1159	30	34.1	34.1	*Myrica gale*	1441	36	45.1	45.1
Calamagrostis canadensis	700	35	20.6	54.7	*Calamagrostis canadensis*	457	35	14.3	59.4
Alnus incana	664	22	19.5	74.3	*Alnus incana*	393	19	12.3	71.7
Pinus strobus	134	5	3.9	78.2	*Carex utriculata*	143	29	4.5	76.2
Carex utriculata	97.1	24	2.9	81.1	*Pinus strobus*	101	5	3.2	79.4
Potentilla palustris	77	14	2.3	83.3	*Carex lacustris*	90	15	2.8	82.2
moss spp.	66.2	18	1.9	85.3	*Lysimachia spp.*	67	32	2.1	84.3
Chamaedaphne calyculata	65	1	1.9	87.2	*Scirpus cyperinus*	65	11	2.0	86.3
Lysimachia spp.	55.3	28	1.6	88.8	*Potentilla palustris*	56.1	16	1.8	88.1
Spiraea alba	48	5	1.4	90.2	*Phalaris arundinacea*	43	3	1.3	89.4
Polygonum amphibium	41	9	1.2	91.5	*Polygonum amphibium*	42	15	1.3	90.7
Cornus sericea	36	5	1.1	92.5	*Spiraea alba*	36	3	1.1	91.9

Table 33. Comparison of mean quadrat cover (1 m x 1 m), total frequency, importance values, and richness across four sampling times at two shoreline transects in Namakan Reservoir (NAM05 and NAM07). All taxa grouped into six life forms for the first three analyses.

	Raw Values					Relativized to 100%			
Mean Quadrat Cover	**1987**	**2002**	**2004**	**2006**		**1987**	**2002**	**2004**	**2006**
Aquatic	0.04	0.01	0.15	0.00		0.1	0.0	0.2	0.0
Emergent	0.11	0.20	0.15	0.43		0.4	0.2	0.2	0.5
Facultative Wet	5.89	8.47	8.46	8.76		21.7	9.8	10.0	11.0
Graminoid	20.46	16.11	21.74	20.24		75.3	18.6	25.6	25.4
Tree/shrub	0.65	61.80	54.23	50.38		2.4	71.3	63.9	63.1
Upland Herb	0.02	0.05	0.20	0.03		0.1	0.1	0.2	0.0
						100.0	100.0	100.0	100.0
Frequency Total (overall)	**1987**	**2002**	**2004**	**2006**		**1987**	**2002**	**2004**	**2006**
Aquatic	5	3	2	1		1.9	1.2	0.6	0.3
Emergent	5	4	4	7		1.9	1.5	1.2	1.9
Facultative Wet	142	112	149	174		52.6	43.1	45.8	47.4
Graminoid	89	63	85	106		33.0	24.2	26.2	28.9
Tree/shrub	22	76	81	77		8.1	29.2	24.9	21.0
Upland Herb	7	2	4	2		2.6	0.8	1.2	0.5
totals	270	260	325	367		100.0	100.0	100.0	100.0
Importance Value	**1987**	**2002**	**2004**	**2006**		**1987**	**2002**	**2004**	**2006**
Aquatic	1.77	1.18	0.81	0.28		0.9	0.6	0.4	0.1
Emergent	2.27	1.82	1.41	2.40		1.1	0.9	0.7	1.2
Facultative Wet	74.51	53.60	55.83	58.41		37.3	26.8	27.9	29.2
Graminoid	108.15	43.13	51.70	54.59		54.1	21.6	25.9	27.3
Tree/shrub	10.99	99.41	88.76	83.74		5.5	49.7	44.4	41.9
Upland Herb	2.31	0.86	1.49	0.58		1.2	0.4	0.7	0.3
	1987	**2002**	**2004**	**2006**					
Mean Richness	6.75	6.525	8.125	9.175					
Mean Quadrat Cover	27.16	86.65	84.92	79.84					
(all taxa)									

Table 34. Frequency of occurrence for all 33 taxa reorded at 1.25 m depth transects over four sampling years at two Namakan sites (NAM05 and NAM07). Frequency is over 40, 1 m x 1 m quadrats.

Taxa	**Life Form**	**1987**	**2002**	**2004**	**2006**
Bidens beckii	SUBTALL		2	2	1
Bidens spp.	EMERGENT		1		
Callitriche hermaphroditica	SUBLOW			2	10
Cardamine spp.	EMERGENT	1			
Ceratophyllum demersum	SUBTALL		11	14	12
Chara sp.	SUBLOW	9		8	7
Crassula aquatica	ISOETID	37			
Elatine minima	SUBLOW	15	7	20	22
Eleocharis acicularis	SUBLOW	37		9	
Eleocharis palustris	EMERGENT				1
Elodea canadensis	SUBTALL		5	21	20
Eriocaulon aquaticum	ISOETID			21	
Glyceria borealis	EMERGENT	21	2		4
Isoetes spp.	ISOETID	35		23	35
Juncus pelocarpus	ISOETID			17	7
Littorella uniflora	ISOETID		7		25
Myriophyllum spp	SUBTALL		3	6	12
Najas flexilis	SUBLOW	9	17	31	38
Nymphaea odorata	FLOATLF	6	21	24	21
Polygonum spp.	EMERGENT	19			
Potamogeton gramineus	SUBTALL	9	20	17	29
Potamogeton narrow-leaved	SUBTALL	5	22	33	33
Potamogeton richardsonii	SUBTALL	2	1	3	4
Potamogeton zosteriformis	SUBTALL		2	2	1
Ranunculus flammula	SUBLOW	22			
Ranunculus longirostris	SUBTALL	2	1	14	11
Rorippa sp.	EMERGENT	3			
Sagittaria rosette	ISOETID	21		1	31
Sagittaria spp.	EMERGENT		7	2	
Sparganium spp.	EMERGENT	1			
Subularia aquatica	ISOETID	4		3	
Utricularia vulgaris	SUBTALL		1		
Vallisneria americana	SUBTALL	14	29	24	34
	Totals	272	159	297	358

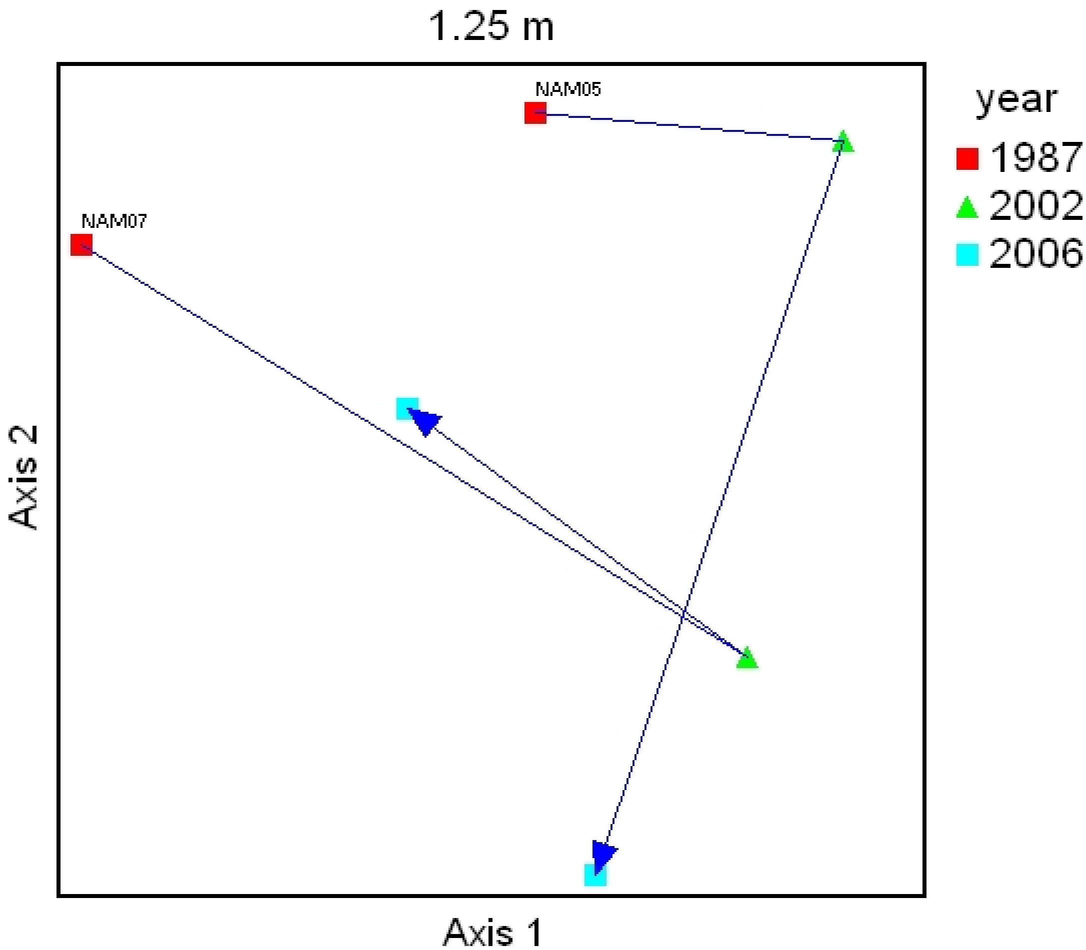


Figure 15. Non-metric multidimensional scaling (NMS) ordination of 1.25 m depth transects at two Namakan Reservoir sites, 1987 to 2006. Importance Value data used in the ordination. Successional vectors join the series of repeated samples on the transect.

Overall, quadrat cover was significantly greater in 2006 (94.7%) and 2004 (79.7%) when compared to 2002 (41.7%) and 1987 (35.2%) ($p = 0.00001$ Kruskal-Wallis;Table 35). Richness per quadrat was significantly lower in 2002 (3.97 taxa) compared to all other years ($p = 0.00001$, Kruskal-Wallis) where it ranged from 6.80 to 8.95.

A particularly troubling aspect of the aquatic results over time includes the disparity among estimates of the low growing isoetid life forms (Table 35). (Isoetids include low lying, slow growing, rosette-leaved taxa such as *Crassula aquatica*, *Eriocaulon aquaticum*, *Isoetes* spp., *Juncus pelocarpus*, *Littorella uniflora*, and rosette forms of *Sagittaria*). Since these are difficult to identify and often obscured by other vegetation, it may be that they have been misidentified. For example, in 2004 *Eriocaulon* cover was estimated to be 614.1 overall, the only time it was recorded. Similarly, *Crassula aquatica* was recorded only in 1987 with a cover value of 136.5. In addition, in 2006, *Littorella* cover was estimated at 415.7 compared to zero in 1987and 2004,

Table 35. Total quadrat cover for all 33 taxa reorded at 1.25 m depth transects over four sampling years at two Namakan sites (NAM05 and NAM07). Total cover is over 40, 1 m x 1 m quadrats.

		1987		2002		2004		2006	
Taxa	**Life Form**	**Cover**	**Rel. to year total**	**Cover**	**Rel. to year total**	**Cover**	**Rel. to year total**	**Cover**	**Rel. to year total**
Bidens beckii	SUBTALL			3.1	0.2	0.2	0.0	0.1	0.0
Bidens spp.	EMERGENT			0.1	0.0				
Callitriche hermaphroditica	SUBLOW					0.2	0.0	1.9	0.1
Cardamine spp.	EMERGENT	0.1	0.0						
Ceratophyllum demersum	SUBTALL			10.6	0.6	33.4	1.0	14.5	0.4
Chara sp.	SUBLOW	12.4	0.9			62.0	1.9	9.5	0.3
Crassula aquatica	ISOETID	136.5	9.7						
Elatine minima	SUBLOW	7.9	0.6	0.7	0.0	3.8	0.1	5.8	0.2
Eleocharis acicularis	SUBLOW	416.8	29.6			59.1	1.9		
Eleocharis palustris	EMERGENT							1.0	0.0
Elodea canadensis	SUBTALL			11.2	0.7	62.6	2.0	16.2	0.4
Eriocaulon aquaticum	ISOETID					614.1	19.3		
Glyceria borealis	EMERGENT	97.1	6.9	5.0	0.3			3.3	0.1
Isoetes spp.	ISOETID	46.3	3.3			280.3	8.8	633.4	16.7
Juncus pelocarpus	ISOETID					313.1	9.8	22.2	0.6
Littorella uniflora	ISOETID			1.6	0.1			415.7	11.0
Myriophyllum spp	SUBTALL			5.0	0.3	15.2	0.5	11.5	0.3
Najas flexilis	SUBLOW	9.2	0.7	623.0	37.3	635.3	19.9	716.6	18.9
Nymphaea odorata	FLOATLF	47.0	3.3	77.2	4.6	123.0	3.9	56.3	1.5
Polygonum spp.	EMERGENT	45.1	3.2						
Potamogeton gramineus	SUBTALL	16.0	1.1	67.1	4.0	100.0	3.1	179.2	4.7
Potamogeton narrow-leaved	SUBTALL	6.0	0.4	169.1	10.1	431.5	13.5	212.4	5.6
Potamogeton richardsonii	SUBTALL	2.0	0.1	0.1	0.0	4.2	0.1	6.1	0.2
Potamogeton zosteriformis	SUBTALL			3.0	0.2	8.0	0.3	0.1	0.0
Ranunculus flammula	SUBLOW	451.0	32.1						
Ranunculus longirostris	SUBTALL	2.0	0.1	0.1	0.0	40.3	1.3	3.8	0.1
Rorippa sp.	EMERGENT	3.0	0.2						
Sagittaria rosette	ISOETID	36.4	2.6			80.0	2.5	978.1	25.8
Sagittaria spp.	EMERGENT			48.3	2.9	3.0	0.1		
Sparganium spp.	EMERGENT	3.0	0.2						
Subularia aquatica	ISOETID	0.4	0.0			0.3	0.0		
Utricularia vulgaris	SUBTALL			1.0	0.1				
Vallisneria americana	SUBTALL	68.1	4.8	643.0	38.5	319.0	10.0	499.4	13.2
Mean Cover/Quadrat		35.2		41.7		79.7		94.7	
Mean Richness/Quadrat		6.8		4.0		7.4		9.0	

and only 1.6 in 2002. Since these are patchily distributed resources, an alternative explanation is that 40 quadrats are not enough to describe the vegetative structure. However, this appears unlikely to us in that the frequency data also suggests that these taxa have been misidentified. For example, *Crassula* was reported in 37 of 40 quadrats in 1987 and not in subsequent years, while *Eriocaulon* was reported in 21 of 40 quadrats in 2004 only, suggesting confusion between taxa (Table 35).

A more fruitful way to compare aquatic resources over time, especially for the low submergent life forms, is to group taxa prior to analyses of variance. We compared quadrat cover among four life forms, including emergent, floating leaf, low submergent, and tall submergent (Table 36). (These life forms are slightly modified from that presented in Tables 34 and 35, in that the isoetid life form was merged into the low submergents in order to create more values for each life form for the analyses.)

Although the emergents were not prevalent in any year, they were significantly greater in 1987, with a mean quadrat cover of 3.6%, when compared to 2002-2006 ($p<0.00001$, Kruskal-Wallis; Table 36). Taxa that were important in this difference include the smartweeds (*Polygonum* spp.) and *Glyceria borealis*, both of which likely responded to the drawdowns that were typical prior to the Namakan sampling in 1987 (Meeker and Wilcox 1989).

Low submergent cover was significantly less in 2002 (15.6%) when compared to all other years ($p< 0.00001$ Kruskal-Wallis;Table 36). This again suggests that the high water in 2002 hampered visibility. In addition, both 2004 (51.2%) and 2006 (69.6%) had significantly greater low submergent cover than in 1987 (27.9%).

Differences among years in tall submergent cover were as expected, as all three recent sampling times (ranging from 22.8 to 25.4%) were significantly greater than in 1987 (only 2.4%). As suggested above, these differences primarily reflect increases in *Bidens beckii*, *Ceratophyllum demersum*, *Elodea canadensis*, *Myriophyllum spp*., and *Potamogeton zosteriformis*.

Table 36. Comparison of mean quadrat cover (1 m x 1 m), total frequency, and importance values across four sampling times at two 1.25 m depth transects in Namakan Reservoir (NAM05 and NAM07).

	Mean Cover				**Relativized to 100%**			
Mean Quadrat Cover	**1987**	**2002**	**2004**	**2006**	**1987**	**2002**	**2004**	**2006**
Emergent	3.6	1.3	0.1	0.1	10.3	3.2	0.1	0.1
Floating Leaf	1.3	1.9	3.1	1.4	3.6	4.6	3.9	1.5
Low Submergent	27.9	15.6	51.2	69.6	79.4	37.5	64.2	73.5
Tall Submergent	2.4	22.8	25.4	23.6	6.7	54.7	31.8	24.9
Frequency Total (overall)	**1987**	**2002**	**2004**	**2006**	**1987**	**2002**	**2004**	**2006**
Emergent	44	10	2	5	16.2	6.3	0.7	1.4
Floating Leaf	7	21	24	21	2.6	13.2	8.1	5.9
Low Submergent	189	31	135	175	69.5	19.5	45.5	48.9
Tall Submergent	32	97	136	157	11.8	61.0	45.8	43.9
Totals	272	159	297	358	100.0	100.0	100.0	100.0
Importance Value	**1987**	**2002**	**2004**	**2006**	**1987**	**2002**	**2004**	**2006**
Emergent	26.5	7.2	0.8	1.4	13.3	3.6	0.4	0.7
Floating Leaf	6.0	20.9	11.6	7.4	3.0	10.4	5.8	3.7
Low Submergent	148.9	37.2	99.3	117.2	74.4	18.6	49.7	58.6
Tall Submergent	18.6	134.8	88.3	74.0	9.3	67.4	44.1	37.0
Totals	200.0	200.0	200.0	200.0	100.0	100.0	100.0	100.0

2.0 m Depth

Twenty-five taxa were recorded over all sampling times at the 2.0 m elevation (Table 37). Of these, *Bidens beckii* and *Elodea canadensis* were not recorded in 1987, but consistently seen at all the later times. Again, as in the mid deep transects, there was lower floristic similarity between 1987 and other years (Table 30). Similarly, a NMS ordination suggests that the greatest change in species composition (i.e. longest successional vectors) occurred between 1987 and 2004 at both sites (Figure 16). Subsequent change was smaller and not in a uniform direction, especially at NAM07.

The 2006 sampling had significantly greater quadrat cover (48.96%,Table 38) than sampling year 2004 (25.03%), whereas the other years were not significantly different from each other ($p = 0.0086$, Kruskal-Wallis). The taxa that showed the greatest increase in cover over the sampling years include *Elodea canadensis, Myriophyllum* spp., and rosette forms of *Sagittaria* spp., all approaching an order of magnitude increase in 2006.

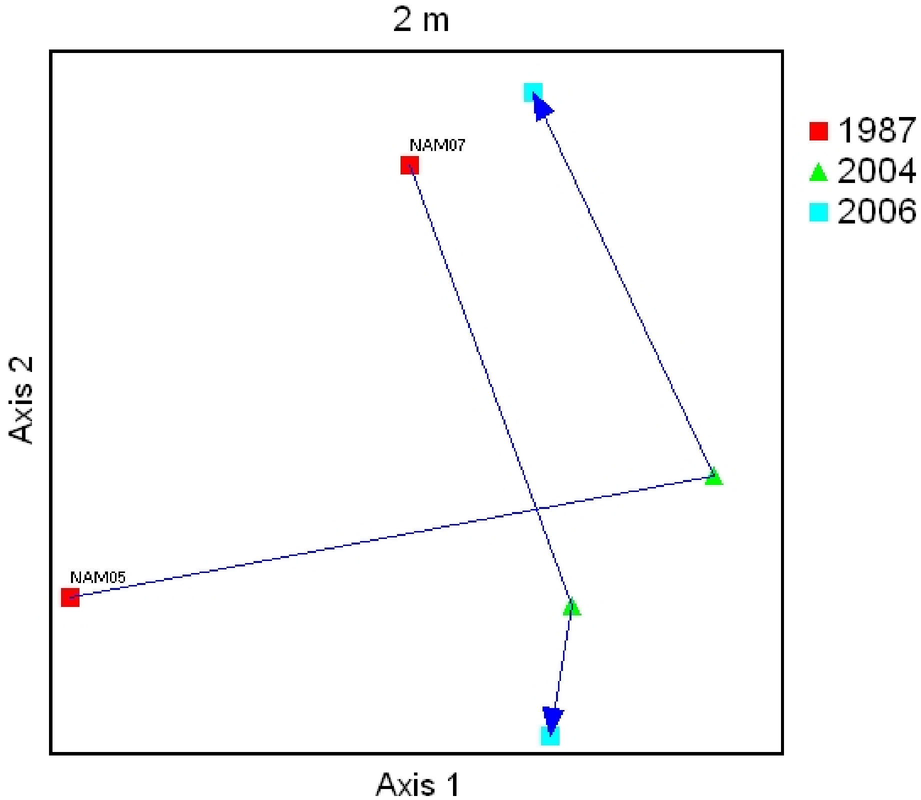


Figure 16. Non-metric multidimensional scaling (NMS) ordination of 2.0 m depth transects at two Namakan Reservoir sites, 1987 to 2006. Importance Value data used in the ordination. Successional vectors join the series of repeated samples on the transect.

Table 37. Frequency of occurrence for all 25 taxa reorded at 2 m depth transects over four sampling years at two Namakan sites (NAM05 and NAM07). Frequency is over 40, 1 m x 1 m quadrats.

Taxa	**Life Form**	**1987**	**2002**	**2004**	**2006**
Bidens beckii	SUBTALL		4	3	18
Ceratophyllum demersum	SUBTALL		17	11	
Chara spp.	SUBLOW	35	8	11	9
Crassula aquatica	ISOETID	31			
Elatine minima	SUBLOW	20			2
Eleocharis acicularis	SUBLOW	27			
Elodea canadensis	SUBTALL		14	23	18
Glyceria borealis	EMERGENT	1			
Isoetes spp.	ISOETID	29		11	4
Juncus pelocarpus	ISOETID			2	
Myriophyllum spp.	SUBTALL	6	7	18	21
Najas flexilis	SUBLOW	19	6	13	20
Nuphar spp.	FLOATLF				3
Nymphaea odorata	FLOATLF	5	14	7	19
Potamogeton gramineus	SUBTALL	6			
Potamogeton narrow-leaved	SUBTALL	19	7	20	21
Potamogeton richardsonii	SUBTALL	21	5	11	2
Potamogeton zosteriformis	SUBTALL	2	1	3	5
Ranunculus flammula	SUBLOW	4			
Ranunculus longirostris	SUBTALL	5		5	9
Sagittaria rosette	ISOETID	1	1	1	4
Sagittaria spp.	EMERGENT	2			
Subularia aquatica	ISOETID	1			
Utricularia vulgaris	SUBTALL				1
Vallisneria americana	SUBTALL	15	28	33	33
	Totals	249	112	172	189

Table 38. Total quadrat cover for all 25 taxa reorded at 2 m depth transects over four sampling years at two Namakan sites (NAM05 and NAM07). Total cover is over 40, 1 m x 1 m quadrats.

		1987		2002		2004		2006	
Taxa	**Life Form***	**Cover**	**Rel. to year total**	**Cover**	**Rel. to year total**	**Cover**	**Rel. to year total**	**Cover**	**Rel. to year total**
Bidens beckii	SUBTALL			5.2	0.3	0.3	0.0	35.6	1.8
Ceratophyllum demersum	SUBTALL			330.2	20.4	18.4	1.8		
Chara spp.	SUBLOW	508.1	44.7	1.7	0.1	40.2	4.0	78.6	4.0
Crassula aquatica	ISOETID	26.5	2.3						
Elatine minima	SUBLOW	15.5	1.4					0.2	0.0
Eleocharis acicularis	SUBLOW	38.4	3.4						
Elodea canadensis	SUBTALL			7.9	0.5	37.9	3.8	383.0	19.6
Glyceria borealis	EMERG.	1.0	0.1						
Isoetes spp.	ISOETID	32.4	2.9			17.3	1.7	4.1	0.2
Juncus pelocarpus	ISOETID					15.1	1.5		
Myriophyllum spp.	SUBTALL	9.0	0.8	6.4	0.4	23.8	2.4	314.0	16.0
Najas flexilis	SUBLOW	25.2	2.2	2.4	0.1	19.4	1.9	74.6	3.8
Nuphar spp.	FLOATLF							5.1	0.3
Nymphaea odorata	FLOATLF	43.0	3.8	119.2	7.4	5.2	0.5	39.5	2.0
Potamogeton gramineus	SUBTALL	14.0	1.2						
Potamogeton narrow-leaved	SUBTALL	120.0	10.6	11.5	0.7	233.7	23.3	148.3	7.6
Potamogeton richardsonii	SUBTALL	144.0	12.7	26.2	1.6	81.2	8.1	7.0	0.4
Potamogeton zosteriformis	SUBTALL	1.1	0.1	1.0	0.1	3.1	0.3	22.0	1.1
Ranunculus flammula	SUBLOW	3.1	0.3						
Ranunculus longirostris	SUBTALL	11.0	1.0			2.3	0.2	7.4	0.4
Sagittaria rosette	ISOETID	1.0	0.1	1.0	0.1	40.0	4.0	256.0	13.1
Sagittaria spp.	EMERG.	2.0	0.2						
Subularia aquatica	ISOETID	0.1	0.0						
Utricularia vulgaris	SUBTALL							15.0	0.8
Vallisneria americana	SUBTALL	141.0	12.4	1107.3	68.4	464.2	46.3	568.1	29.0
		1987		**2002**		**2004**		**2006**	
Mean Richness		6.23		2.80		4.30		4.73	
Mean Quadrat Cover all taxa		28.41		40.50		25.05		48.96	

* Isoetid and low submergent taxa were combined for analyses of variance depicted in Table 39.

Interestingly, 1987 had the greatest taxa richness per quadrat (6.23,Table 38), significantly more than 2002 (2.80), 2004 (4.30), and 2006 (4.73)($p < 0.00001$ Kruskal-Wallis). This greater richness can be attributed to the high frequencies of *Crassula aquatica*, *Elatine minima*, *Eleocharis acicularis*, and *Isoetes* spp., all occurring in more than half of the quadrats, much more than in subsequent years (Table 38).

As in the mid deep transects, grouping taxa indicated that 1987 had significantly less tall submergent cover (11.0%, Table 39) when compared to 2002 (37.4), 2006 (37.5), and 2004 (21.6).

Unlike the mid deep transects, 1987 had the highest low submergent cover, significantly more than in 2002 and 2004 (Table 39), primarily due to the high cover of *Chara* spp., a macroscopic algae favored in draw-down conditions (Table 38).

Table 39. Comparison of mean quadrat cover (1 m Xx1 m), total frequency, importance values, and richness across four sampling times at two 2 m depth transects in Namakan Reservoir (NAM05 and NAM07).

					Relatived to 100%			
Mean Quadrat Cover	**1987**	**2002**	**2004**	**2006**	**1987**	**2002**	**2004**	**2006**
Emergent	0.08	0.00	0.00	0.00	0.3	0.0	0.0	0.0
Floating Leaf	1.08	2.98	0.13	1.12	3.8	7.4	0.5	2.3
Low Submergent	16.26	0.13	3.30	10.34	57.2	0.3	13.2	21.1
Tall Submergent	11.00	37.39	21.62	37.51	38.7	92.3	86.3	76.6
Frequency Total (overall)	**1987**	**2002**	**2004**	**2006**	**1987**	**2002**	**2004**	**2006**
Emergent	3	0	0	0	1.2	0.0	0.0	0.0
Floating Leaf	5	14	7	22	2.0	12.5	4.1	11.6
Low Submergent	167	15	38	39	67.1	13.4	22.1	20.6
Tall Submergent	74	83	127	128	29.7	74.1	73.8	67.7
Importance Value	**1987**	**2002**	**2004**	**2006**	**1987**	**2002**	**2004**	**2006**
Emergent	1.7	0.0	0.0	0.0	0.8	0.0	0.0	0.0
Floating Leaf	5.8	18.0	4.5	13.9	2.9	9.0	2.2	7.0
Low Submergent	122.8	17.2	34.0	49.0	61.4	8.6	17.0	24.5
Tall Submergent	69.7	164.7	161.6	137.0	34.9	82.4	80.8	68.5

Changes over time in the Rainy and Lac la Croix basins, 1987 to 2002

In order to follow the general vegetational changes across the Rainy and Lac la Croix basins, data for each replicate site at each sampling time was combined for each elevational transect. For example, at Lac la Croix, 1987 data from both shoreline transects at Lady Boot Bay (east and west) were combined for a total of 40 quadrats (20 for each site). In addition, summary data from two sampling years at Namakan (1987 and 2002) is included in the following discussion for comparative purposes. In 1987 water levels ranged from 20 to 70 cm below average across all basins, while in 2002, water levels ranged from 0 to 40 cm above average in Namakan Reservoir and 10 to 20 cm below average in Lac la Croix. In 2003 water levels ranged from 0 to 25 cm below average in Rainy Lake.

A visual inspection of the NMS ordinations suggests that most of the repeat sample sites are reasonably representative of the lake (Figures 10, 12, and 13—an exception was Rainy 07 at the 1.25 m depth, which is an outlier in the ordination space). We felt that these data were adequate for an exploratory analysis to allow insight into whether the plant communities at each depth appear to have changed more in the Namakan Reservoir than in the other two bodies of water. NMS ordination was performed on Importance Values for each transect (methods are described in Section 1). The sample size (2 sites / basin / year) was too small to test for significant differences in vegetation data between years in each basin using MRPP analysis. However, data from all three basins was pooled for each year and subjected to MRPP analysis.

Results

Shoreline Transects

All three basins showed substantial increases in the total and mean cover per quadrat at shoreline (0.0 m) elevations over the 15-16 year period from 1987 to 2002-3 (Table 40). All the values in 2002-3 were at least double that of 1987. As we saw for Namakan, most of these changes can be attributed to increases in woody cover.

At the Lac la Croix 0.0 m transect, total woody taxa cover increased greatly, from 37 to 2325% (Table 41), and most of this change is due to increases in sweet gale (*Myrica gale*) and ash (*Fraxinus* spp.) (Table 42). Rainy's shoreline change in woody taxa can be attributed to increases in *Myrica gale* and also *Spirea alba.* The Namakan shoreline, as discussed above, also showed major increases in woody taxa cover (46.1 to 2472%, Table 41) including *Myrica gale*, but also in *Pinus strobus* and *Alnus incana* (Table 31).

Graminoid cover overall showed modest, but non-significant changes, with declines at Lac la Croix (1078 to 915%, Table 41), increases in Rainy (885 to 1292%), and a modest decline at Namakan. Some individual taxa, however, appear to respond in opposition, for example at Rainy *Calamagrostis canadensis* increased from 383 to 1020% while *Scirpus cyperinus* declined from 202 to 35% (Table 42). Similarly, *Carex lacustris* decreased greatly at Lac la Croix from 515% in 1987 to none in 2002.

Table 40. Total cover, mean cover, and frequency for the Lac la Croix, Rainy and Namakan basins over two sampling times, 1987 and 2002 at each of three elevational transects relative to mean high water (shoreline 0.0 m, mid deep 1.25 m, deep 2 m). Each value is based on 40 quadrats at each depth / time / basin.

Year	**1987**	**2002**	**1987**	**2003**	**1987**	**2002**
Basin	**Lac la Croix**		**Rainy**		**Namakan**	
Shoreline						
Cover						
Total Cover	1859	4051.3	1493	3069.5	1106.3	3465.9
Mean/quadrat	46.5	101.3	37.3	76.7	27.7	86.6
Frequency						
Total Frequency	352	433	333	380	271	261
Mean richness/quadrat	8.80	10.83	8.33	9.50	6.78	6.53
1.25 m						
Cover						
Total Cover	2167.1	1316.4	635.9	1737.9	1406.3	1669.2
Mean/quadrat	54.2	32.9	15.9	43.4	35.2	41.7
Frequency -						
Total Frequency	150	227	166	133	272	159
Mean richness/quadrat	3.75	5.68	4.15	3.33	6.80	3.98
2.0 m						
Cover						
Total Cover	785	323.7	222	1402.8	1136.4	1620
Mean/quadrat	19.6	8.1	5.6	35.1	28.4	40.5
Frequency						
Total Frequency	78	218	41	71	249	112
Mean richness/quadrat	1.95	5.45	1.03	1.78	6.23	2.80

Table 41. Changes in cover, frequency and relative importance values for six life forms between 1987 and 2002 at three basins shoreline transects. 102 overall taxa were recorded in all three basins over both times.

Year	**1987**	**2002**	**1987**	**2003**	**1987**	**2002**
Basin	**Lac la Croix**		**Rainy**		**Namakan**	
Cover						
Aquatic	25	0	1.2	0	1.4	0.3
Emergent	15	11.2	34	14.6	4.2	8
Fac. Wetland Herb	696	793.9	500.8	404.5	235.7	338.9
Graminoid	1078	915.4	885	1292	818.2	644.6
Tree/shrub	37	2324.6	63.8	1358	46.1	2472
Upland herb	8	6.2	8.2	0.4	0.7	2.1
Totals	1859	4051.3	1493	3069.5	1106.3	3465.9
Frequency						
Aquatic	9	0	3	0	5	3
Emergent	11	7	16	11	5	4
Fac. Wetland Herb	202	184	182	186	142	112
Graminoid	99	115	102	104	89	64
Tree/shrub	25	121	20	75	23	76
Upland herb	6	6	10	4	7	2
Totals	352	433	333	380	271	261
Relative Importance Value						
Aquatic	2.0	0.0	0.5	0.0	1.0	0.6
Emergent	2.0	0.9	3.5	1.7	1.1	0.9
Fac. Wetland Herb	47.4	31.0	44.1	31.1	36.9	26.3
Graminoid	43.1	24.6	45.0	34.7	53.4	21.6
Tree/shrub	4.5	42.7	5.1	32.0	6.3	50.2
Upland herb	1.1	0.8	1.8	0.5	1.3	0.4
Totals	100	100	100	100	100	100

Table 42. The 30 most abundant taxa at Lac la Croix and Rainy shoreline transects. Each basin is represented by two sites and 40 quadrats total for each year. (Taxa are ordered by cover, combined over both basins and years.)

			Lac la Croix				Rainy			
			Cover	Freq.	Cover	Freq.	Cover	Freq.	Cover	Freq.
	Life Form	**Taxa**	**1987**	**1987**	**2002**	**2002**	**1987**	**1987**	**2003**	**2003**
1	TRSHRUB	*Myrica gale*	21	12	1491	40	51.2	11	1117	37
2	GRAMIN	*Calamagrostis canadensis*	425	31	676	39	383	25	1020	37
3	FACWET	*Thelypteris palustris*	294	22	469	22	0	0	0	0
4	TRSHRUB	*Fraxinus spp.*	2	2	553	23	0	0	0	0
5	GRAMIN	*Carex lacustris*	515	32	0	0	18	4	3	1
6	GRAMIN	*Carex utriculata*	22	4	107.1	26	134	20	117.3	24
7	GRAMIN	*Scirpus cyperinus*	40	5	31	13	202	9	35	7
8	TRSHRUB	*Spiraea alba*	2	2	109	18	0	0	148	15
9	FACWET	*Polygonum sagittatum*	0	0	0.1	1	24.1	9	191.1	31
10	FACWET	*Polygonum spp.*	0	0	0	0	167.2	31	10.1	14
11	FACWET	*Hypericum majus*	38	26	0.1	1	89.2	26	39.5	17
12	FACWET	*Lysimachia spp.*	51	27	47.4	34	35.2	21	19.2	23
13	FACWET	*Polygonum amphibium*	12	3	35.3	16	48	11	37	10
14	FACWET	moss spp.	0	0	78.1	11	0	0	34.1	5
15	FACWET	*Euthamia graminifolia*	85	20	2	1	0.1	1	1	1
16	TRSHRUB	*Rosa spp.*	4	2	76.2	14	0	0	6	2
17	GRAMIN	*Agrostis hyemalis*	20	3	37	2	17	10	11.2	7
18	FACWET	*Galium spp.*	31	19	13.3	10	10	6	26.5	11
19	FACWET	*Potentilla palustris*	48	8	1	1	23.1	3	3.1	2
20	FACWET	*Triadenum fraseri*	34	14	33.3	18	4	4	2.4	5
21	FACWET	*Potentilla norvegica*	0	0	0.1	1	53.2	27	18.1	21
22	FACWET	*Aster spp.*	0	0	60.2	16	0	0	9.3	9
23	TRSHRUB	*Chamaedaphne calyculata*	3	2	61	8	0	0	0	0
24	TRSHRUB	*Alnus incana*	3	3	20	1	0.3	3	35.1	3
25	GRAMIN	*Carex lasiocarpa*	0	0	0	0	0	0	56.1	4
26	GRAMIN	*Juncus spp.*	46	19	0.1	1	1	1	0	0
27	FACWET	*Mentha arvensis*	44	14	2.1	2	0.2	2	0.2	2
28	GRAMIN	*Carex atherodes*	0	0	0	0	37	3	8.1	4
29	GRAMIN	*Juncus filiformis*	0	0	44.7	21	0	0	0	0
30	FACWET	*Sium suave*	26	20	1.2	3	10	8	6.6	10

Other taxonomic reversals at shoreline transects include changes in abundance with some facultative wetland herbs, such as the increase in cover at Rainy of *Polygonum sagittatum*, accompanied by a decline in general *Polygonum* spp. (Table 42).

The shoreline frequency and mean frequency (mean quadrat richness) did not appear to change as much as cover, with modest, non-significant increases in Lac la Croix (8.8 to 10.8) and Rainy (8.3 to 9.5), and slight decreases in Namakan (6.8 to 6.5,Table 40).

1.25 m Depth
At the 1.25 m elevation basins responded disparately, where Lac la Croix experienced declines in cover from 1987 to 2002 (2167 to 1316% at 1.25 m, Table 40), compared to modest increases at Namakan and major increases in Rainy Lake.

Richness per quadrat increased significantly in Lac la Croix (3.8 to 5.7, Table 40), while there were non-significant declines in quadrat richness at Rainy. Namakan also experienced non-significant declines at the 1.25 m elevation (6.8 to 4.0, Table 40).

At Lac la Croix, tall submergent cover declined significantly (647% to 182%, Table 43), and frequency of occurrence of low submergents increased. This is in contrast to Rainy where tall submergent cover increased significantly (282 to 901%, Table 43) and low submergent frequency showed modest declines. It should be noted that while all basins were experiencing below average water levels during the 1987 sampling, Rainy was lowest (0.7-0.9 m down), Lac la Croix was moderately low (0.3 to 0.5 m down), and Namakan the least below MHW (0.2 to 0.3 m). Each basin was responding to a different set of hydrological conditions in 1987 and from 1987 to 2002.

Four taxa, *Najas flexilis*, *Nymphaea odorata*, *Bidens beckii*, and the native *Myriophyllum* spp., comprise the bulk of the decline in cover at the Lac la Croix mid depths (Table 44), while the only taxa that increased considerably was *Sagittaria* (rosette forms).

At Rainy, where there were major increases in cover at mid depth, three taxa accounted for most of it, including *Vallisneria americana*, *Sparganium* spp., and *Potamogeton gramineus.* Curiously, none of the “gainers” in Rainy are well represented in Lac la Croix, while none of the “losers” at Lac la Croix are well represented in Rainy. It should be re-iterated that the biggest changes at mid depths at Namakan between 1987 and 2002 were increases in the submergents *Vallisneria americana* and *Najas flexilis* and losses in *Eleocharis acicularis* and *Ranunculus flammula*, both mat-forming drawdown taxa (Table 35).

2.0 m Depth
At the deepest transects in Lac la Croix, cover decreased by over 50% (785 to 323, Table 45) from 1987 to 2002. This was a very patchily vegetated habitat. The same deep elevation at Rainy showed significant changes over the years, increasing from 222 to 1402 (Table 45). In the deep Rainy transects, as we saw in Namakan (Table 38), the major changes occurred as increases in *Vallisneria americana*, which increased in total cover from 131 in 1987 to 1275 in 2003, while its frequency increased only slightly (Table 46).

Table 43. Changes in cover, frequency, and relative importance values for four life forms between 1987 and 2002 at three basins 1.25 m depth transects. 42 overall taxa were recorded in all three basins over both times.

Year	**1987**	**2002**	**1987**	**2003**	**1987**	**2002**
Basin	**Lac la Croix**		**Rainy**		**Namakan**	
Cover						
Emergent	0	55	192.4	673	148.3	53.4
Floating leaf	499	121.3	0	0	47	77.2
Low Submergent	1021	958.6	161.3	163.2	1116.9	625.3
Tall submergent	647.1	181.5	282.2	901.7	94.1	913.3
Totals	2167.1	1316.4	635.9	1737.9	1406.3	1669.2
Frequency						
Emergent	0	32	28	23	45	10
Floating leaf	26	23	0	0	6	21
Low Submergent	47	85	77	50	189	31
Tall submergent	77	87	61	60	32	97
Totals	150	227	166	133	272	159
Rel. Importance Value						
Emergent	0.0	9.1	23.6	28.0	13.5	4.7
Floating leaf	20.2	9.7	0.0	0.0	2.8	8.9
Low Submergent	39.2	55.1	35.9	23.5	74.5	28.5
Tall submergent	40.6	26.1	40.6	48.5	9.2	57.9
Totals	100.0	100.0	100.0	100.0	100.0	100.0

Table 44. The 25 most abundant taxa at Lac la Croix and Rainy 1.25 m depth transects. Each basin is represented by two sites and 40 quadrats total for each year. (Taxa are ordered by cover, combined over both basins and years.)

			Lac la Croix				Rainy			
			Cover	Freq.	Cover	Freq.	Cover	Freq.	Cover	Freq.
	Taxa	**Life Form**	**1987**	**1987**	**2002**	**2002**	**1987**	**1987**	**2003**	**2003**
1	*Najas flexilis*	SUBLOW	925	22	544.3	25	15.1	11	69.4	15
2	*Vallisneria americana*	SUBTALL	34	10	6	5	213	31	570	28
3	*Sparganium spp.*	EMERGENT	0	0	40.7	21	145	7	553	11
4	*Nymphaea odorata*	FLOATLF	452	23	30.2	17	0	0	0	0
5	*Potamogeton gramineus*	SUBTALL	0	0	38	7	23	7	317	17
6	*Eleocharis acicularis*	SUBLOW	0	0	6.3	6	23.2	15	8.6	10
7	*Ranunculus flammula*	SUBLOW	0	0	0.1	1	0	0	0	0
8	*Sagittaria rosette*	SUBLOW	0	0	346.3	22	10	4	10	2
9	*Myriophyllum spp*	SUBTALL	340	17	46.8	18	2	2	0	0
10	*Potamogeton narrow-leaved*	SUBTALL	21.1	14	13.8	16	17.1	12	7.6	11
11	*Bidens beckii*	SUBTALL	186	14	32.9	17	2	1	0	0
12	*Isoetes spp.*	SUBLOW	0	0	0.1	1	78	39	35.2	12
13	*Crassula aquatica*	SUBLOW	0	0	0	0	0	0	0	0
14	*Chara sp.*	SUBLOW	94	23	21.9	17	0	0	0	0
15	*Glyceria borealis*	EMERGENT	0	0	14.1	9	0	0	0	0
16	*Sagittaria spp.*	EMERGENT	0	0	0	0	30.1	12	37	6
17	*Eleocharis palustris*	EMERGENT	0	0	0.1	1	9.1	5	83	6
18	*Potamogeton epihydrus*	FLOATLF	8	1	71.1	4	0	0	0	0
19	*Potamogeton robbinsii*	SUBLOW	2	2	1	1	35	8	40	11
20	*Potamogeton richardsonii*	SUBTALL	28	9	2.1	3	25.1	8	6	2
21	*Nuphar sp.*	FLOATLF	39	2	20	2	0	0	0	0
22	*Polygonum spp.*	EMERGENT	0	0	0	0	0	0	0	0
23	*Utricularia vulgaris*	SUBTALL	9	3	30.4	10	0	0	0	0
24	*Callitriche hermaphroditica*	SUBLOW	0	0	33.1	5	0	0	0	0
25	*Potamogeton zosteriformis*	SUBTALL	11	7	8.2	7	0	0	0	0

Table 45. Changes in cover, frequency, and relative importance values for four life forms between 1987 and 2002 at three basins 2.0 m depth transects. 32 overall taxa were recorded in all three basins over both times.

Year	**1987**	**2002**	**1987**	**2003**	**1987**	**2002**
	Lac la Croix		**Rainy**		**Namakan**	
Cover						
Emergent	0	0	0	0	3	0
Floating Leaf	132	93.3	0	59	43	119.2
Low Submergent	346	46	5	18.8	650.3	5.1
Tall Submergent	307	184.4	217	1325	440.1	1495.7
Totals	785	323.7	222	1402.8	1136.4	1620
Frequency						
Emergent	0	0	0	0	3	0
Floating Leaf	9	36	0	8	5	14
Low Submergent	33	66	1	16	167	15
Tall Submergent	36	116	40	47	74	83
Totals	78	218	41	71	249	112
Relative Importance Value						
Emergent	0.0	0.0	0.0	0.0	0.7	0.0
Floating Leaf	14.2	22.7	0.0	7.7	2.9	9.9
Low Submergent	43.2	22.2	2.3	11.9	62.1	6.9
Tall Submergent	42.6	55.1	97.7	80.3	34.2	83.2
Totals	100.0	100.0	100.0	100.0	100.0	100.0

Table 46. The 15 most abundant taxa at Lac la Croix and Rainy 2.0 m depth transects. Each basin is represented by two sites and 40 quadrats total for each year. (Taxa are ordered by cover, combined over both basins and years.)

			Lac la Croix				Rainy			
			Cover	Freq.	Cover	Freq.	Cover	Freq.	Cover	Freq.
	Taxa	Life Form	1987	1987	2002	2002	1987	1987	2003	2003
1	*Vallisneria americana*	SUBTALL	134	14	69.2	18	131	23	1275.1	28
2	*Najas flexilis*	SUBLOW	317	20	20.6	31	5	1	13.3	7
3	*Potamogeton gramineus*	SUBTALL	158	16	0	0	9	3	0.1	1
4	*Nymphaea odorata*	FLOATLF	62	4	87.1	19	0	0	1	1
5	*Potamogeton epihydrus*	FLOATLF	70	5	0	0	0	0	58	7
6	*Potamogeton richardsonii*	SUBTALL	0	0	6.7	10	67	13	36	6
7	*Chara spp.*	SUBLOW	29	13	23.3	23	0	0	3.4	6
8	*Utricularia vulgaris*	SUBTALL	0	0	41.5	23	0	0	0	0
9	*Bidens beckii*	SUBTALL	0	0	41.1	29	0	0	0.2	2
10	*Myriophyllum spp.*	SUBTALL	11	4	2.9	11	0	0	0	0
11	*Ceratophyllum demersum*	SUBTALL	4	2	9.1	2	0	0	0	0
12	*Potamogeton amplifolius*	SUBTALL	0	0	1.1	2	10	1	0.1	1
13	*Potamogeton* narrow leaved	SUBTALL	0	0	0.9	8	0	0	8.2	5
14	*Potamogeton zosteriformis*	SUBTALL	0	0	7.5	8	0	0	0.1	1
15	*Sparganium spp.*	FLOATLF	0	0	6.2	17	0	0	0	0

Ordinations
NMS ordinations depicting changes in vegetation from 1987 to 2002/2003 were run at each of the three elevations including transects in all three basins.

On the shoreline the Rainy sites and one of the Namakan sites (NAM07) appear to be converging with the Lac la Croix sites (Figure 17). This suggests that the vegetation composition of the Rainy and Namakan shorelines was more similar to Lac la Croix in 2002-2003 than in 1987.

At the 1.25 m depth the vegetation showed a greater change in Rainy and Namakan (i.e. longer successional vectors) than at Lac la Croix (Figure 18). At both the 1.25 m and 2.0 m depths, the Rainy and Namakan sites appear to be converging with Lac la Croix towards the middle of the ordination space (except Rainy07 at 1.25 m and NAM05 at 2.0 m) (Figures 18 and 19).

Multi-response Permutation Procedure
The species composition of the shoreline transect in 1987 is significantly different from 2002-03

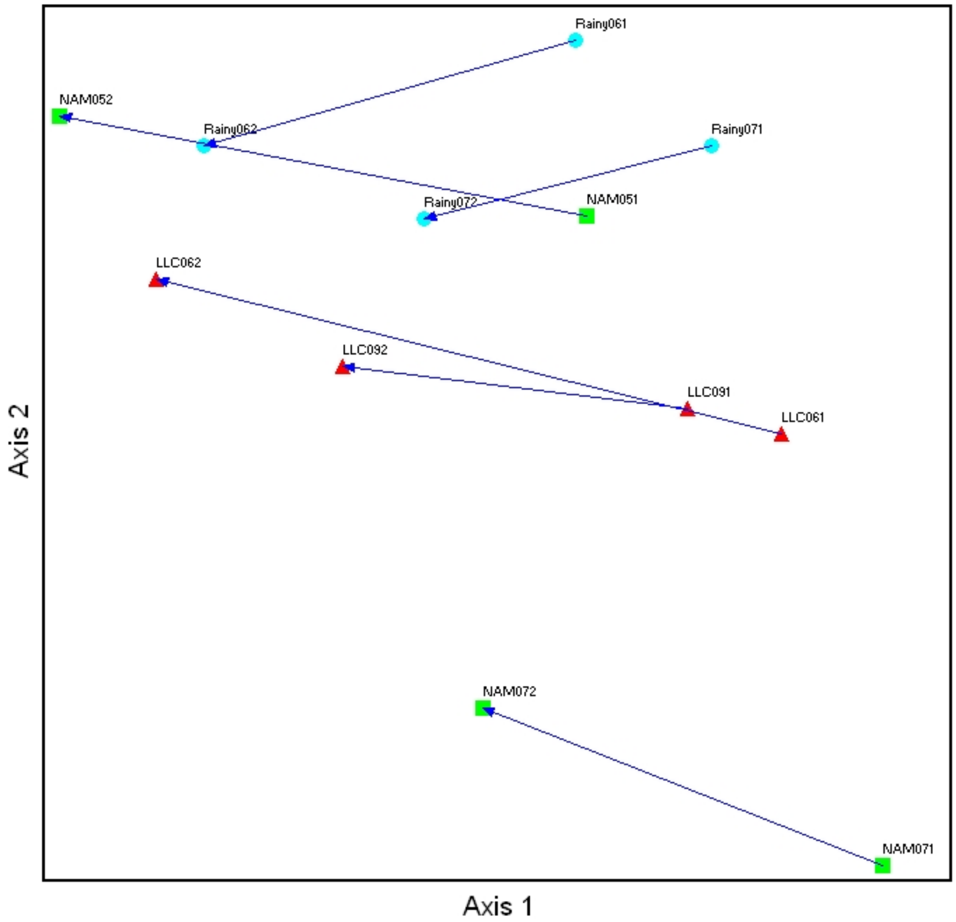


Figure 17. Non-metric multidimensional scaling (NMS) ordination of 1987 and 2002-05 shoreline transects. Triangles = Lac la Croix, circles = Rainy, squares = Namakan. Successional vectors join the 1987 transect with its corresponding 2002-2003 transect. Importance values were used as the metric in the ordination.

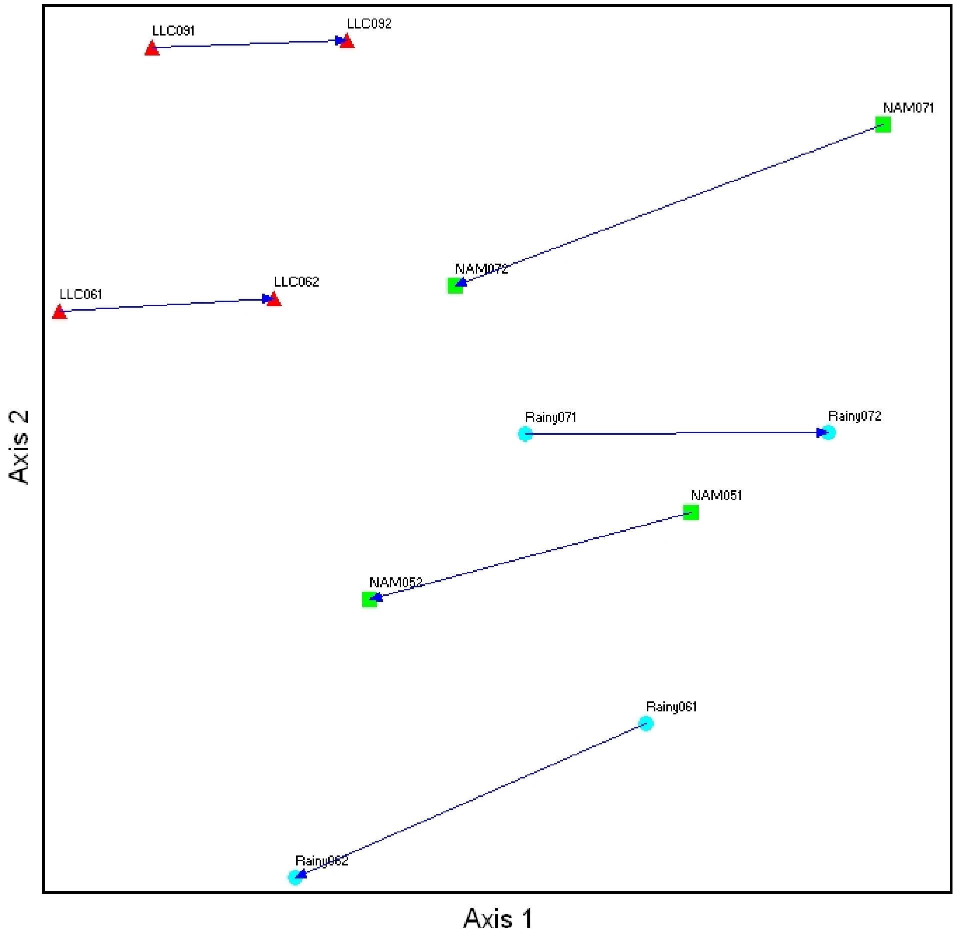


Figure 18. Non-metric multidimensional scaling (NMS) ordination of 1987 and 2002-05 1.25 m depth transects. Triangles = Lac la Croix, circles = Rainy, squares = Namakan. Successional vectors join the 1987 transect with its corresponding 2002-2003 transect. Importance values were used as the metric in the ordination.

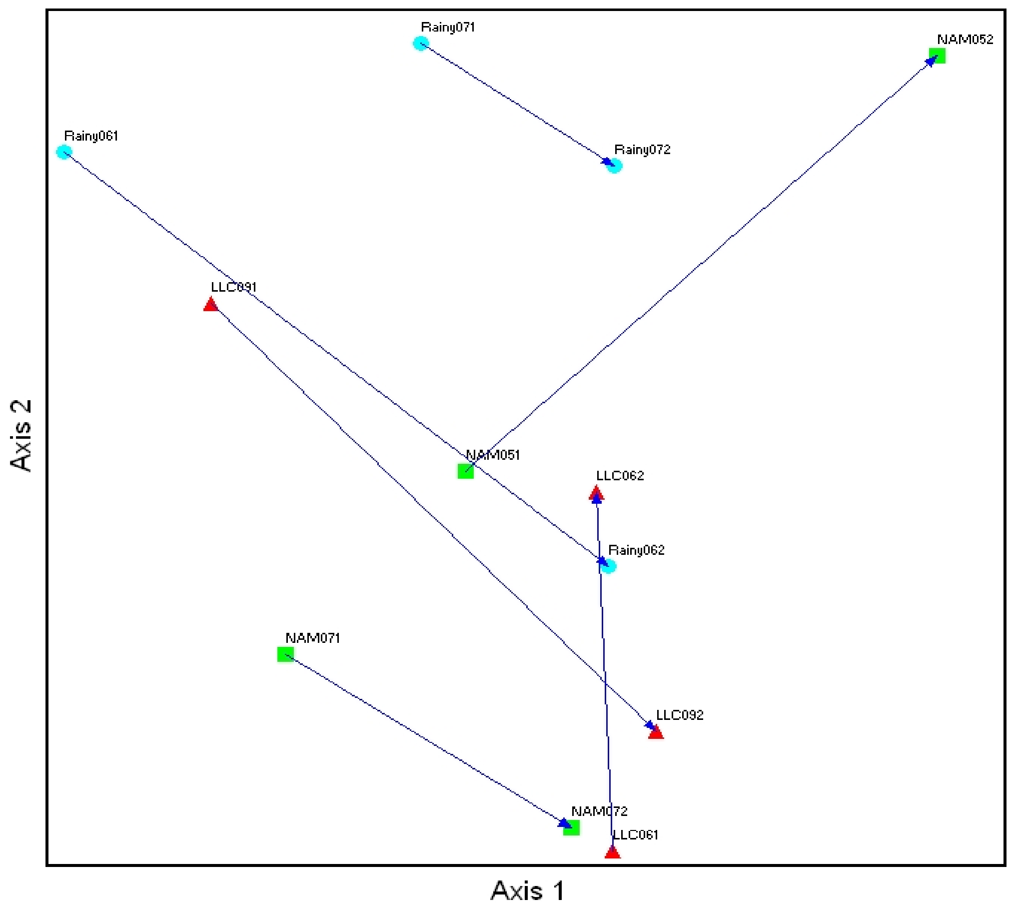


Figure 19. Non-metric multidimensional scaling (NMS) ordination of 1987 and 2002-05 2 m depth transects. Triangles = Lac la Croix, circles = Rainy, squares = Namakan. Successional vectors join the 1987 transect with its corresponding 2002-2003 transect. Importance values were used as the metric in the ordination.

(all three basins pooled) (A = 0.15582833, p = 0.00789557). However, at the 1.25 m (A = -0.02607350, p = 0.91371824) and 2.0 m (A = -0.00980794, p = 0.26674043) depths, there was no significant difference between years.

Discussion

Although samples sizes are small, the ordinations of vegetation data suggest that the Rainy and Namakan sites at all three depths are converging with Lac la Croix, indicating that the wetland communities were more similar in 2002-03 than in 1987. The convergence of vegetation is further supported by comparisons among aquatic transects, which suggest a trend of increasing similarity indices. At the 1.25 m transects, all recent (2002 to 2006) comparisons were 70.0% or greater (to a high of 83.7%), while the comparisons with 1987 ranged from 47.4 to 61.9%. The deep transect comparisons were also more similar among recent years (78.6 to 88.9%) than the values from 1987 (58.1 to 68.6%).

Of perhaps the greatest interest is the apparent changes in the mid and deep water transects. In general, the last two sampling years (2004 and 2006) have twice the vegetative cover in the mid aquatic zone compared to that of 1987 and 2002. Figure 20 suggests that the tall submergent species responded positively to the changes in the rule curve. Taxa such as *Elodea canadensis*, *Myriophyllum* spp., *Ceratophyllum demersum*, and *Bidens beckii* are all more frequently found in recent years at levels much greater than in 1987. At the same time, mat-forming cover has declined (see discussion in the Intensive Sampling section). This is consistent with the prediction that the reduced drawdown in Namakan Reservoir between 1987 and 2002-2003 should have allowed the vegetation at the 2.0 m depth to begin to recover to a more natural state. Total taxa frequency generally decreases with depth but no clear patterns are evicent between the three basins (Figure 21).

These data support the prediction that aquatic vegetation at the 2.0 m depth should have increased in cover between 1987 and 2002 because areas formerly exposed in late winter should now be more-or-less permanently inundated. This should favor the growth of aquatics and at the same time inhibit the growth of the mat-forming drawdown taxa.

Although mean similarity among the six shoreline comparisons showed no evident trends among comparison years, tree and shrub cover on Namakan shoreline increased, consistent with our predictions, due to the summer drawdown. Along the Namakan shorelines there appears to be more cover in general, and particularly woody cover, and not loss (in absolute terms) of grasses and sedges. It could be that shrub encroachment had been primarily due to increases in overhanging vegetation (which is tallied if it is less than 2 m tall) compared to plants rooted in the shoreline zone. One may expect a gradual decline in graminoid cover to accompany the woody plant increases with future encroachment.

Except for one high water year in 1996, there appears to have been a steady decline in the magnitude of the annual high water mark since our 1987 sampling. On the other hand, the low water marks appear not to have changed over the 15-year period. This contraction of mean high water should favor an increase in woody plant taxa along the shoreline transects. These predictions are born out in the assessment of change for the shoreline transects discussed above.

However, as in the case of Rainy Lake, the Lac la Croix hydrograph does not help explain the decline in aquatic cover that we measured over the same sampling period. Again, it may be that our sampling of only two sites in this reference lake was inadequate to get the overall "signal."

As we saw in the results above, however, the Rainy Basin showed vegetation changes much like that of the Namakan Reservoir; aquatic cover increased in the deep transects. We have no one good explanation for this result, unless our sample size was inadequate to get an accurate picture of submergent vegetation in Rainy Lake. It could be however, since the 1987 Rainy sampling occurred during an extreme drawdown year (0.7 to 0.9 m below MHW), and submergent vegetation would have been stressed, that any comparisons with these data are not well advised. Another explanation could be that regional productivity may be increasing due to factors acting at larger scales, such as climate change or atmospheric deposition. We are not yet capable at this time to choose among these alternative hypotheses, but since we have increased the number of sites and transects it should provide a more complete picture the next time the sites are re-assessed.

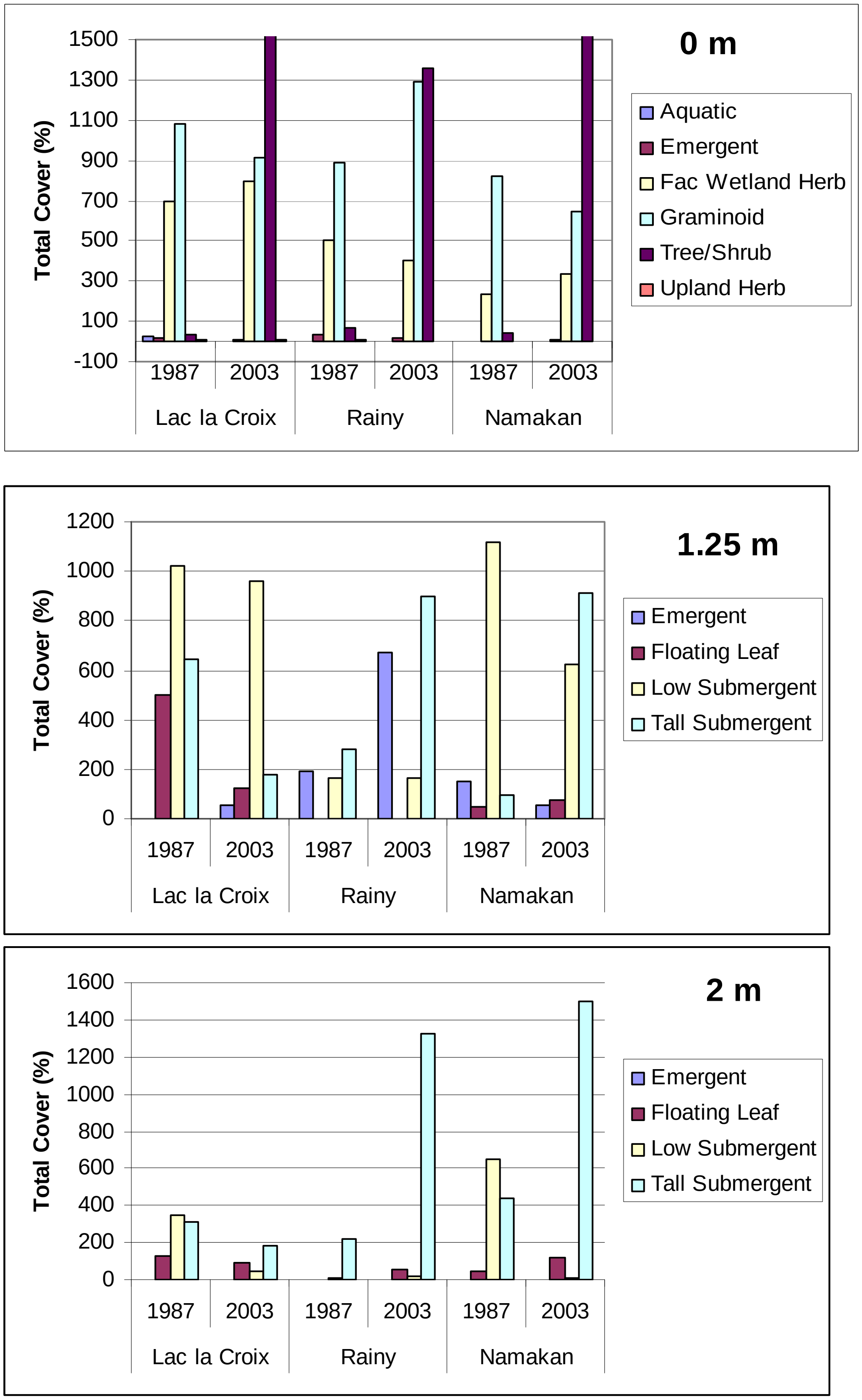


Figure 20. Total vegetation cover by life form for the Lac la Croix, Rainy and Namakan basins over two sampling times, 1987 and 2003 at each of three elevational transects relative to mean high water (shoreline 0.0 m, mid deep 1.25 m, deep 2 m). Each value is based on 40 quadrats at each depth / time / basin.

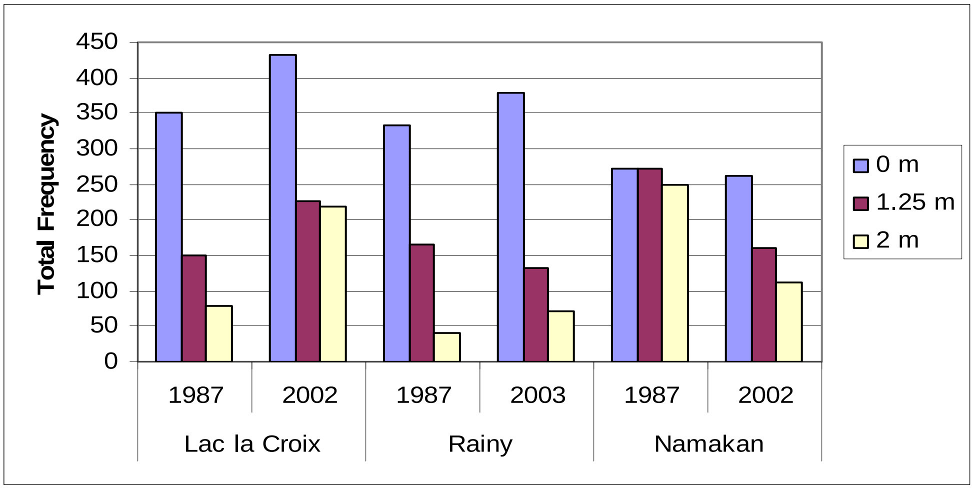


Figure 21. Total taxa frequency for the Lac la Croix, Rainy, and Namakan basins over two sampling times, 1987 and 2002, at each of three elevational transects relative to mean high water (shoreline 0.0 m, mid deep 1.25 m, deep 2 m). Each value is based on 40 quadrats at each depth / time / basin.

Other observed changes were not predicted, such as the increase in tall submergents on Namakan at the 1.25 m depth. All the analyses point to understandable difficulty in sampling the aquatic habitat, such as likely omissions due to loss of visibility in deeper water, and variable identification of the low lying isoetid groups. This suggests that monitoring these habits in the future must take water levels into account and somehow be flexible enough to not sample in extreme years (a daunting task). A good portion of these difficulties can be mitigated through the comparative use of life forms, as we report here. Another difficulty in assessing the aquatic habitat is its patchy nature. Increasing the number of quadrats (sub-samples) from 20 per transect to 25, as suggested in the Sampling Bias section, would reduce variability in the summaries. In addition, these above analyses were done on two sites over time; we now have 10-11 intensives sites per basin to be used on the next stage of monitoring.

Peatland Assessment

In addition to following vegetation changes relative to water level control in the intensively studied sites (Intensive Sampling section), along the shoreline segments (Shoreline Surveys section), and the extensive sites (Extensive Sampling section), we have also begun to monitor for change in floristic composition and structure within peatlands adjacent to the large lakes. Many of these peatland habitats may have been modified relatively recently, having responded to the 1.0 m to 1.5 m inundation brought on by the Rainy and Namakan dams in 1911-1914. Continued change within these peatlands, which are also referred to as bogs, shore fens and sedge meadows, are likely due to the continued influence of control structures on the hydrology of these areas. In particular, increases in the abundance of cattail in general (*Typha spp.*) may be occurring *within* shoreline fens, especially in areas that are above and near the dams at International Falls and Kettle Falls, in that these areas may have experienced greater water level increases. On the other hand, the recent modification of the rule curves has resulted in summer drawdowns that may favor other groups of plants.

Methods

Site Selection

In 2004, peatlands on the US and Canadian sides of Namakan, Sand Point, and Rainy Lake below Kettle Falls were sampled, and in 2005 additional sites were added from the North Arm of Rainy, the South Arm of Rainy, and Red Gut Bay, as well as sites in the Lac la Croix Basin. The 2004 Namakan and Sand Point sites were selected from a pool of peatlands created from the VNP vegetation map aided by the use of the Ikonos imagery; the 2005 sites in Rainy were identified using a Rainy Lake vegetation map and available Ikonos imagery. From these pools, peatlands were randomly selected. Four peatlands in the Lac la Croix Basin were also located along a randomly chosen flight line (LLC 2). The peatlands were labeled using the basin or sub-basin names followed by the order in which they were surveyed (example: NAM US 1).

Field Methods

Once at a selected site, two transects of 50 meters in length were established. Unlike the intensive study methods that utilized a single transect which followed a contour, we used two transects in each peatland to increase the area sampled. Both transects shared a common start point that was selected by choosing a random compass bearing (from a stratified arc, usually of 20-25 degrees) and walking from the lake water/vegetation interface up elevation to the mean high water level. Once this start point was located, two additional random compass bearings were chosen (again within limited arcs to stay in the peatlands) to layout these two transects. All start, mid, and end points of the transects were marked by two meter long PVC pipe labelled with black marker according to their location (e.g. Rainy 2 - Transect 2 midpoint). A Trimble GPS was then used to record the positions of the start, mid, and end points. In addition, start and end points were marked with a section of PVC pipe driven into the peat for relocation in future surveys.

Ten 1 m x 1 m quadrats were established at each transect by randomly placing one quadrat in each five meter segment. All quadrat sampling took place on the left side of the transect line as one faces from start to end. These points along the 50 transect were recorded on the data sheets (e.g. the first quadrat of the transect could have been placed at the 3 m to 4 m mark, the second quadrat at the 6 m to 7 m mark, the third at 12 m to 13 m, etc.). Hence, the same quadrats were designed to be repeatedly sampled. Percent cover for each species and a total estimated cover (all taxa) was taken at each quadrat, along with the number of live and dead *Typha* stems. Photos were taken of each transect for future reference.

Data Analysis

We performed an NMS ordination on cover on the matrix of 94 peatland transects and 79 taxa. Select taxonomic groups that correlated highly with axis values at r=0.500 or greater were plotted on the ordination.

Multi-response Permutation Procedure (MRPP) (McCune and Mefford 1999) pair-wise comparison of vegetation data was also conducted to test for significant differences between the sub-basins.

Results

A total of 47 peatlands were sampled over the 2004-2005 seasons, and they were grouped for analysis. These groups included four sub-basins of Rainy Lake: Rainy sites just below Kettle Falls (RbKF) (7), North Rainy (8), South Rainy (7), and Red Gut Bay (5). In addition to Rainy, other basins included Namakan (10), Sand Point (6), and Lac la Croix (4).

Waypoint data, including UTM coordinates for each transect's start, mid-point, and end-point, as well as vegetation data for all 47 sites (940 quadrats over 94 transects), is provided in the accompanying database. General location maps as well as site-specific maps showing the relationship of the transects to VNP vegetation map polygons and open water are also provided in the database for all peatland sites.

Structural Differences

The sampled peatlands in Lac la Croix had less cover (78.7%, summed for all taxa) and the lowest mean richness (5.4) when compared to the other sites (Table 47). North Rainy has the most summed cover (111.0%) and the greatest richness, about twice that of Lac la Croix (11.4). The Lac la Croix peatlands were also distinct in that *Typha* was not recorded in the quadrats (and rarely seen anywhere on the lake) (Table 48). Among the other sites, Namakan, Rainy near Kettle Falls, and Sand Point Lake had greater *Typha* stem densities (3.6, 1.7, and 4.5/m^2 respectively) and higher frequencies of occurrence (84.5, 41.4, and 89.2%) when compared to most of the Rainy sites. Density of dead *Typha* stems was higher than live for all sites except Rainy below Kettle Falls (where it was the same as live stem density). This indicates a *Typha* presence for longer than the current year. (We believed that we counted only dead stems from the previous year, but could not always be certain of that.)

Differences Among Taxa

Seventy-nine taxa were recorded in the 940 peatland quadrats and ranged in frequency from a high of 66.3% (*Calamagrostis canadensis*, Table 49) to a few taxa seen only once. Five taxa were found in over half of all quadrats, including *Calamagrostis canadensis*, *Carex utriculata*, *Lysimachia* spp., *Potentilla palustris*, and *Typha latifolia*. Of interest are differences among taxa

Table 47. Mean summed cover (summed over all taxa), mean cover by single estimate, and mean quadrat richness in peatland habitat for seven basins/sub-basins. Lower and upper limits indicate 95% confidence levels at noted number of quadrats.

Basin	n	Mean summed cover per quadrat	St.dev.	Lower limit CI	Upper limit CI	Mean estimated cover per quadrat	St.dev.	Lower limit CI	Upper limit CI	Mean richness per quadrat	St. dev.	Lower limit CI	Upper limit CI
Lac la Croix	80	78.7	24.8	73.2	84.3	72.8	15.2	69.4	76.2	5.4	2.4	4.8	5.9
Namakan	200	94.6	30.8	90.2	98.9	71.6	14.4	69.5	73.6	9.6	3.0	9.2	10.0
North Rainy	160	111.0	41.6	104.4	117.6	74.9	17.0	72.2	77.6	11.4	3.0	10.9	11.9
Rainy below Kettle Falls	140	101.9	41.2	95.0	108.9	70.0	17.8	67.0	73.0	9.0	3.2	8.4	9.5
Red Gut Bay	100	100.8	36.4	93.5	108.1	73.2	15.8	70.0	76.4	10.3	2.2	9.9	10.7
Sandpoint	120	96.8	38.6	89.8	103.9	67.7	14.6	65.0	70.4	10.8	2.6	10.3	11.2
South Rainy	140	106.8	42.5	99.6	114.0	72.6	17.8	69.6	75.6	9.4	3.8	8.7	10.0

Table 48. Mean *Typha* stem density for live and dead (previous year's stems) in peatland habitat for seven basins/sub-basins.

	n	Live Typha Stems			Dead Typha Stem		
		Stem Density per 1 m^2	St. Dev.	% Frequency	Stem Density per 1 m^2	St. Dev.	% Frequency
Lac la Croix	80	0.0	0.0	0.0	0.0	0.0	0.0
Namakan	200	3.6	3.1	84.5	5.2	3.8	91.0
North Rainy	160	0.9	1.3	41.3	4.4	5.5	66.9
Rainy below Kettle Falls	140	1.7	3.0	41.4	1.7	3.7	40.7
Red Gut Bay	100	0.7	1.3	28.0	1.2	2.8	31.0
Sandpoint	120	4.5	3.9	89.2	7.0	5.2	90.8
South Rainy	140	0.7	1.2	28.6	3.5	5.6	46.4

Table 49. Summary total cover, relative cover, frequency, mean cover per occurrence, and mean cover overall for all taxa in 47 peatland sites, each with two transects of 10 quadrats each (47 sites x 2 transects x 10 quadrats = 940 quadrats overall).

	Species	**Total cover**	**Relative cover**	**Freq.**	**Percent freq.**	**Mean cover per occurrence**	**Mean cover per 940 quads.**
1	*Acer rubrum*	1.0	0.0	1	0.1	1.0	0.0
2	*Acorus calamus*	2631.7	2.8	358	38.1	7.4	2.8
3	*Alnus incana*	175.1	0.2	21	2.2	8.3	0.2
4	*Andromeda glaucophylla*	54.0	0.1	7	0.7	7.7	0.1
5	*Aster spp.*	41.2	0.0	19	2.0	2.2	0.0
6	*Betula papyrifera*	27.3	0.0	11	1.2	2.5	0.0
7	*Betula pumila*	427.2	0.5	22	2.3	19.4	0.5
8	*Calamagrostis canadensis*	7609.7	8.1	623	66.3	12.2	8.1
9	*Calla palustris*	317.2	0.3	45	4.8	7.0	0.3
10	*Caltha palustris*	38.0	0.0	10	1.1	3.8	0.0
11	*Campanula aparinoides*	1274.5	1.4	453	48.2	2.8	1.4
12	*Carex acutae group*	189.1	0.2	18	1.9	10.5	0.2
13	*Carex canescens*	1192.6	1.3	234	24.9	5.1	1.3
14	*Carex chordorrhiza*	165.4	0.2	32	3.4	5.2	0.2
15	*Carex diandra*	9.1	0.0	6	0.6	1.5	0.0
16	*Carex lacustris*	7820.1	8.3	403	42.9	19.4	8.3
17	*Carex lasiocarpa*	7378.7	7.9	353	37.6	20.9	7.8
18	*Carex spp.*	59.0	0.1	7	0.7	8.4	0.1
19	*Carex stipata*	12.5	0.0	10	1.1	1.3	0.0
20	*Carex utriculata*	7458.5	7.9	616	65.5	12.1	7.9
21	*Chamaedaphne calyculata*	5677.4	6.0	139	14.8	40.8	6.0
22	*Cicuta spp.*	34.1	0.0	39	4.1	0.9	0.0
23	*Drosera rotundifolia*	101.4	0.1	49	5.2	2.1	0.1
24	*Dulichium arundinaceum*	818.3	0.9	40	4.3	20.5	0.9
25	*Eleocharis palustris*	33.0	0.0	8	0.9	4.1	0.0
26	*Eleocharis spp.*	215.0	0.2	39	4.1	5.5	0.2
27	*Epilobium sp.*	103.0	0.1	57	6.1	1.8	0.1
28	*Equisetum spp.*	415.6	0.4	83	8.8	5.0	0.4
29	*Eriophorum spp.*	216.6	0.2	59	6.3	3.7	0.2
30	*Galium spp.*	493.4	0.5	335	35.6	1.5	0.5
31	*Glyceria borealis*	5.1	0.0	2	0.2	2.6	0.0

	Species	Total cover	Relative cover	Freq.	Percent freq.	Mean cover per occurrence	Mean cover per 940 quads.
32	*Glyceria spp.*	284.2	0.3	49	5.2	5.8	0.3
33	*Hypericum majus*	161.8	0.2	78	8.3	2.1	0.2
34	*Impatiens capensis*	2.0	0.0	1	0.1	2.0	0.0
35	*Iris versicolor*	425.2	0.5	52	5.5	8.2	0.5
36	*Juncus filiformis*	7.1	0.0	6	0.6	1.2	0.0
37	*Kalmia polifolia*	31.2	0.0	11	1.2	2.8	0.0
38	*Larix laricina*	39.0	0.0	3	0.3	13.0	0.0
39	*Lemna trisulca*	1.6	0.0	16	1.7	0.1	0.0
40	*Lycopus spp.*	417.5	0.4	131	13.9	3.2	0.4
41	*Lysimachia spp.*	2372.1	2.5	596	63.4	4.0	2.5
42	*Mentha arvensis*	9.0	0.0	3	0.3	3.0	0.0
43	*moss spp.*	1546.7	1.6	231	24.6	6.7	1.6
44	*Myrica gale*	2911.3	3.1	109	11.6	26.7	3.1
45	*Onoclea sensibilis*	7.0	0.0	2	0.2	3.5	0.0
46	*Petasites sagittatus*	35.0	0.0	1	0.1	35.0	0.0
47	*Phalaris arundinacea*	199.0	0.2	25	2.7	8.0	0.2
48	*Phragmites australis*	11.0	0.0	2	0.2	5.5	0.0
49	*Pinus banksiana*	12.0	0.0	3	0.3	4.0	0.0
50	*Pinus strobus*	121.0	0.1	8	0.9	15.1	0.1
51	*Poa spp.*	587.6	0.6	110	11.7	5.3	0.6
52	*Polygonum amphibium*	1298.7	1.4	248	26.4	5.2	1.4
53	*Potamogeton gramineus*	2182.1	2.3	250	26.6	8.7	2.3
54	*Potentilla palustris*	5184.0	5.5	569	60.5	9.1	5.5
55	*Ranunculus spp.*	6.0	0.0	14	1.5	0.4	0.0
56	*Rhynchospora alba*	2.0	0.0	1	0.1	2.0	0.0
57	*Rorippa spp.*	2.0	0.0	2	0.2	1.0	0.0
58	*Rumex spp.*	194.6	0.2	53	5.6	3.7	0.2
59	*Sagittaria rosette*	181.1	0.2	19	2.0	9.5	0.2
60	*Sagittaria spp.*	160.0	0.2	41	4.4	3.9	0.2
61	*Salix spp.*	3120.4	3.3	291	31.0	10.7	3.3
62	*Scirpus cyperinus*	939.5	1.0	141	15.0	6.7	1.0
63	*Scirpus fluviatilis*	8.0	0.0	1	0.1	8.0	0.0
64	*Scirpus validus*	7.0	0.0	4	0.4	1.8	0.0
65	*Scutellaria spp.*	216.7	0.2	119	12.7	1.8	0.2
66	*Sium suave*	509.4	0.5	110	11.7	4.6	0.5

	Species	Total cover	Relative cover	Freq.	Percent freq.	Mean cover per occurrence	Mean cover per 940 quads.
67	*Smilacina trifolia*	5.0	0.0	2	0.2	2.5	0.0
68	*Sparganium erect*	45.0	0.0	12	1.3	3.8	0.0
69	*Sparganium spp.*	232.1	0.2	30	3.2	7.7	0.2
70	*Sphagnum spp.*	14522.8	15.5	353	37.6	41.1	15.4
71	*Spiraea alba*	276.3	0.3	49	5.2	5.6	0.3
72	*Stachys palustris*	2.0	0.0	1	0.1	2.0	0.0
73	*Thelypteris palustris*	1165.4	1.2	93	9.9	12.5	1.2
74	*Triadenum fraseri*	359.6	0.4	131	13.9	2.7	0.4
75	*Typha latifolia*	4594.5	4.9	477	50.7	9.6	4.9
76	*Utricularia intermedia*	4143.4	4.4	414	44.0	10.0	4.4
77	*Utricularia vulgaris*	5.0	0.0	1	0.1	5.0	0.0
78	*Vaccinium oxycoccos*	142.3	0.2	19	2.0	7.5	0.2
79	*Viola spp.*	212.8	0.2	78	8.3	2.7	0.2
	totals	93893.8	100.0				

in their manner of abundance. *Lysimachia*, for example, was regularly found (in 63.4% of all quadrats), but at a low percent cover per quadrat occurrence (4.0%). In contrast, *Chamaedaphne calyculata* was much less frequent (14.8%), but when it was present it dominated the quadrat with a mean cover per occurrence of 40.6%. *Sphagnum* spp. similarly dominated quadrats when it was present and had the highest total cover value as well (>14,000% all quadrats), almost double the next highest taxa by cover (*Carex lacustris* at 7820%).

Five taxa accounted for almost half of all cover in the peatlands sampled (Table 50), with a cumulative relative percent cover of 47.7%. These include *Sphagnum* spp., *Calamagrostis*, and three sedges (*Carex lacustris*, *C. utriculata* , and *C. lasiocarpa*). Of the next six most abundant taxa by cover (through #11 in Table 50), three are woody taxa (*Chamaedaphne calyculata*, *Salix* spp., and *Myrica gale)*.

Comparisons of Abundant Taxa Across Basins

Contributions of the eleven most abundant taxa by cover at each of the seven basins are shown in Table 51. *Sphagnum* differs considerably across basins, accounting for 29.2, 25.3, 18.5 and 11.7% of all cover at the Rainy sites (North Rainy, South Rainy, Red Gut, and Rainy below Kettle Falls respectively), while at only 3.7, 5.4 and 6.5% at Lac la Croix, Namakan, and Sand Point. Other taxa, such as *Calamagrostis*, were distributed more evenly across basins, while *Carex lacustris*, *Typha*, and *Utricularia intermedia* were absent at the Lac la Croix sites, apparently replaced by a greater shrub component, with high percents for *Myrica* (31.8%) and *Chamaedaphne* (16.8%).

Table 50. Summary of the twenty most abundant taxa (by total cover) in 47 peatland sites, each with two transects of 10 quadrats each (47 sites x 2 transects x 10 quadrats = 940 quadrats overall).

	Species	Total cover	Relative cover	Cum. Rel. Cover	Freq. of occurrence	Percent frequency	mean cover per occurrence	mean cover per 940 quads.
1	*Sphagnum* spp.	14522.8	15.5	15.5	353	37.6	41.1	15.4
2	*Carex lacustris*	7820.1	8.3	23.8	403	42.9	19.4	8.3
3	*Calamagrostis canadensis*	7609.7	8.1	31.9	623	66.3	12.2	8.1
4	*Carex utriculata*	7458.5	7.9	39.8	616	65.5	12.1	7.9
5	*Carex lasiocarpa*	7378.7	7.9	47.7	353	37.6	20.9	7.8
6	*Chamaedaphne calyculata*	5677.4	6.0	53.7	139	14.8	40.8	6.0
7	*Potentilla palustris*	5184.0	5.5	59.3	569	60.5	9.1	5.5
8	*Typha latifolia*	4594.5	4.9	64.2	477	50.7	9.6	4.9
9	*Utricularia intermedia*	4143.4	4.4	68.6	414	44.0	10.0	4.4
10	*Salix* spp.	3120.4	3.3	71.9	291	31.0	10.7	3.3
11	*Myrica gale*	2911.3	3.1	75.0	109	11.6	26.7	3.1
12	*Acorus calamus*	2631.7	2.8	77.8	358	38.1	7.4	2.8
13	*Lysimachia* spp.	2372.1	2.5	80.3	596	63.4	4.0	2.5
14	*Potamogeton gramineus*	2182.1	2.3	82.7	250	26.6	8.7	2.3
15	moss spp.	1546.7	1.6	84.3	231	24.6	6.7	1.6
16	*Polygonum amphibium*	1298.7	1.4	85.7	248	26.4	5.2	1.4
17	*Campanula aparinoides*	1274.5	1.4	87.0	453	48.2	2.8	1.4
18	*Carex canescens*	1192.6	1.3	88.3	234	24.9	5.1	1.3
19	*Thelypteris palustris*	1165.4	1.2	89.6	93	9.9	12.5	1.2
20	*Scirpus cyperinus*	939.5	1.0	90.6	141	15.0	6.7	1.0

Table 51. Cover, frequency and within site relative cover for the eleven most abundant taxa across seven basins/sub-basins for all 94 peatland monitoring sites (July 2004-2005).

Basin		***Sphagnum spp.***	***Carex lacustris***	***Calamagrostis canadensis***	***Carex utriculata***	***Carex lasiocarpa***	***Chamaedaphne calyculata***	***Potentilla palustris***	***Typha latifolia***	***Utricularia intermedia***	***Salix spp.***	***Myrica gale***
Lac la Croix	sum	235.9	0.0	554.6	826.4	539.7	1056.0	104.5	0.0	0.0	320.1	2004.2
	count	23	0	62	52	48	23	45	0	0	23	53
	within site rel.%	3.7	0.0	8.8	13.1	8.6	16.8	1.7	0.0	0.0	5.1	31.8
Namakan	sum	1029.7	987.0	1793.2	2036.0	3541.1	662.4	1021.2	2062.2	1256.9	514.1	149.0
	count	65	54	108	145	100	27	101	175	141	53	7
	within site rel.%	5.4	5.2	9.5	10.8	18.7	3.5	5.4	10.9	6.6	2.7	0.8
North Rainy	sum	5185.4	931.0	1315.5	418.4	1626.1	1045.0	1074.9	334.1	233.8	776.6	465.0
	count	92	75	123	54	86	26	131	68	45	87	23
	within site rel.%	29.2	5.2	7.4	2.4	9.2	5.9	6.1	1.9	1.3	4.4	2.6
Rainy below	sum	1670.0	2569.0	827.4	1014.3	185.0	698.0	783.0	585.0	1161.2	249.0	41.0
Kettle Falls	count	30	87	83	92	10	11	51	58	81	20	3
	within site rel.%	11.7	18.0	5.8	7.1	1.3	4.9	5.5	4.1	8.1	1.7	0.3
Red Gut Bay	sum	1863.2	1039.0	1744.0	919.0	248.1	0.0	625.1	155.0	110.1	565.0	13.0
	count	36	64	87	93	15	0	74	28	11	37	3
	within site rel.%	18.5	10.3	17.3	9.1	2.5	0.0	6.2	1.5	1.1	5.6	0.1
Sandpoint	sum	758.1	1277.1	334.6	1231.0	462.1	480.0	802.1	1221.0	1046.1	64.0	107.0
	count	29	69	55	109	25	13	75	107	80	6	9
	within site rel.%	6.5	11.0	2.9	10.6	4.0	4.1	6.9	10.5	9.0	0.6	0.9
South Rainy	sum	3780.5	1017.0	1040.4	1013.4	776.6	1736.0	773.2	237.2	335.3	631.6	132.1
	count	78	54	105	71	69	39	92	41	56	65	11
	within site rel.%	25.3	6.8	7.0	6.8	5.2	11.6	5.2	1.6	2.2	4.2	0.9

Of note is the emerging pattern for *Typha*, indicating a greater relative cover contribution at Namakan (10.9%) and Sand Point (10.5%) when compared to the Rainy sites (North Rainy 1.9%, South Rainy 1.6%, and Red Gut Bay 1.5%), with Rainy at Kettle Falls intermediate (4.1%).

Ordination

Transects with greater *Sphagnum* cover plotted higher on both axis one and axis two (r=0.56 and r=0.64) (Figure 22). Most of these sites were in the Rainy basin, primarily North Rainy and South Rainy. Fine leaf sedges (primarily *Carex lasiocarpa* and *C. canescens*) were negatively correlated with axis two (r=-0.50), and transects dominated by these taxa include those at Lac la Croix and at Namakan. The coarse sedge group consisted of *Carex utriculata* and *C. lacustris*, and transects dominated by these taxa plotted lower on axis one (r=- 0.669) and included transects from a number of sub-basins, including Rainy below Kettle Falls, Sand Point, and Red Gut Bay.

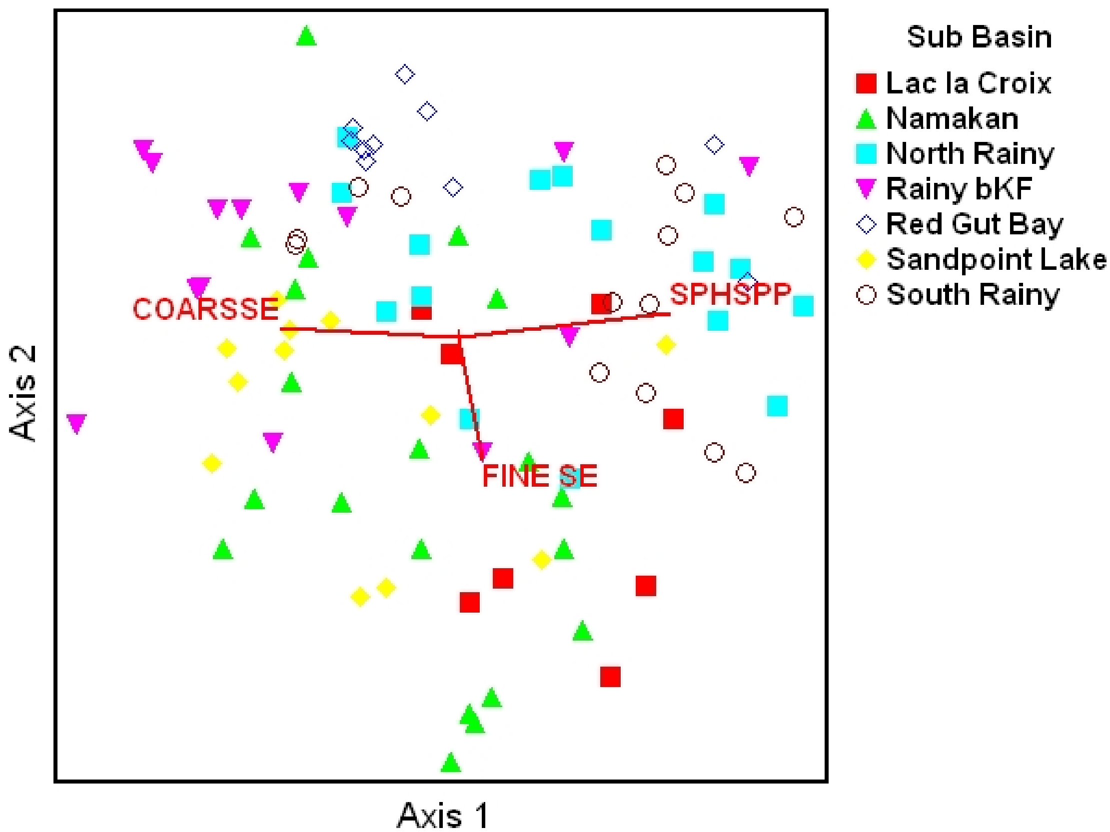


Figure 22. Non-metric multidimensional scaling (NMS) ordination of 94 peatland transects and 79 taxa. Vectors represent taxonomic groups that are correlated with axis scores. Cover was used as the metric in the ordination.

In general, the ordination of all taxa reflects the differences discussed above relative to dominant taxa distributions, particularly of *Typha* and *Sphagnum* (Figures 23 and 24). *Typha*, for example, appears to be abundant in the many of the transects dominated by both coarse and fine leaf sedges (Figure 23), but not common in the *Sphagnum* dominated sites (Figure 24).

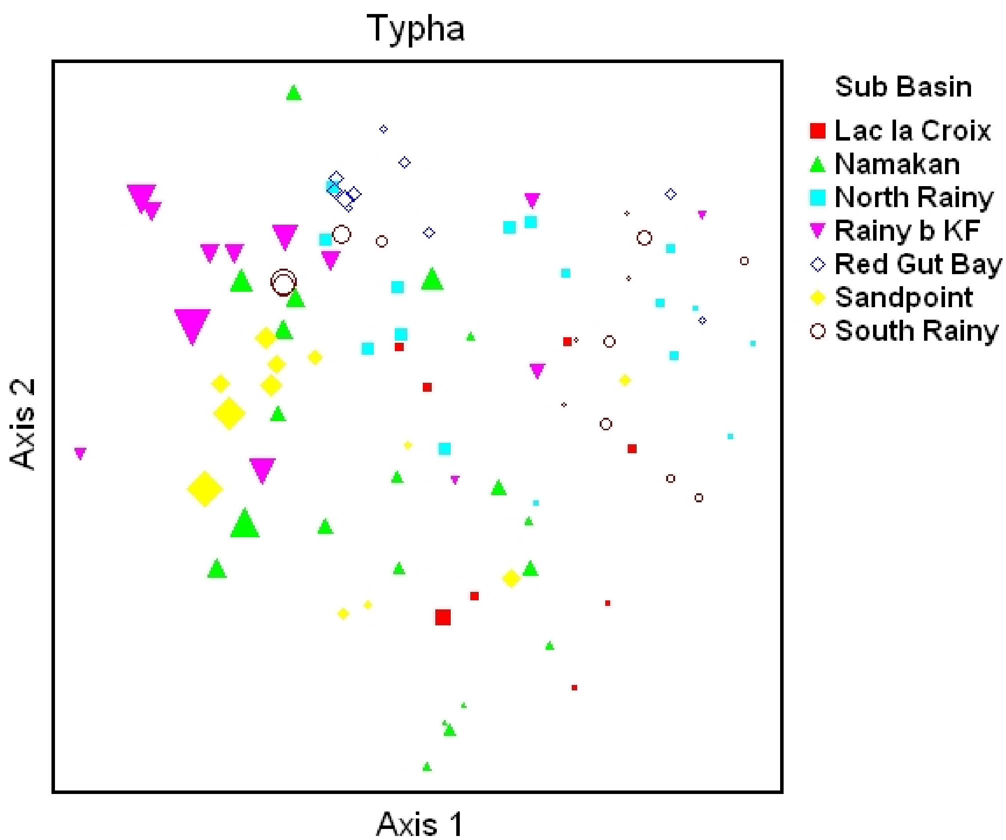


Figure 23. Non-metric multidimensional scaling (NMS) ordination of 94 peatland transects and 79 taxa. Distribution of *Typha* across the 94 transects is indicated by increasing symbol size. Cover was used as the metric in the ordination.

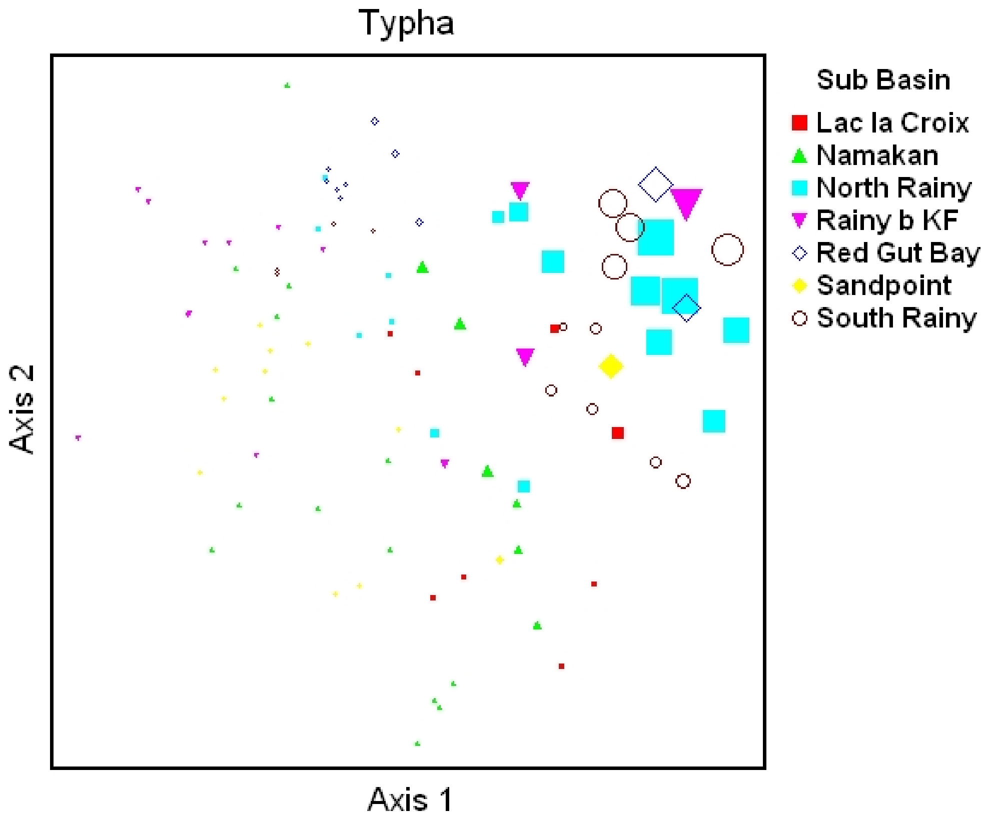


Figure 24. Non-metric multidimensional scaling (NMS) ordination of 94 peatland transects and 79 taxa. Distribution of *Sphagnum* across the 94 transects is indicated by increasing symbol size. Cover was used as the metric in the ordination.

Multi-response Permutation Procedure

MRPP analysis indicates significant differences in peatland vegetation between the three major basins (Table 52). Lac la Croix is significantly different from all other basins. Namakan is significantly different from Lac la Croix and Rainy sub-basins, but not the Sandpoint Lake sub-basin (a part of the Namakan Reservoir). The Rainy Lake sub-basins (North Rainy, South Rainy, Rainy BKF, and Red Gut Bay) are significantly different from the other basins, but not from each other. The only exception is that Rainy below Kettle Falls peatlands are not significantly different from Sandpoint Lake peatlands.

Discussion

The three taxonomic groups depicted as vectors on the ordination correspond with well-established ecological terms for three different peatland types. *Sphagnum* dominated peatlands are often referred to as bogs or poor fens (corresponding to the *Northern Open Bog* and *Northern Poor Fen* classes, respectively, of Minnesota's Laurentian Mixed Forest Province land classification; Minnesota DNR 2003), fine leaf sedge habitats as shore fens (*Northern Rich Fen – Basin*; Minnesota DNR 2003), and coarse leaf sedge peatlands as sedge meadows (*Northern Wet Meadow/Carr*; Minnesota DNR 2003).

Table 52. Multi-response Permutation Procedure (MRPP) pairwise comparison of peatland vegetation data by sub-basin. "*" indicates significant difference at p=0.01 level.

Sub Basin	T	A	p
Sandpoint vs. South Rainy	-3.65175267	0.05671066	0.00832941*
Red Gut Bay vs. Sandpoint	-3.66748746	0.06884549	0.00450651*
North Rainy vs. Sandpoint	-4.81008098	0.08366197	0.00331300*
Namakan vs Red Gut Bay.	-4.82018113	0.06029101	0.00099665*
Namakan vs. Rainy bKF	-5.01147634	0.04676360	0.00083210*
Lac la Croix vs. N. Rainy	-6.11965681	0.12493727	0.00056430*
Lac la Croix vs. South Rainy	-5.73838921	0.10627081	0.00037001*
Namakan vs. South Rainy	-5.68342775	0.05738523	0.00028034*
Namakan vs. North Rainy	-6.33776447	0.07236345	0.00026074*
Lac la Croix vs. Red Gut Bay	-6.36029423	0.15177913	0.00001846*
Lac la Croix vs. Rainy bKF	-8.25537745	0.12404818	0.00001108*
Lac la Croix vs. Sandpoint	-8.74942965	0.14071337	0.00001101*
Lac la Croix vs. Namakan	-7.99049707	0.09769458	0.00000922*
N.Rainy vs. Rainy bKF	-3.58031841	0.05515044	0.01091029
Namakan vs. Sandpoint	-2.10496187	0.02200863	0.04057224
Rainy bKF vs Red Gut Bay	-2.03316770	0.03366619	0.04552025
Rainy bKF vs South Rainy	-1.74544608	0.02700583	0.06416956
N.Rainy vs. Red Gut Bay	-1.31104286	0.03067177	0.09669475
Red Gut Bay vs. South Rainy	-1.31102107	0.02712673	0.09902395
Rainy bKF vs. Sandpoint	-0.99400812	0.01135369	0.14941947
North Rainy vs. South Rainy	-0.00415578	0.25202458	0.46311835

The significant differences in vegetation composition of the peatlands in the three major basins supports the suggestion that the water regimes are influencing peatland ecology. Development of peatland communities is generally related to water level fluctuations: 1) *Sphagnum* dominated peatlands are intolerant of regular flooding, 2) shore fens are associated with an intermediate degree of inundation, and 3) sedge meadows are associated with regular flooding by lake or stream water. This gradient partially corresponds with the pattern of water levels: *Sphagnum* dominated bogs and poor fens are most frequent on Rainy Lake where water level fluctuations are smallest, while shore fens are most frequent on Lac la Croix with intermediate water level fluctuations. However, the picture is complicated by other factors, such as nutrient availability, which also influence peatland development. Furthermore, shoreline peatlands on Rainy and Namakan are relatively young since most peatlands existing before the establishment of the dams in 1911-1914 were almost certainly flooded out and may be still changing towards a new equilibrium.

Typha is much more abundant (about 10 times greater relative cover) in Namakan and Sand Point peatlands than in most Rainy Lake peatlands and is virtually absent in Lac la Croix. This pattern of increased *Typha* abundance in waterbodies with a wide range of water level fluctuation is consistent with patterns observed elsewhere (c.f. Weisner 1993). However, these results are inconsistent with the results of the shoreline segments (see Shoreline Surveys section), where

Sand Point Lake had a relatively low proportion of *Typha* invaded shoreline, suggesting that are differences in factors influencing *Typha* invasions across shoreline and peatland habitats. The picture is further complicated by evidence that narrow-leaf cattail (*Typha angustifolia* and the hybrid *T.* x *glauca*) has invaded the Rainy-Namakan system within the last few decades.

Other changes expected under the new rule curves that call for a gradual later summer drawdown (in both Rainy and Namakan) include increase in abundance of shrubs.

In summary, we feel the descriptions above are a good snap shot in time of the different non-treed peatland types in the study area and provide a baseline for future monitoring. However, the comparisons of these sites with Lac la Croix may not be apt, since there were only four sites chosen from that basin, and these were chosen in a pseudo-random fashion that may not represent the greater Lac la Croix region.

Like the intensively sampled sites (see Intensive Sampling section), the peatland sites were located by GPS. In addition, they were monumented with PVC pipe. This allows an exact repeat sampling of individual quadrats if care is taken to 1) maintain the monuments at least once every four to five years (suggesting that these sites should be re-visited in 2008-2009), 2) carefully extend the meter tape through the midpoint making sure the lines are straight, 3) establish the quadrats on the left side of the sampling transect as one looks from start to finish (in order to sample the exact same spot), and 4) bring copies of the old data sheets to help locate the quadrats in the same location (e.g. at the 4-5m mark) and have a readily available known species pool. If this attention to detail is adopted, the next analysis could be from quadrat 'X' at time one to quadrat 'X' at time two, and would be a robust metric to monitor stem density changes in *Typha*. We recommend that the *Typha* (live stem density) sampling take place each time the sites are maintained (every 4-5 years), while full community assessment (as we did, of all taxa) occur once every 10 years. The analyses of the every decade re-sampling could target those taxa that may drop out of the community as either *Typha* or shrub abundance increases.

Extensive Site Sampling

A general component of the 2001-2002 VNP vegetation study (Meeker and Harris 2004) was to sample vegetation in Rainy and Namakan at select deeper water elevations in a greater number of wetlands. This “extensive” approach is in contrast to the “intensive sampling” of about 10 sites per basin described in the Intensive Sampling section. The rationale for this approach would be to develop a more rapid, more extensive metric focusing on the elevation where we expect the greatest vegetative response to the new rule curve.

The vegetative predictions relative to the changes in rule curves would suggest that the Namakan sites would increase in macrophyte abundance since the new rule curve indicates that these areas (zone 1) will not be drawn down and exposed to winter/spring dessication and freezing, and that the Rainy aquatics would likely not change because the rule curve modifications in that basin were minor.

In this section we summarize the 2002 extensive sampling methodology and results, as well as report on a test of repeatability that we completed in 2006 to estimate the variability of this type of sampling.

Methods

Sampling took place in August of 2002 and included 31 sites in the Namakan Reservoir and 22 sites in Rainy Lake. Extensive sampling of vegetation was conducted at sites chosen from a pool of potential wetland areas on both lakes, randomly chosen from the VNP vegetation database in the same manner as the intensive sites, using the following cover types: northern water lily, midwest pondweed, deep marsh mosaic, and wild-rice marsh (Hop et al. 2001). This extensive sampling was restricted to a sampling of submerged and floating aquatic habitat at elevations 2.25 m below mean high water mark in both Rainy and Namakan basins.

2002 Extensive Surveys

At each chosen **site** an axis of approach from deep to shallow water was established as a compass bearing that appeared to bisect the chosen wetland polygon near the 2.25-2.50 m elevations. The sampling team motored slowly landward in this direction and established the first of four sampling **locations** when an elevation of 2.25 m below mean high water was *first* reached. At this point the boat was used as a platform to place nine, 1 x 1 meter quadrats to assess aquatic vegetation. Within each quadrat every species’ percent cover was estimated. Estimates only included those species that were visible by looking at the water from a standing position in the boat, and in most cases meant that the observer could see about 0.25 meters below the water’s surface. (Hence, plants growing in the lower portion of the water column were not assessed.) The same nine sampling spots were marked with duct tape on the boat and used for the entirety of sampling.

In addition, at the first location the center of the boat was geo-referenced using Trimble GPS. From this point three more sampling locations were established, each along the same 2.25 m contour, either to the left or right of the first geo-referenced location, depending on which direction the 2.25 m contour extended the farthest, resulting in 36 quadrats per site.

2006 Variability Assessment

In order to assess the repeatability of the extensive approach described above, in 2006, we sampled to assess the within site variability of extensive sampling. In order to estimate the variability in estimates of frequency and cover in the Namakan Reservoir, four sites were chosen in 2006, and each site was repeatedly sampled at four different trials over a four day period (July 19-22, 2006). To minimize bias, observers did not refer to the previous day's data prior to re-sampling. At each of the four chosen sites, the same axis of approach from deep to shallow water was used and quadrats were sampled as in 2002.

Results

2002 Extensive Surveys

All locational data and summaries of cover and frequency for this extensive sampling are included in Table 53 and Table 54 for Namakan and Rainy lakes respectively. These include the bearing of approach to the wetland area, GPS coordinates for the first location, and the direction headed after establishing the first location. Maps for all extensive sampling sites are located in the accompanying database.

The percent of quadrats containing aquatic taxa varied considerably among sites in both basins. At Namakan several sites had no recorded vegetation, while 13 of the 31 sites had frequencies of 50% and greater. Mean frequency (of quadrats with any vegetation) over all Namakan sites was 39.2%, and the mean quadrat cover was 2.45% (Total cover of 2739 per 1116 quadrats, Table 53).

In Rainy the vegetation at the 2.25 m elevation was sparser compared to Namakan, as seven sites had no recorded vegetation at that elevation, and no sites had frequencies greater than 50% (Table 54). The mean frequency at Rainy sites was 13.4%, with a mean quadrat cover of 0.9%, less than half of the Namakan cover. The most abundant taxa in the Namakan extensive sites were, in order of quadrat frequency, *Nymphaea odorata*, *Potamogeton richardsonii*, and *Vallisneria americana* (Table 55), whereas the only taxa consistently recorded in Rainy was *Potamogeton richardsonii* (Table 56).

2006 Variability Assessment

Replicate estimates of frequency and cover for all taxa over the four trials is presented in Table 57. At Hoist Bay the same two taxa (*Nymphaea odorata* and *Potamogeton richardsonii*) were encountered each of the four times, whereas at Moose Bay and at Kohler Bay three of four taxa were recorded at all four times. At Eks Bay the two prevalent taxa were repeatedly recorded. In general, observers saw the same dominant taxa at each trial.

Comparisons of the repeated total cover estimates indicated moderate variability, and it differed among sites (Table 58). At the low end, at Hoist Bay the total taxa cover over the four trials varied from 64.4 to 109.8%, and at Kohler Bay the estimates ranged from 35.1 to 49.4%. At the high end of variability, one of the trials at Moose Bay (175%) was 3-4 times greater than the other trials. Coefficients of variation (standard deviations/mean) for total cover ranged from 16.9% at Kohler to as much as 86.5% at Eks Bay.

Table 53. Summary of frequency, cover, and site descriptions and locations for extensive sites in The Namakan Reservoir, sampled in 2002. Thirty-six quadrats were sampled at each site, for a total of 1116 quadrats.

Map #	Site Name	Easting	Northing	Bearing	Dir.	Freq.	% freq.	Total cover
1	LaBonty's Point	496648.7	5374489.5	26	Right	0	0.0	0.0
2	Blind Ash Bay	509615.3	5364218.2	110	Right	0	0.0	0.0
3	Lost Lake	511072.9	5365559.4	153	Right	9	25.0	15.2
4	Eks Bay W	511211.9	5368222.9	245	Right	17	47.2	35.7
5	Eks Bay E	511333.1	5368429.7	345	Right	8	22.2	6.3
6	Kohler Bay	514091.9	5366195.3	235	Right	28	77.8	179.2
7	Lone Squaw Bay (S of Kohler)	514964.2	5365720.1	267	Left	7	19.4	17.1
8	Moose Bay South	517195.1	5363670.2	262	Left	22	61.1	58.5
9	Moose Bay North	517430.0	5364078.5	270	Right	12	33.3	27.1
10	Johnson Bay	519537.0	5368803.0	260	Left	12	33.3	115.0
11	Namakan Island	521447.5	5365293.2	328	Right	14	38.9	53.2
12	No. of Junction Bay	521750.0	5363788.0	114	Right	19	52.8	67.3
13	Canadian Channel N of Moose Isl.	523406.1	5368386.7	312	Right	1	2.8	1.0
14	Canadian Channel NE of Moose Isl.	523627.2	5368295.3	87	Right	13	36.1	48.0
15	Canadian Channel Paddy Bay	524106.6	5369135.5	47	Right	5	13.9	9.0
16	Canadian Channel Bay E of Paddy	524980.9	5369069.5	27	Left	18	50.0	36.5
17	Canadian Channel Bay E of Paddy	525279.1	5369052.8	47	Right	18	50.0	82.7
18	NE of Black Point	527033.0	5368054.3	326	Left	19	52.8	299.1
19	Blackstone Island West	527441.8	5366517.7	17	Right	19	52.8	110.5
20	Blackstone Island East	527718.3	5366822.0	236	Left	22	61.1	189.1
21	North of Deep Slu	52812.1	5364508.8	275	Right	19	52.8	73.7
22	North Namakan Lake, small bay W	532505.4	5368747.0	305	Left	27	75.0	521.0
23	North Namakan Lake, small bay E	532772.6	5368940.1	32	Right	8	22.2	6.4
24	Hammer Bay W	534553.6	5364423.0	211	Right	31	86.1	190.3
25	Hammer Bay E	536744.2	5363528.6	92	Right	26	72.2	361.1
26	S of Blind Pig	537229.6	5364059.9	100	Right	5	13.9	13.0
27	Unnamed Bay, S of Nam. Narrows N	538156.3	5363444.7	245	Left	8	22.2	8.3
28	Unnamed Bay, S of Nam. Narrows S	538204.0	5363310.2	332	Left	16	44.4	108.4
29	NE of Burnt Island	539517.1	5361907.6	216	Right	12	33.3	46.1
30	Clearwater Lake (Sand Pt.)	540015.8	5357437.4	247	Right	5	13.9	17.0
31	N of Redhorse Bay	539875.9	5363348.2	246	Right	18	50.0	43.5
				Means		14.1	39.2	88.4
				Standard Deviations			23.16	118.9

Table 54. Summary of frequency, cover, and site descriptions and locations for extensive sites in Rainy Lake, sampled in 2002. Thirty-six quadrats were sampled at each site, for a total of 792 quadrats.

Map ID #		**Easting**	**Northing**	**Bearing**	**Dir.**	**Freq.**	**% Freq.**	**Total cover**
1	Harrison Bay	490902	5384405.7	340	Right	0	0.0	0.0
2	Findlander Bay	505539	5378842.2	225	Left	0	0.0	0.0
5	No. of Manitou Rock far W	511703	5383440.6	108	Right	3	8.3	3.0
6	No. of Manitou Rock W	511937	5383546	262	Right	9	25.0	49.0
7	No. of Manitou Rock N	512590	5383850.8	277	Right	11	30.6	57.1
8	No. of Manitou Rock E	514022	5383566	235	Right	5	13.9	11.1
9	Browns Bay	515141	5374947.9	260	Right	1	2.8	12.0
10	Moose Bay W	515124	5383635.3	275	Right	10	27.8	18.0
11	Moose Bay E	517572	5383027.2	190	Right	8	22.2	28.0
12	Deerhorn Point	519854	5379020.3	255	Right	8	22.2	99.0
13	Cormorant Bay N	520684	5382250.7	35	Right	2	5.6	7.0
14	Cormorant Bay S	520659	5382224.2	99	Right	6	16.7	10.0
15	Friendly Passage	521831	5378893.9	280	Right	0	0.0	0.0
16	Friendly Passage	521878	5378732.2	245	Right	0	0.0	0.0
17	Friendly Passage	522482	5379113.2	269	Right	0	0.0	0.0
18	Friendly Passage	522944	5380120.1	312	Right	0	0.0	0.0
19	Smith Island	523616	5374799.7	180	Right	2	5.6	7.0
20	So.of Rabbit Island	525878	5374485.3	175	Right	4	11.1	24.0
21	Vague Point	525835	5378862.7	47	Right	0	0.0	0.0
22	Canadian Channel W	528051	5374216.6	82	Right	11	30.6	37.2
23	Knox Bay	528228	5371139	260	Left	14	38.9	187.0
24	Canadian Channel E	529756	5373539	122	Right	12	33.3	166.2
				Means		4.8	13.4	32.5
				Standard Deviations			13.2	52.7

Table 55. Overall taxa frequency and cover for the Namakan Reservoir extensive sampling, 1116 quadrats total.

Genus	Species	Quadrat Frequency	Percent Frequency	Total Quadrat Cover
Ceratophyllum	*dermersum*	24	2.15	57.8
Myriophyllum	spp.	7	0.63	26.1
Nuphar	*variegata*	3	0.27	12
Nymphea	*odorata*	165	14.78	1536.1
Potamogeton	*gramineus*	18	1.61	35
Potamogeton	*pusillus*	1	0.09	20
Potamogeton	*richardsonii*	145	12.99	730.1
Potamogeton	*spirillis*	1	0.09	0.1
Potamogeton	*zosteriformis*	26	2.33	193.1
Vallisneria	*americana*	48	4.30	129
All Taxa		438	39.25	2739.3
		Mean quadrat cover		2.45

Table 56. Overall taxa frequency and cover for the Rainy Lake extensive sampling, 792 quadrats total.

Genus	Species	Quadrat Frequency	Percent Frequency	Total Quadrat Cover
Myriophyllum	spp.	1	0.13	1
Nuphar	*variegata*	2	0.25	12
Nymphea	*odorata*	2	0.25	61
Polygonum	*amphibium*	3	0.38	18.1
Potamogeton	*amplifolius*	4	0.51	23
Potamogeton	*gramineus*	26	3.28	169.1
Potamogeton	*richardsonii*	67	8.46	430.4
Vallisneria	*americana*	1	0.13	1
All taxa		106	13.38	715.6
		Mean quadrat cover		0.90

Table 57. Replicate estimates of cover and frequency for all taxa recorded at four locations in the Namakan Reservoir, July 2006. Locations were sampled as "extensive" sites, using 36, 1 m x 1 m quadrats at each site each time.

	Hoist Bay		**Freq.**	**Cover**		**Eks Bay**		**Freq.**	**Cover**
Trial 1	*Nymphaea*	*odorata*	14	56.2	Trial 1	*Lemna*	*trisulca*	1	0.1
	Potamogeton	*richardsonii*	5	8.2		*Potamogeton*	*richardsonii*	7	5.6
		sum	19	64.4		*Vallisneria*	*americana*	17	1.7
Trial 2	*Nymphaea*	*odorata*	15	57.6			sum	25	7.4
	Potamogeton	*richardsonii*	9	28.4	Trial 2	*Nymphaea*	*odorata*	2	2.1
		sum	24	86		*Potamogeton*	*richardsonii*	11	18.8
Trial 3	*Nymphaea*	*odorata*	13	50.4		*Vallisneria*	*americana*	17	9.3
	Potamogeton	*richardsonii*	7	22.2			sum	30	30.2
		sum	20	72.6	Trial 3	*Nymphaea*	*odorata*	1	2
Trial 4	*Nymphaea*	*odorata*	13	84.4		*Potamogeton*	*richardsonii*	6	7.4
	Potamogeton	*richardsonii*	8	25.4		*Potamogeton*	*zosteriformis*	1	0.1
		sum	21	109.8		*Vallisneria*	*americana*	21	3
							sum	29	12.5
	Kohler Bay				Trial 4	*Nymphaea*	*odorata*	2	0.2
Trial 1	*Myriophyllum*	*spp.*	1	0.1		*Potamogeton*	*richardsonii*	4	0.4
	Potomogeton	*richardsonii*	9	28.2		*Vallisneria*	*americana*	14	3.3
	Potomogeton	*zosteriformis*	4	11.1			sum	20	3.9
		sum	14	39.4					
Trial 2	*Myriophyllum*	*spp.*	1	0.1		**Moose Bay**			
	Nymphea	*odorata*	4	15.2	Trial 1	*Nymphaea*	*odorata*	1	0.1
	Potamogeton	*richardsonii*	6	9.3		*Potamogeton*	*gramineus*	9	10.4
	Potamogeton	*zosteriformis*	8	10.5		*Potamogeton*	*richardsonii*	17	32.8
		sum	19	35.1		*Vallisneria*	*americana*	4	0.4
Trial 3	*Myriophyllum*	*spp.*	2	0.2			sum	31	43.7
	Nymphaea	*odorata*	1	0.1	Trial 2	*Potamogeton*	*gramineus*	32	155.8
	Potamogeton	*richardsonii*	5	35.4		*Potamogeton*	*richardsonii*	8	18.1
	Potamogeton	*zosteriformis*	11	13.7		*Vallisneria*	*americana*	11	1.1
		sum	19	49.4			sum	51	175
Trial 4	*Nymphaea*	*odorata*	1	10	Trial 3	*Potamogeton*	*gramineus*	14	40.4
	Potamogeton	*richardsonii*	10	19.6		*Potamogeton*	*richardsonii*	8	3.6
	Potamogeton	*zosteriformis*	7	5.6		*Vallisneria*	*americana*	7	0.7
		sum	18	35.2			sum	29	44.7
					Trial 4	*Nymphaea*	*odorata*	1	0.1
						Potamogeton	*gramineus*	19	60.6
						Potamogeton	*richardsonii*	5	6.2
						Vallisneria	*americana*	5	0.5
							sum	30	67.4

Table 58. Replicate estimates of cover and frequency for all taxa combined at four sites sampled as “extensive” sites in the Namakan Reservoir, July 2006.

Replicate	**Quadrat Frequency**	**Total Cover**	
Hoist Bay			
1	19	64.4	% Coefficient of Variation
2	24	86.0	(standard deviation/mean)
3	20	72.6	of quadrat frequency
4	21	109.8	10.3
Mean	21	83.2	of total cover
Standard deviation	2.2	19.8	23.8
Kohler Bay			
1	14	39.4	% Coefficient of Variation
2	19	35.1	(standard deviation/mean)
3	19	49.4	of quadrat frequency
4	18	35.2	13.6
Mean	17.5	39.8	of total cover
Standard deviation	2.4	6.7	16.9
Eks Bay			
1	25	7.4	% Coefficient of Variation
2	30	30.2	(standard deviation/mean)
3	29	12.5	of quadrat frequency
4	20	3.9	17.5
Mean	26.0	13.5	of total cover
Standard deviation	4.5	11.7	86.5
Moose Bay			
1	31	43.7	% Coefficient of Variation
2	51	175.0	(standard deviation/mean)
3	29	44.7	of quadrat frequency
4	30	67.4	29.9
Mean	35.3	82.7	of total cover
Standard deviation	10.5	62.5	75.6

The variability in the multiple estimates of frequency also differed across sites. At Hoist Bay frequency (the sum of frequency for all taxa) ranged from 19 to 24, with an average of 21, while variability of frequency at Moose Bay was greater, ranging from 29 to 51. None of the sites had coefficients of variation (standard deviations/mean) greater than 30% (Table 58).

Discussion

This section was intended to assess a “quick and dirty” methodology for sampling floating leaf and submergent vegetation and to establish a baseline for future monitoring. We feel that the methods described above are satisfactory. The assessment of variability suggests that frequency, rather than cover, is the best monitoring metric. If we use the highest estimate of site error in frequency (30%) and add this to the mean 2002 frequency (39.2%,Table 53) the result would be 51.0%. This suggests that a minimum increase of 50% will indicate a real increase in vegetation frequency.

Wild Rice Surveys

Historical populations of wild rice (*Zizania palustris* var. *palustris*) in the Rainy/Namakan systems were thought to be more numerous and of greater size than they were in the 1960s and 1970s (Monson 1986; Meeker and Wilcox 1989; L. K. Kallemeyn pers. comm.). In Namakan it is likely that the 2.5-3.0 meter annual spring increase in water levels under the old curve was too great for wild-rice to elongate through, and/or the annual drawdowns exposed the seed to freezing and desiccation. In Rainy the lack of periodic fluctuations likely lead to intense competition from other taxa over time (Meeker 1996). Documenting the potential recovery of wild rice, especially in Namakan where the new rule curves would suggest a more favorable environment for this notable annual aquatic species, is an important goal for VNP and other stakeholders.

We initiated a monitoring program to 1) document the present extent and abundance of wild rice in the Namakan Reservoir and 2) establish methods and a baseline for monitoring future change in the Namakan Reservoir and Rainy Lake.

Methods

Namakan Reservoir

In the 2004 sampling, VNP park staff helped to identify known locations of wild rice, and new locations were sought by surveying large sections of the Namakan shoreline. The shoreline was visually surveyed for wild rice using binoculars from a slow moving boat approximately 25 meters from shore. Once located, a site would be labeled by project ID (R for rice) followed by the Ikonos image it was found in (example: R 39-2, this site would be on Ikonos image number 39 and would be the second site found on that Ikonos). Between five and fifteen 1 m x 1 m quadrats were assessed at each wild-rice location, depending on the size, by placing quadrats quasi-randomly starting at the edge of the rice patch and then moving towards shore. The total number of stems, percent flowering stems, and actual water depth (i.e. not depth relative to mean high water level) was recorded at each quadrat. Each site was also delineated using a Trimble GPS, which calculated the area of the stand. For small sites all of the stems were counted and areas were estimated visually. Photos were taken at each of the sites for future reference.

The entire shorelines of Kabetogama, Namakan, and partial sections of Sand Point Lake were surveyed for the presence of wild rice. Also in 2004, a small section of the eastern Rainy basin was assessed immediately below Kettle Falls.

Rainy Lake

We opted to sample Rainy Lake (2005) differently due to the difference in density and frequency between the two basins. In Namakan stands tended to be fewer and more disparate, yet more discrete, allowing for an estimate of both stem density and stand size. In Rainy Lake wild rice was more widely distributed, but was more diffuse, and these scattered stems precluded the delineation and description on an individual stand.

In 2005 on Rainy Lake, wild rice was surveyed along shorelines by presence and absence. In this method the shoreline was scanned for wild rice with binoculars from a slow moving boat 15 to

20 meters from shore, depending on depth of water. Successive segments of shoreline were classified either as wild rice "present" if there were at least scattered stems less than 10 m apart, or if no stems existed in that segment, wild rice "absent." Both segments were created with the Trimble GPS. Wild rice density and stand size were not quantified as was done in the Namakan Reservoir in 2004.

The assessment extended to parts of western Rainy from Lost Bay to Tilson Creek.

Mapping

The sections of shoreline surveyed in both years are highlighted on a wild rice survey overview maps (Figures 25 to 28). More detailed maps of the shorelines are included in the accompanying database, along with the delineation of individual wild rice stands assessed in 2004. UTM coordinates and the raw data for 2004 sites are also compiled in the accompanying database.

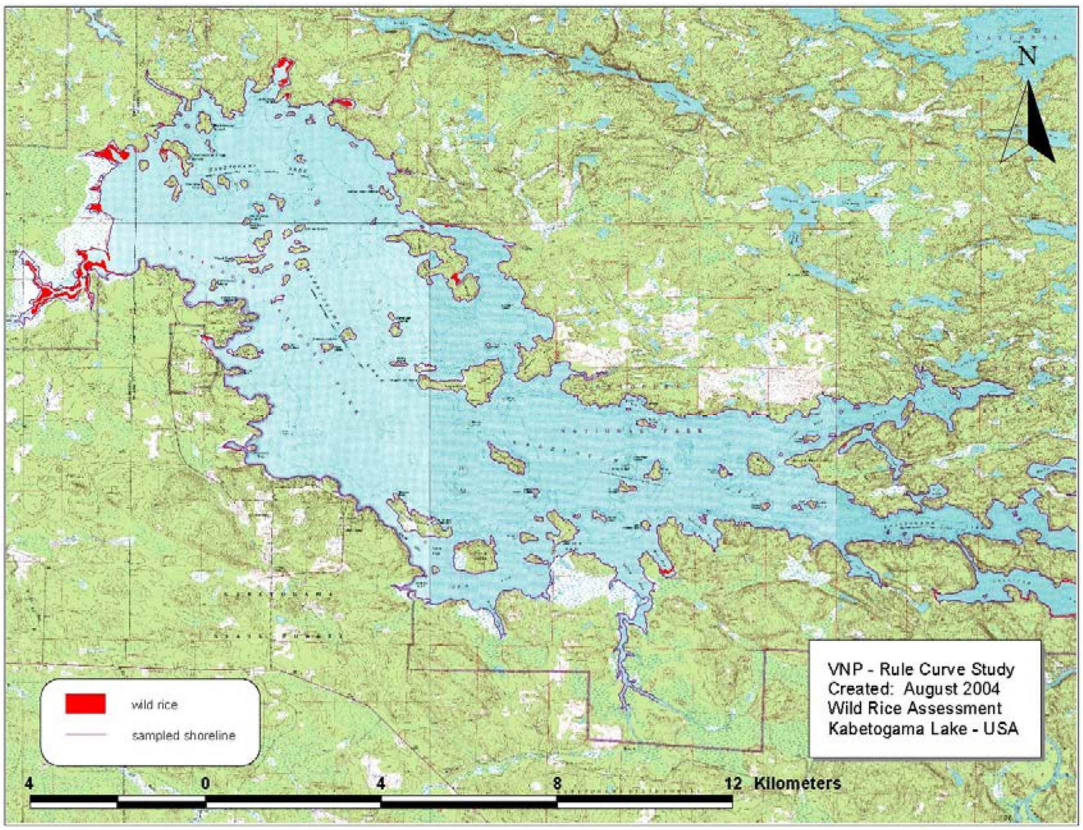


Figure 25. Map of Kabetogama Lake showing extent of shoreline surveyed for wild rice (purple line) and sites where wild rice was observed (red).

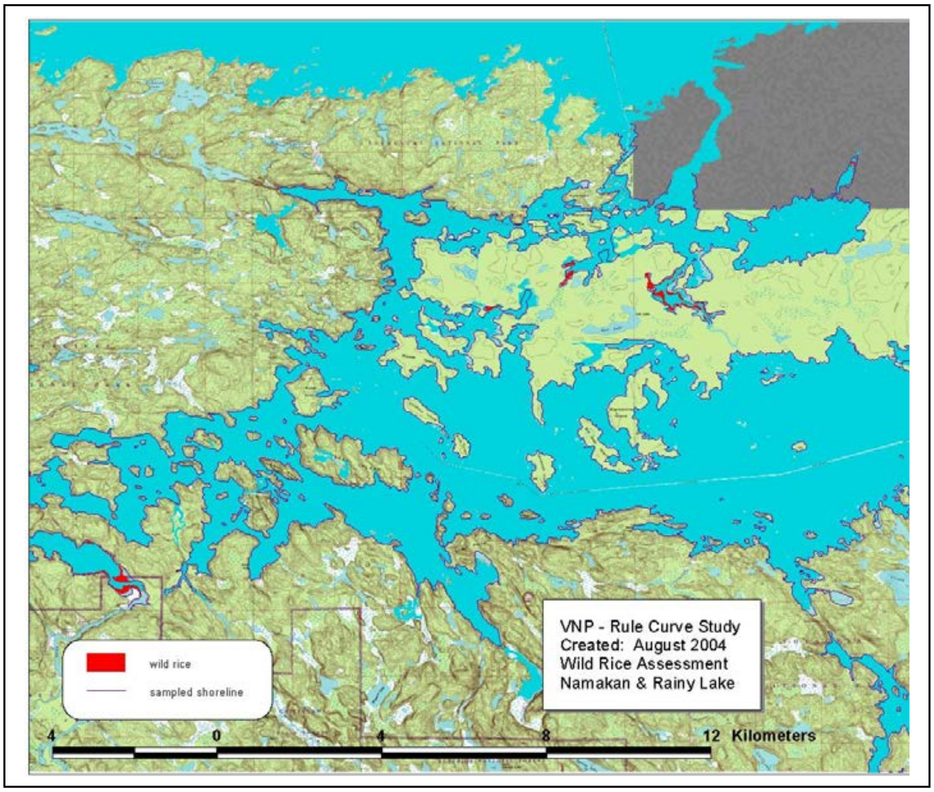


Figure 26. Map of Namakan Lake showing extent of shoreline surveyed for wild rice (purple line) and sites where wild rice was observed (red).

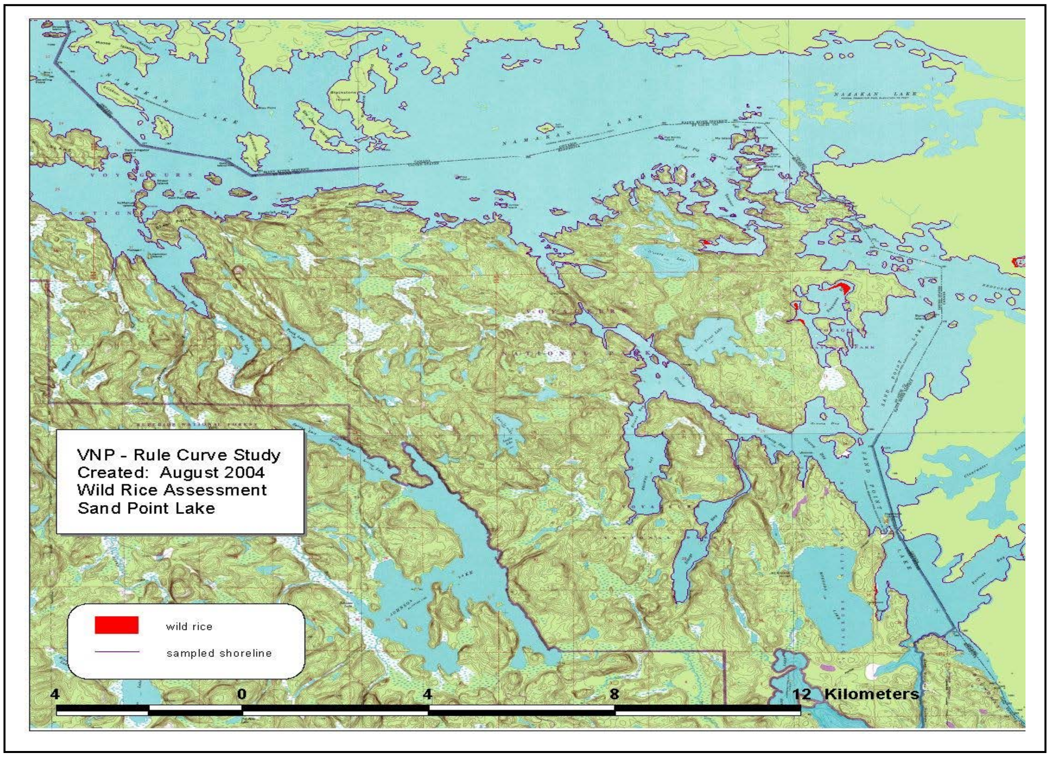


Figure 27. Map of Sandpoint Lake showing extent of shoreline surveyed for wild rice (purple line) and sites where wild rice was observed (red).

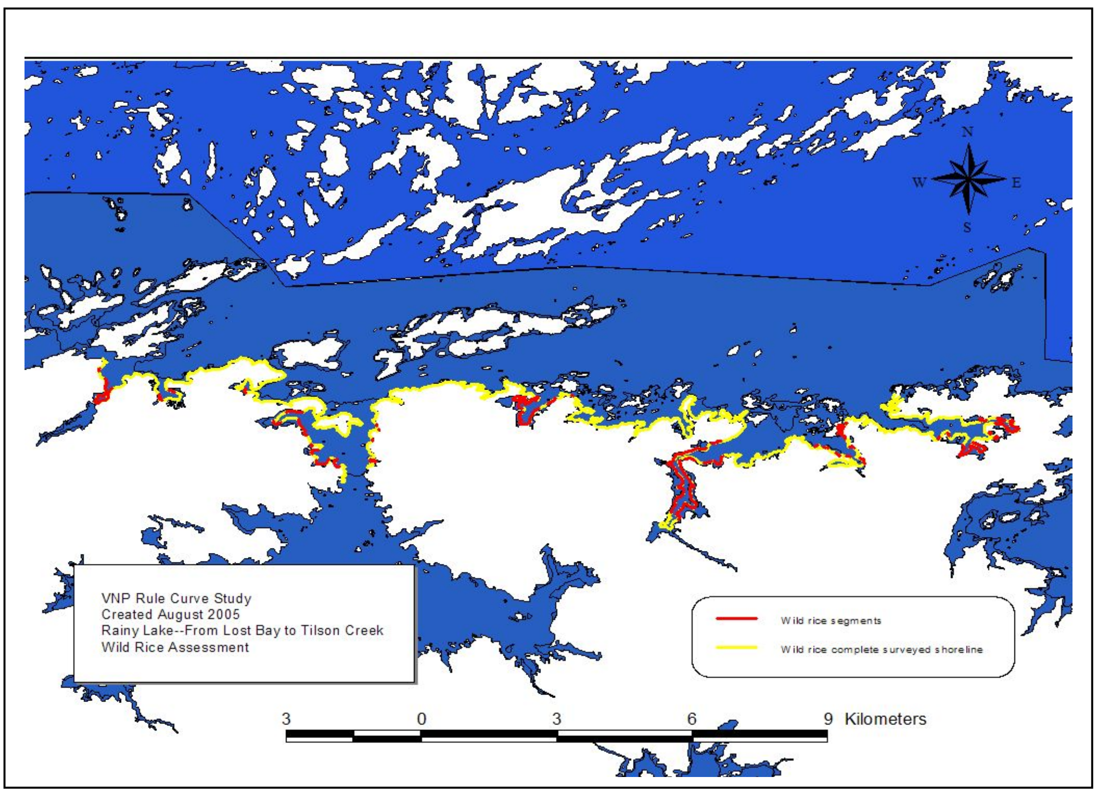


Figure 28. Map of Rainy Lake showing extent of shoreline surveyed for wild rice (yellow line) and sites where wild rice was observed (red).

Results

Seventy-five wild rice locations were identified in 2004, for a total estimated size of 168 ha (Table 59). Thirty-seven different patches of wild rice were found on Kabetogama, averaging 27,266.8 m^2 each, but ranging from 8.16 m^2 to 414,049 m^2 (Figure 25). Sand Point also had numerous wild rice occurrences (24; Figure 27), while in Namakan there were only five recorded (Figure 26), and the assessed part of eastern Rainy had nine (Figure 28). A greater proportion of stems were flowering on Rainy (53.2%), especially when compared to Kabetogama (21.4%). Mean depth of quadrats was greatest in Sand Point at 1.37 m, whereas wild rice grew at an average depth of around 1.0 m on Kabetogama, Namakan, and Rainy.

Rainy Lake shoreline surveys in 2005 indicated that 24.2% of the area surveyed had at least scattered stems of wild rice.

Table 59. Summary of wild rice (*Zizania palustris*) assessment, 2004-2005. In 2004 shorelines in Kabetogama, Namakan, Sand Point, and a small section of eastern Rainy were surveyed. In 2005 sections of southwestern Rainy were surveyed. In 2005 assessment was presence/absence only, see text.

Wild rice Assessment 2004	**Basin**				
	Kabetogama	**Namakan**	**Rainy**	**Sand Point**	**Totals**
Total # of known patches	37	5	9	24	75
Total area (m^2)	1,008,870.13	33,382.13	253,595.01	389,277.58	1,685,124.85
Total area (ha)	100.89	3.34	25.36	38.93	168.51
Average area (m^2)	27,266.76	6,676.43	28,177.22	16,219.90	
Maximum area (m^2)	414,049.60	19,473.76	131,890.67	220,886.08	
Minimum area (m^2)	8.2	1.9	1.1	7.3	
Average depth (m)	1.0	1.1	1.0	1.4	
Average flowering stems/m^2	6.8	11.2	11.5	6.2	
Average total stems/m^2	19.2	20.6	18.0	11.9	
Average % flowering	21.4	44.8	53.3	39.9	
Wild rice Assessment 2005					
Southwestern Rainy					
		Shoreline Surveyed (meters)			
Wild rice present		18,456.03			
Wild rice absent		57,919.86			
Total shoreline Surveyed		76,375.89			
Percent of shoreline sampled with wild rice		24.16			

Discussion

Verbal accounts (L. Kallemeyn pers. comm.) and other unpublished sources suggest that wild rice has increased, especially in Kabetogama Lake, relative to the extreme drawdowns of the 1960s and 1970s. However, the lack of consistently collected pre- and post-2000 rule curve data preclude statistical comparison of wild rice abundance between time periods. Similarly, different sampling techniques (due to differences in wild rice distribution) used in Namakan vs. Rainy preclude statistical comparison between basins. Furthermore, since wild rice is a variable resource, it is difficult to monitor annually, and especially difficult to interpret changes from year to year in stem density and area and what they might mean for long term trends.

However, we did successfully test a sampling technique and established a baseline for future monitoring. We recommend that VNP make efforts to repeat the whole Kabetogama /Namakan /Sand Point sampling during a normal water level year at approximately 10 year intervals. To use these data as a baseline for future monitoring, VNP will need to recognize the different metrics used for each basin. In the Kabetogama /Namakan/Sand Point basin, the number of stands and their areas and densities can be used, while in Rainy the percent of the shoreline with wild-rice present is the only metric. Since the Kabetogama /Namakan /Sand Point basin was assessed in a two week period in 2004, the process could be re-done with the same methods (omitting perhaps the 1 m x 1 m quadrat assessment) beginning about 2012. In the meantime, we recommend that VNP utilize the GIS maps of wild rice locations in the Kabetogama /Namakan /Sand Point basins (in the accompanying database) to create more detailed maps that can used in the field by VNP personnel to check on observed wild rice locations. As field personnel spot a wild rice bed they could refer to their maps to see if the location is new or not. In this manner the cumulative number of known locations could then be used as an ongoing metric of abundance, regardless of their size and density in a given year. In addition, when the whole process is to be repeated every 8-10 years, all locations from the first total census as well as any new locations can be targeted first, making that year’s reconnaissance more efficient.

Shoreline Surveys

Voyageurs Park Service staff and researchers have observed increases in the abundance of invasive narrow-leaf cattail (*Typha angustifolia* and the hybrid *T.* x *glauca*) and common reed grass (*Phragmites australis*) along shorelines and on the outer edges of shoreline fens, especially in the southern parts of Rainy Lake and the Kabetogama sub-basin. Preliminary surveys of a portion of the Rainy Lake shoreline completed in 2002 on both the Canadian and US sides indicated that an average of about 6% of 23 shoreline transects in Rainy were invaded by these species (Meeker and Harris 2004). Shoreline assessments were continued and expanded in this study to assess the present shoreline vegetation condition in other areas including other parts of Rainy, Namakan, Kabetogama, and Sand Point, as well as the Lac la Croix Basin outside of Voyageurs National Park.

Methods

The initial Rainy shoreline data was collected in 2002 (Meeker and Harris 2004), and the additional assessments were conducted as part of this study in 2004-2005. Random selection of shoreline segments differed slightly among years depending on the mapping resources available.

Shoreline Site Selection in 2002

Shoreline sampling of vegetation in 2002 was conducted at 23 sites chosen from a pool of potential wetland areas on both lakes, randomly chosen from the VNP vegetation database in the same manner as the intensive sites (see Intensive Sampling section) using the following cover-types: northern water lily, midwest pondweed, deep marsh mosaic, and wild-rice marsh (Hop et al. 2001).

Shoreline Site Selection in 2004-2005

Selection of shoreline segments in 2004 utilized aerial photographs (true color, approximately 1:5000 scale) taken along eight flight lines in August 2003. The aerial photographs were labeled: Rainy (two flight lines, labeled R1 and R2), Lac la Croix (two flight lines, labeled LC1 and LC2), and Namakan (four flight lines, labeled NAM1-NAM4). During the summer of 2004, shorelines covered in the aerial images from the Namakan flight lines (NAM1-4) were assessed. The Namakan four flight lines included flight line NAM1, which was divided into two parts (Namakan Lake/Squirrel Narrows and Rainy Lake/ Knox Bay), NAM2 (encompassing Namakan Lake, Paddy Bay), NAM3 (Sand Point Lake, Grassy Bay) and NAM4 (Kabetogama Lake, Daley Bay).

On each photo the shoreline was broken up into segments that likely supported wetlands vegetation, each approximately 200-250m long. In 2004, shoreline surveys focused on Namakan, Kabetogama, and Sand Point Lakes. The segments were named by using the abbreviation NAM then the flight line (or photo set), followed by the individual photo number, and finally the shoreline segment number. For example, NAM4-10-3 represents the third shoreline segment of photo #10 along the NAM4 flight line. Flight Line 1, which was divided into two parts, was named like the others except that it also included the name of the lake that the segments were on (example: NAM (Rainy) 1-1-1).

In 2005 the survey focused on Rainy Lake and Lac la Croix. The Rainy basin had two flight lines, of which only flight line R2 was used for shoreline assessment, as R1 covered First Nation Lands that we did not assess. On each photo of flight line R2 the shoreline was broken up into approximately 200-250 m long segments. As in 2004, the segments were named by using the abbreviation for the basin (R for Rainy), the flight line number (photo set), followed by the individual photo number, and finally the segment number (example R2-1-1).

In 2005, to increase coverage of northern parts of Rainy where we had no 1: 5000 color photographs, another segment selection method was used. The Rainy Basin was divided into four separate sub-basins: North Rainy, South Rainy (both eastern and western portions), Red Gut Bay, and Black Bay using the 1:50,000 scale VNP base map. The shorelines in each of these basins were divided into 5000-meter long sections, which were then randomized. The shoreline assessment in these sub-basins started with the first randomly selected section in each basin. Not all portions of the 5000-meter sections supported shoreline vegetation, as in the cases where upland trees grew down to steep sided rocky shoreline. These sections were omitted from the assessment. When the first 5000-meter section was surveyed for all possible shoreline segments, the next randomly selected section was used. This process was repeated until approximately fifty, 200 m long segments were surveyed in each sub-basin. The segments were named starting with the sub-basin abbreviation—North Arm - Rainy (NR), South Arm - Rainy (SR), Red Gut Bay – Rainy (RG), and Black Bay - Rainy, (BB)—then the random 5000 meter section number, followed by the segment number (example BB1-2). Lac la Croix shorelines were sampled in a similar manner, but we used the Ikonos imagery, as well as LLC flight line number two (LLC 2), for the pool of segments. The segments were named with the abbreviation of Lac la Croix, LLC, followed by the segment number in the basin (example LLC 5).

Field Methods

In the field, the dominant vegetation cover across the shoreline segments was assessed by classifying lengths into one of nine groups: *Typha angustifolia*; *T. latifolia*; *Phalaris arundindacea*; *Phragmites australis*; mixed *Typha*; mixed *Typha* & *Phragmites*; *Typha angustifolia* & *Phragmites; T. latifolia* & *Phragmites*; and non-invaded by either *Typha*, *Phragmites* nor dense *Phalaris*.

We measured the line segments using a Trimble GPS either from a boat or by walking along the shoreline (the preferred choice if possible). In either case the total length was traversed and segments were broken into partial segments based upon changes in the vegetation. Our intent was to classify the linear shoreline fringe, and we did not include vegetation more than 15 m back from the shoreline/open water interface. If there was more than a 2 m gap between clusters of the target taxa, these clusters were considered separate occurrences and expressed as discontinuous linear segments. The classification no *Typha*, *Phragmites*, nor *Phalaris* indicates the segment was dominated by native, non-invasive species and this was treated as one vegetation type (=non-invaded). All shoreline segments were mapped in Arcview (see accompanying database). Overall, 23 segments were assessed in 2002, 121 segments in 2004, and 184 segments in 2005. Segment locations (waypoint coordinates) and partial segment lengths are also included in the accompanying database.

Results

The total length and percent of shoreline dominated by either *Typha* spp., *Phragmites*, or *Phalaris*, or any of these three aggressive taxa is shown in Table 60. Eight sub-basins were recognized, and the number of shoreline segments and total lengths of shore assessed varied from 4930 m in Lac la Croix (n=26) to as much as 18,117 m assessed throughout the southern Rainy basin (n=61).

The sub-basins have considerably different invasive status (Table 60, Figure 29). The percent of shorelines dominated by *Typha* ranged from as low as 0.2% and 2.9% in Lac la Croix and Sand Point Lake respectively to as high as 99.2% in Black Bay (Rainy Lake). *Phragmites* was in greatest abundance along shorelines in Kabetogama (59.8%) and was uncommon (≤ 13%) in other sub-basins. Only at Sand Point and Lac la Croix is the majority of the shoreline still dominated by native, non-invasive taxa. *Phalaris* was present in substantial amounts (10 to 18%) only in the Rainy Lake sub-basins (North Rainy, South Rainy, and Red Gut Bay).

The degree of invasion is positively correlated with surface water conductivity (Figure 30). Black Bay and Kabetogama Lake have much higher specific conductivity (approximately 70 to 100 uS/cm) than other basins in the study area (Kallemeyn et al. 2003). The remainder of the study area has predominantly till soils and lower specific conductivity (Lac la Croix: 44 uS/cm; Sand Point: 42 to 46 uS/cm; Namakan: 39 to 46 uS/cm; South Rainy: 40 to 46 uS/cm; North Rainy: 67 to 77 uS/cm; and Red Gut Bay: 35 uS/cm).

Discussion

Since highly invaded (Kabetogama and Black Bay) and relatively uninvaded (Lac la Croix and Sand Point) shorelines occur in basins with very different water regimes, the degree of invasion cannot be explained by rule curve differences alone.

The very high degree of invasion (>85%) of Black Bay (Rainy Lake) and Kabetogama Lake may be related to nutrient availability. Although in different watersheds, these two sub-basins are in close proximity to each other and a minor channel flows from Kabetogama into Black Bay most of the year. Both Kabetogama and Black Bay also are underlain by clay soils, consequently possessing higher specific conductivity than other basins in the study area. Artificial nutrient enrichment has been shown to increase hybrid *Typha* biomass in sedge meadows (Woo and Zedler 2002) and *Phragmites* biomass (Saltonstall and Stevenson 2007).

The percent of invaded shoreline in the study area is higher than that of inland lakes and Lake Superior bays at Isle Royale National Park (1.2% for all invasive species) (Meeker et al. 2007). The difference probably represents an earlier stage of invasion at Isle Royale than at Voyageurs rather than the influence of water level regulation or other habitat attributes (Meeker et al. 2007).

The pattern of *Typha* invasion of the shorelines is different from that of peatlands (see Peatland Assessment section). Peatlands in Sand Point Lake had much more *Typha* invasion than the other basins but a low level of invasion (2.9%) of shorelines. This may reflect the different habitat preferences of the native *T. latifolia* (wet soil and very shallow water) vs. *T. angustifolia* and *T.* x *glauca* (deeper water). In this case *T. latifolia* may be prevalent in peatlands and *T. angustifolia* (and hybrid) on shorelines. Although *Typha* hybrids could not be reliably identified

Table 60. Length (m) and percent of shoreline dominated by *Typha* spp., *Phragmites*, *Phalaris*, or any of these three aggressive taxa (invaded), or none of these three taxa (not invaded). N=the number of shoreline segments sampled in each sub-basin.

	Length (m)	**Percent**			**Length (m)**	**Percent**
Kabetogama (n=45)				**Black Bay (Rainy) (n=24)**		
Typha spp.	3,886.2	44.3		*Typha* spp.	5,260.2	99.2
Phragmites	5,237.7	59.8		*Phragmites*	0	0
Phalaris	0	0		*Phalaris*	0	0
Invaded total	8,114.6	92.6		Invaded total	5,260.2	99.2
Not invaded total	649.2	7.4		Not invaded total	41.9	0.8
Total shoreline	8,763.7			Total shoreline	5,302.1	
Lac la Croix (n=26)				**North Rainy (n=48)**		
Typha spp.	10.1	0.2		*Typha* spp.	5,313.1	54.3
Phragmites	407.6	8.3		*Phragmites*	136.6	1.4
Phalaris	4.9	0.1		*Phalaris*	1,013.5	10.4
Invaded total	422.6	8.6		Invaded total	6,463.1	66.0
Not invaded total	4,507.6	91.4		Not invaded total	3,325.8	34.0
Total shoreline	4,930.2			Total shoreline	9,788.9	100.0
Namakan (n=52)				**South Rainy (n=61)**		
Typha spp.	4,314.7	45.7		*Typha* spp.	5,788.6	32.0
Phragmites	781.8	8.3		*Phragmites*	1,304.7	7.2
Phalaris	0	0		*Phalaris*	1,657.2	9.1
Invaded total	4,833.2	51.2		Invaded total	8,569.0	47.3
Not invaded total	4,598.5	48.8		Not invaded total	9,548.0	52.7
Total shoreline	9,431.7	100.0		Total shoreline	18,117.0	100.0
Sand Point (n=24)				**Red Gut Bay (Rainy) (n=48)**		
Typha spp.	125.6	2.9		*Typha* spp.	3,523.9	38.5
Phragmites	0	0		*Phragmites*	1,211.7	13.2
Phalaris	0	0		*Phalaris*	1,650.6	18.0
Invaded total	125.6	2.9		Invaded total	6,386.2	69.8
Not invaded total	4,263.9	97.1		Not invaded total	2,764.2	30.2
Total shoreline	4,389.5	100.0		Total shoreline	9,150.3	100.0

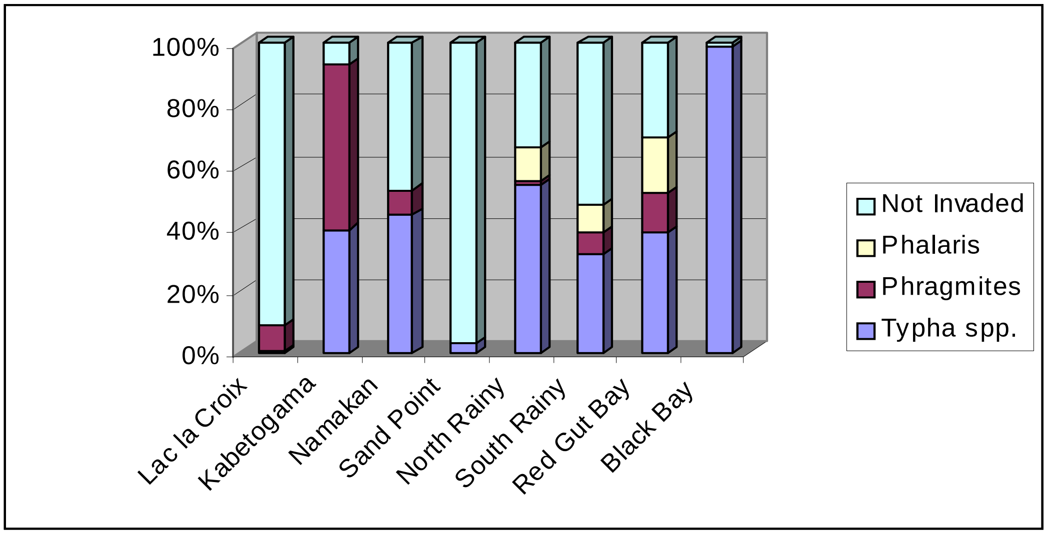


Figure 29. Percent of shoreline dominated by *Typha* spp., *Phragmites*, *Phalaris*, or none of these three taxa (not invaded).

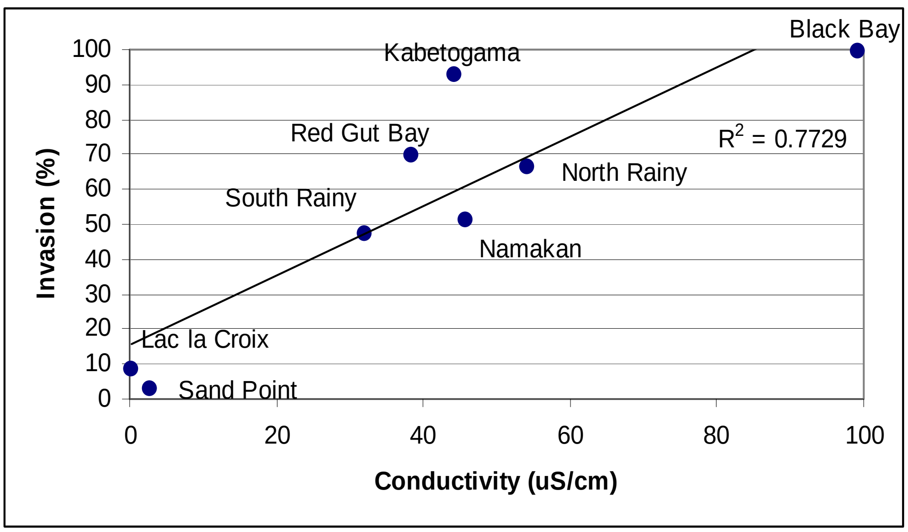


Figure 30. Relationship between invasion of shorelines (all species combined) and surface water conductivity (median values reported by Kallemeyn et al. 2003).

in the field, genetic analysis of *Typha* samples from Voyageurs Park indicates that the more isolated sites on inland lakes are mostly pure *T. latifolia*, but that hybrids are widely distributed (Steve Windels, pers. comm.).

Both native (relatively non-invasive) and introduced (invasive) genotypes of *Phragmites* may occur in the study area, but distinguishing the genotypes in the field is very difficult and was not attempted in this study. Subsequent monitoring may determine if *Phragmites* is increasing and genetic analysis or detailed examination of specimens could determine which genotypes are present.

In summary, although increases in invasive shoreline species have been attributed to altered water regimes in other studies (e.g. Wilcox et al. 2008), other factors, especially nutrient availability, are apparently also important in the study area. Regardless of cause, the invasion of hybrid *Typha* is likely to have large impacts of the shoreline ecosystems of these lakes as is already evident in Black Bay and Kabetogama Lake.

Estimates of Sampling Bias

Sampling is an attempt to provide enough information from the whole to make sound inferences, and part of this process is an attempt to estimate bias and error in sampling. In our goals to establish long term monitoring recommendations for the Park, we have made inroads in these estimations in a number of categories. First, as in the intensive site analyses (Vegetative Change section) discussed above, we have made efforts to increase sample sizes. In this section we will present our results in estimating three sources of variance in our sampling: 1) Intra-observer bias, that is, the sampling variability inherent in estimates made by a single, experienced observer repeatedly sampling the same resource, 2) Inter –observer bias, by looking at how different observers and their experiences in sampling may contribute to variability in results, and 3) what we have called placement bias, an attempt to determine the minimum number of sub-samples (in our case quadrats) needed to produce reliable information.

Intra-observer Bias (Single Observer Variability)

Methods

Intra-observer error was estimated for three habitat types, including peatlands, 2.0 m deep aquatic communities, and shoreline communities. In each case a single experienced observer (either J. Meeker or A. Harris) sampled the resource in 1 m x 1 m quadrats along transects at four successive times during six-day periods in July 2004 (shoreline and aquatic) and July 2006 (peatland). Daily after each sampling, the observers would give the data to another person to enter and intentionally not look at the information prior to the next sampling. In the case of the peatland resource, the exact same quadrat locations were sampled and re-sampled by first randomizing the selection of one quadrat in each 5 m section along two 50 m transects for a total of 20 quadrats and then using these exact locations every time. This was accomplished by taking care to keep the meter tapes straight and taut during set up and leaving the tapes set up as such in the field for the four sampling times. In the shoreline intra-observer sampling, the same locations were also sampled each time, again by keeping a tape set up in the field and flagging the meter mark on the tape. The aquatic sampling consisted of first establishing quadrat locations by randomly placing floats anchored with large 20 mm hexagonal nuts at twenty spots along an approximately 150 m long transect set at 2.0 m below mean high water. The sites were then sampled by placing 1 m x 1 m quadrats over the centers of the bolt locations each sampling time.

Results

Raw data for all intra-observer error assessment was entered into digital form, printed out, and error checked by comparison with field notebooks. In addition all sites used for estimates of bias were located by Trimble GPS and mapped (see accompanying database).

Peatland Intra-observer Bias

Overall Means: Total cover in quadrats was estimated in two ways. First, total cover was estimated in the field as one value per quadrat regardless of taxa. Second, all individual taxa's cover recorded in the field was summed during analyses. Total cover estimated in the field falls between 0 and 100%, while summed cover can exceed 100%, with species overlap. Both of these metrics as well as the number of taxa recorded in each quadrat (quadrat richness), and for the peatland the stem density of *Typha*, were compared for each of the four sampling times.

Confidence intervals (95%) surrounding both cover means at the four times suggest there were no differences among the times (Table 61). For example, the mean values for the field estimated cover varied from 67.0% at time one to 71.5% at time three. The overall estimated cover mean was 70.0% (all times), and confidence intervals bracketing these four means fell between 66.7 and 73.3, suggesting the smallest amount of cover change that can be detected is 4.7% (66.7 and 73.3 fall 4.7% above and below the mean value of 70.0), though it is likely higher in that these are ideal conditions (same observer, short time period between sampling). Mean summed cover and variance were both greater than the one estimate of cover, with a grand mean of 78% and minimal detection of change limit of 10.7% above and below the mean. These results make sense in that summed cover includes taxa overlap, and that the variability around the easier task of making one guess at cover in a 1 m x 1 m quadrat is less than doing the same for each taxon and then summing.

Similar calculations suggest species richness per quadrat should vary between 10.7 and 12.9 (95% confidence intervals), suggesting a 9.5% minimum of change detection value (Table 61).

Estimates of live *Typha* stem density ranged between a low of 76 (both transects at time two) to a high of 80 (at time one) (Table 62), and dead stem density between 52 and 65, suggesting that counting dead stems is more error prone. Confidence intervals (95%) surrounding the overall live stem estimates suggest that the minimal detection limits of stem density over time is 4.5% or about 3-4 stems total over 20 quadrats.

Comparisons of frequency: Twenty-six taxa were sampled over the 20 quadrats during four time periods (Table 63). Some taxa were ubiquitous, or nearly so, and found consistently in every quadrat at each sampling (e.g. *Typha latifolia*, *Potentilla palustris*, *Carex lacustris*, and *Calamagrostis canadensis*). Some were moderately frequent, yet consistently found (e.g. *Calla palustris*, found in 10 quadrats each time), while some are more difficult to spot because they are small and occur in small amounts (such as *Galium* spp.) or sometimes are masked by other taxa (vegetatively *Acorus calamus* and *Typha* can look alike at a glance). Some taxa, such as *Salix* spp., are not missed, but infrequent.

Another means to gauge consistency was to determine, of the twenty quadrats that were repeatedly sampled, the number of times that individual taxa were found only once, two times, three times, or all four times (Table 64). With this information we calculated a percent detection accuracy by assuming that: 1) if a taxon was not seen in a quadrat in any four visits it was not present, and 2) if it was seen at least once then it was present. We make these assumptions because the experienced observer was not likely to mis-identify taxa—if a taxon was only found once it was assumed to have been over-looked the other three times; if it was found twice, it was assumed to have been missed the other two times, etc. Our percent accuracy was calculated by the formula (80 - total the number of misses)/80 x 100. For example whenever *Calla* occurred in a quadrat, it was easily spotted, found in 10 quadrats, and recognized each time, hence no misses, and this results in an estimated accuracy of 100%. Other taxa were observed consistently about half the time, e.g. *Polygonum amphibium* was found in 13 of the 20 quadrats (with an estimated accuracy of 83.8%), and *Triadenum* in 12 quadrats, consistently found in seven of them, resulting in an estimated accuracy of 90%. Other taxa were harder to spot, and *Galium*

Table 61. Comparison of cover and richness assessments over four sampling times on twenty repeatledly sampled peatland quadrats by the same observer over a six day time period in July 2006. One cover metric is a single estimate of all vegetative cover per quadrat (one estimate cover), and the other is the sum of all individual taxa cover values per quadrat (cover summed). Confidence intervals (CI) are set at 95%.

		Total cover (one estimate)	Quadrat Cover (summed)	Quadrat Richness		One estimate cover	Summed cover	Quadrat richness
Time 1	sum	1340	1509.2	223	Time	Means	Means	Means
	Mean	67.00	75.46	11.15	1	67.0	75.5	11.2
	St. dev.	5.94	13.06	1.57	2	71.3	74.9	11.4
	CI lower	64.23	69.37	10.42	3	71.5	85.8	12.7
	CI upper	69.77	81.55	11.88	4	70.3	75.7	12.1
Time 2	sum	1425	1497.9	227	Grand means	70.0	78.0	11.8
	Mean	71.25	74.90	11.35	St. dev.	2.1	5.3	0.7
	St. dev.	6.46	11.36	1.60	CI lower	66.7	69.6	10.7
	CI lower	68.24	69.60	10.60	CI upper	73.3	86.3	12.9
	CI upper	74.26	80.19	12.10	Minumum			
					Minimal % change detectable	4.7	10.7	9.5
Time 3	sum	1430	1716.9	254				
	Mean	71.50	85.85	12.70				
	St. dev.	4.62	14.67	1.56				
	CI lower	69.35	79.00	11.97				
	CI upper	73.65	92.69	13.43				
Time 4	sum	1405	1514.1	241				
	Mean	70.25	75.71	12.05				
	St. dev.	5.50	9.68	1.76				
	CI lower	67.69	71.19	11.23				
	CI upper	72.81	80.22	12.87				

Table 62. Comparisons of total Typha stem counts (live and dead from previous year) by a single observer on repeatedly sampled peatland transects over a six day period, July 2006 (N = 20, 1 m x1 m quadrats per time period, 10 quadrats per transect). Confidence intervals (CI) are set at 95%.

Time	**Total Typha stems live**	**Total Typha stems dead**
1	80	65
2	76	55
3	78	53
4	81	52
Mean	78.75	56.25
St. Dev.	2.22	5.97
CI lower	75.22	46.76
CI upper	82.28	65.74
Estimated minimal detection % (% above/below mean)	4.48	16.87

Table 63. Comparisons of frequency of occurrence for all individual taxa as sampled by one observer on repeatedly sampled peatland quadrats over a six day period, July 2006 (N = 20, 1 m x 1 m quadrats for each each time period).

		Time			
		1	**2**	**3**	**4**
Genus	**species**	**Freq.**	**Freq.**	**Freq.**	**Freq.**
Acorus	*calamus*	2	3	6	6
Alnus	*incana*	1	0	1	1
Calamagrostis	*canadensis*	18	20	20	20
Calla	*palustris*	10	10	10	10
Campanula	*aparinoides*	15	12	18	14
Carex	*lacustris*	20	20	20	20
Carex	*utriculata*	18	19	20	20
Carex	*diandra*	9	11	11	13
Epilobium	*leptophyllum*	3	3	3	4
Equisetum	*fluviatile*	1	1	1	2
Galium	*trifidum*	6	3	9	7
Lysimachia	*thyrsiflora*	17	14	16	17
moss	spp.	16	17	17	14
Polygonum	*amphibium*	9	9	9	12
Polygonum	*punctatum*	0	1	1	0
Potentilla	*palustris*	20	20	20	20
Rumex	*orbiculata*	2	1	1	1
Salix	spp.	1	1	1	1
Scirpus	*cyperinus*	1	5	5	1
Scutellaria	*galericulata*	6	6	9	7
Sphagnum	spp.	15	15	19	17
Spirea	*alba*	1	1	1	2
Triadenum	*fraseri*	10	10	11	9
Typha	*latifolia*	20	20	20	20
Utricularia	*intermedia*	0	1	2	0
Viola	sp.	2	4	3	3
Total Frequency		223	227	254	237

Table 64. Frequency of occurrence and consistancy of observations of all peatland taxa in 20 quadrats each sampled four separate times (80 quadrats total). All twenty quadrats were sampled by the same observer each time.

			Of the twenty quadrats repeatedly sampled, number of quadrats when taxa on list was found (once, twice, etc.):						
Genus	**species**	**Frequency per 80 quadrats**	**1**	**2**	**3**	**4**	**0**	**# quadrats seen at least once**	**Estimated % accuracy***
Acorus	*calamus*	17	3	5		1	11	9	76.3
Alnus	*incana*	3			1		19	1	98.8
Calamagrostis	*canadensis*	78			2	18	0	20	97.5
Calla	*palustris*	40				10	10	10	100.0
Campanula	*aparinoides*	59	1	4	6	8	1	19	78.8
Carex	*diandra*	44	5	2	5	5	3	17	70.0
Carex	*lacustris*	80				20	0	20	100.0
Carex	*utriculata*	77		1	1	18	0	20	96.3
Epilobium	*leptophyllum*	13	1	3	3		13	7	85.0
Equisetum	*fluviatile*	5		1	1		18	2	96.3
Galium	*trifidum*	25	4	5	1	2	8	12	71.3
Lysimachia	*thyrsiflora*	64	1	3	7	9	0	20	80.0
moss	spp.	64	2		6	11	1	19	85.0
Polygonum	*amphibium*	39	2	3	1	7	7	13	83.8
Polygonum	*punctatum*	2		1			19	1	97.5
Potentilla	*palustris*	80				20	0	20	100.0
Rumex	*orbiculata*	5	1		1		18	2	95.0
Salix	spp.	4				1	19	1	100.0
Scirpus	*cyperinus*	12	4	2		1	13	7	80.0
Scutellaria	*galericulata*	28	1	1	3	4	11	9	90.0
Sphagnum	spp.	66		5	4	11	0	20	82.5
Spirea	*alba*	5	1			1	18	2	96.3
Triadenum	*fraseri*	40	1	1	3	7	8	12	90.0
Typha	*latifolia*	80				20	0	20	100.0
Utricularia	*intermedia*	3	1	1			18	2	93.8
Viola	sp.	12		1	1	2	16	4	96.3
								mean	90.0

* estimated by assuming that four sampling times without noticing a taxon indicates it is not present in the quadrat, and if it was seen at least once it was present in the quadrat (# times seen/ # times possibly seen x 100)

(small stature) and *Carex* (a fine leaf sedge) had the lowest estimated accuracy (71.3 and 70% respectively).

Estimates of Cover by Taxa: Cover was estimated each time period over the 20 quadrats, and estimates of the mean per quadrat cover was calculated for all 26 taxa for each of the four sampling times (Table 65). Only five taxa had raw cover values consistently (each time) greater

Table 65. Estimated minimal detection limits on raw percent cover for all taxa as sampled by one observer on repeatedly sampled peatland quadrats over a six day period, July 2006 (N = 20, 1 m x 1 m quadrats for each each time period). Taxa sorted by overall percent cover, and confidence intervals are set at 95%.

	Genus	species	Time 1	Time 2	Time 3	Time 4	Grand mean	St. dev.	CI lower	CI upper	% Estimated minimal detection
1	*Carex*	*lacustris*	23.55	20.30	22.20	20.30	21.59	1.6	19.1	24.1	11.7
2	*Carex*	*utriculata*	8.80	11.05	15.85	13.40	12.28	3.0	7.4	17.1	39.3
3	*Typha*	*latifolia*	12.50	11.90	12.95	10.15	11.88	1.2	9.9	13.8	16.4
4	*Potentilla*	*palustris*	8.45	9.75	9.40	9.40	9.25	0.6	8.4	10.1	9.6
5	*Calamagrostis*	*canadensis*	6.75	7.25	6.85	8.60	7.36	0.9	6.0	8.7	18.4
6	*Sphagnum*	sp	2.67	1.77	2.84	2.43	2.43	0.5	1.7	3.2	30.8
7	moss	spp.	2.36	2.16	2.80	1.81	2.28	0.4	1.6	2.9	29.0
8	*Calla*	*palustris*	2.45	1.95	2.15	2.30	2.21	0.2	1.9	2.6	15.4
9	*Lysimachia*	*thrsifolia*	1.51	1.45	1.50	1.41	1.47	0.0	1.4	1.5	5.1
10	*Triadenum*	*fraseri*	1.15	1.10	1.50	0.76	1.13	0.3	0.6	1.6	43.1
11	*Polygonum*	*amphibium*	1.20	1.00	1.20	1.10	1.13	0.1	1.0	1.3	13.5
12	*Carex*	*diandra*	0.80	1.15	1.00	0.57	0.88	0.3	0.5	1.3	45.5
13	*Salix*	spp.	0.40	1.00	1.00	1.10	0.88	0.3	0.4	1.4	58.2
14	*Campanula*	*aparinoides*	0.87	0.71	1.15	0.44	0.79	0.3	0.3	1.3	59.7
15	*Spirea*	*alba*	0.40	0.50	0.60	0.55	0.51	0.1	0.4	0.6	26.5
16	*Scirpus*	*cyperinus*	0.15	0.60	0.65	0.10	0.38	0.3	-0.1	0.8	123.1
17	*Scutellaria*	*galericulata*	0.40	0.30	0.46	0.21	0.34	0.1	0.2	0.5	50.6
18	*Acorus*	*calamus*	0.25	0.25	0.45	0.40	0.34	0.1	0.2	0.5	48.6
19	*Galium*	*trifidum*	0.35	0.15	0.45	0.21	0.29	0.1	0.1	0.5	75.3
20	*Viola*	sp.	0.06	0.21	0.25	0.25	0.19	0.1	0.0	0.3	77.4
21	*Epilobium*	*leptophyllum*	0.16	0.20	0.20	0.11	0.17	0.0	0.1	0.2	41.2
22	*Rumex*	*orbiculata*	0.10	0.05	0.05	0.05	0.06	0.0	0.0	0.1	63.6
23	*Alnus*	*incana*	0.10		0.05	0.05	0.07	0.0	0.0	0.1	68.9
24	*Equisetum*	*fluviatile*	0.05	0.05	0.05	0.01	0.04	0.0	0.0	0.1	79.5
25	*Utricularia*	*intermedia*		0.01	0.15		0.08	0.1	-0.1	0.2	210.5
26	*Polygonum*	*punctatum*		0.05	0.10		0.08	0.0	0.0	0.1	75.0

than 5%, including *Carex lacustris*, *C. utriculata*, *Typha latifolia*, *Potentilla palustris*, and *Calamagrostis canadensis*, and in general, variance (as reported as standard deviation from the mean) increased with increasing cover.

We also looked at the variance surrounding the grand means, and this offers estimates of “estimated minimal detection percent” for each taxa (Table 65) and allows a comparison of the variance associated with the cover, relative cover, and relative importance value metrics.

We estimated the minimal detection of change percent as follows: given these ideal conditions of a single observer and repeated sampling of the exact same quadrats, we asked what was the smallest amount of error possible in estimating cover from one time to the next, over a time period where we assume there has been no change. As we developed monitoring recommendations, these considerations offered guidelines on how much change will need to be observed to be considered significant.

For *Carex lacustris* the grand mean of raw cover (the mean of all four times) was 21.6% with 95% confidence intervals ranging from 19.1 to 24.1% (Table 65), and hence the minimal detection percent is calculated to be 11.7% (the percent the confidence interval surrounds the mean). This suggests that observing a difference in cover greater than this from one time to the next may suggest real change. These estimated minimal detection of change percents vary with taxa and their distributional patterns from greater than 50% for many lesser taxa to as low a 9.6% for *Potentilla palustris*. In general we can assume that low abundance taxa will have to as much as double in cover from one sampling time to the next before real change can be inferred.

Estimates of Relative Cover and Importance Value (IV) by Taxa: Similar calculations designed to estimate minimal detection were undertaken for relative cover (Table 66) and relative importance value (Table 66). In general IV detection limits are lower than those of cover, especially for the mid tier taxa (with mean cover of about 1-2%). For example by using cover, variance estimates suggest the minimum detection percent for *Triadenum* and *Carex diandra* to be 43.1 and 45.5% (Table 65), while using relative cover (Table 66) results in slightly lower estemates at 35.0% and 45.5%, and by using IV (Table 67), estimates are lower yet at 16.8% and 16.7%. We are reminded that IV also reflects frequency of occurrence (simple presence and absence) in addition to cover and hence is a less subjective measure.

2.0 m Aquatic Intra-observer Bias

Overall Means: Confidence intervals surrounding both cover means at the four times suggest there were no differences among the times (Table 68). For example the mean values for the field estimated cover varied from 68.5% at time one to 70.5% at time four. The overall estimated cover mean was 69.8 (all times), and confidence intervals bracketing these four means fell between 68.4 and 71.1, suggesting the smallest amount of cover change that can be detected is 2.0% , though it is likely higher in that these are ideal conditions (same observer, short time period between sampling). The variance associated with summed cover was greater than the one estimate of cover, with minimal detection limits of 7.6% above and below the mean.

Similar calculations suggest species richness per quadrat should vary between 6.1 and 7.2 (95% confidence intervals), suggesting an 8.06% minimum detection value (Table 68).

Comparisons of frequency: Eighteen taxa were sampled over the 20 quadrats during four time periods (Table 69). Some taxa occurred very frequently (e.g. *Ceratophyllum demersum*, *Lemna trisulca,* and *Vallisneria americana*), and some were moderately frequent yet consistently found (e.g. *Elodea canadensis*, found between 10 to 12 quadrats each time). Conversely, some taxa are apparently more difficult to spot because they are small and occur in small amounts (such as *Najas flexilis* and *Chara* spp.), with frequencies ranging from 1 to 5 and 2 to 6 respectively. Some taxa, such as *Sagittaria*, are not missed but infrequent.

Table 66. Estimated minimal detection limits of relative cover values for all individual taxa as sampled by one observer on repeatedly sampled peatland quadrats over a six day period, July 2006 (N = 20, 1 m x 1 m quadrats for each each time period). Values are relativized over the 20 quadrats each time period and sorted by total percent cover. Confidence intervals are set at 95%.

Genus	**species**	1	2	3	4	**Mean**	**St. dev.**	**CI lower**	**CI upper**	**% Estimated minimal detection**
Carex	*lacustris*	31.2	27.1	25.9	26.8	27.7	2.4	24.0	31.5	13.6
Carex	*utriculata*	11.7	14.8	18.5	17.7	15.6	3.1	10.7	20.6	31.5
Typha	*latifolia*	16.6	15.9	15.1	13.4	15.2	1.4	13.1	17.4	14.2
Potentilla	*palustris*	11.2	13.0	10.9	12.4	11.9	1.0	10.3	13.5	13.2
Calamagrostis	*canadensis*	8.9	9.7	8.0	11.4	9.5	1.4	7.2	11.8	23.9
Sphagnum	spp.	3.5	2.4	3.3	3.2	3.1	0.5	2.3	3.9	26.3
moss	spp.	3.1	2.9	3.3	2.4	2.9	0.4	2.3	3.5	21.1
Calla	*palustris*	3.2	2.6	2.5	3.0	2.8	0.4	2.3	3.4	19.7
Lysimachia	*thyrsiflora*	2.0	1.9	1.7	1.9	1.9	0.1	1.7	2.1	9.0
Triadenum	*fraseri*	1.5	1.5	1.7	1.0	1.4	0.3	0.9	1.9	35.0
Polygonum	*amphibium*	1.6	1.3	1.4	1.5	1.4	0.1	1.3	1.6	12.0
Carex	*diandra*	1.1	1.5	1.2	0.8	1.1	0.3	0.6	1.6	45.5
Salix	spp.	0.5	1.3	1.2	1.5	1.1	0.4	0.5	1.8	58.4
Campanula	*aparinoides*	1.1	0.9	1.3	0.6	1.0	0.3	0.5	1.5	51.3
Spirea	*alba*	0.5	0.7	0.7	0.7	0.7	0.1	0.5	0.8	21.2
Scirpus	*cyperinus*	0.2	0.8	0.8	0.1	0.5	0.4	-0.1	1.0	119.9
Scutellaria	*galericulata*	0.5	0.4	0.5	0.3	0.4	0.1	0.2	0.6	44.4
Acorus	*calamus*	0.3	0.3	0.5	0.5	0.4	0.1	0.3	0.6	41.5
Galium	*trifidum*	0.5	0.2	0.5	0.3	0.4	0.2	0.1	0.6	67.1
Viola	sp.	0.1	0.3	0.3	0.3	0.2	0.1	0.1	0.4	75.7
Epilobium	*leptophyllum*	0.2	0.3	0.2	0.1	0.2	0.1	0.1	0.3	38.5
Rumex	*orbiculata*	0.1	0.1	0.1	0.1	0.1	0.0	0.0	0.1	68.1
Alnus	*incana*	0.1	0.0	0.1	0.1	0.1	0.1	0.0	0.2	134.4
Equisetum	*fluviatile*	0.1	0.1	0.1	0.0	0.1	0.0	0.0	0.1	79.6
Utricularia	*intermedia*	0.0	0.0	0.2	0.0	0.0	0.1	-0.1	0.2	302.8
Polygonum	*punctatum*	0.0	0.1	0.1	0.0	0.0	0.1	0.0	0.1	196.8

Table 67. Estimated minimal detection limits of relative importance values (IV) for all individual taxa as sampled by one observer on repeatedly sampled peatland quadrats over a six day period, July 2006 (N = 20, 1 m x 1 m quadrats for each each time period). Values are relativized over the 20 quadrats each time period and sorted by total percent cover. Confidence intervals are set at 95%.

		Time								
		1	**2**	**3**	**4**	**Mean**	**St. dev.**			**% Estimated minimal detection**
Genus	**species**	**Rel. IV.**	**Rel. IV.**	**Rel. IV.**	**Rel. IV.**	**Rel. IV.**	**Rel. IV.**	**CI lower**	**CI upper**	
Carex	*lacustris*	20.1	18.0	16.9	17.6	18.1	1.4	15.9	20.3	12.1
Carex	*utriculata*	9.9	11.6	13.2	13.1	11.9	1.6	9.4	14.4	20.7
Typha	*latifolia*	12.8	12.3	11.5	10.9	11.9	0.8	10.6	13.2	11.2
Potentilla	*palustris*	10.1	10.9	9.4	10.4	10.2	0.6	9.2	11.2	9.8
Calamagrostis	*canadensis*	8.5	9.2	7.9	9.9	8.9	0.9	7.5	10.3	15.4
Sphagnum	spp.	5.1	4.5	5.4	5.2	5.1	0.4	4.4	5.7	12.4
moss	spp.	5.2	5.2	5.0	4.1	4.9	0.5	4.1	5.6	15.9
Calla	*palustris*	3.9	3.5	3.2	3.6	3.6	0.3	3.1	4.0	12.0
Lysimachia	*thyrsiflora*	4.8	4.1	4.0	4.5	4.3	0.4	3.7	5.0	13.9
Triadenum	*fraseri*	3.0	2.9	3.0	2.4	2.8	0.3	2.4	3.3	16.8
Polygonum	*amphibium*	2.8	2.6	2.5	3.0	2.7	0.2	2.4	3.1	14.2
Carex	*diandra*	2.5	3.2	2.7	3.1	2.9	0.3	2.4	3.4	16.7
Salix	spp.	0.5	0.9	0.8	0.9	0.8	0.2	0.5	1.1	41.3
Campanula	*aparinoides*	3.9	3.1	4.2	3.2	3.6	0.5	2.8	4.5	23.3
Spirea	*alba*	0.5	0.6	0.5	0.8	0.6	0.1	0.4	0.8	35.1
Scirpus	*cyperinus*	0.3	1.5	1.4	0.3	0.9	0.7	-0.2	1.9	120.5
Scutellaria	*galericulata*	1.6	1.5	2.0	1.4	1.6	0.3	1.2	2.1	26.7
Acorus	*calamus*	0.6	0.8	1.4	1.5	1.1	0.5	0.4	1.8	65.2
Galium	*trifidum*	1.6	0.8	2.0	1.2	1.4	0.5	0.5	2.3	62.1
Viola	sp.	0.5	1.0	0.7	0.8	0.8	0.2	0.4	1.1	45.9
Epilobium	*leptophyllum*	0.8	0.8	0.7	0.9	0.8	0.1	0.7	0.9	17.4
Rumex	*orbiculata*	0.5	0.3	0.2	0.2	0.3	0.1	0.1	0.5	70.5
Alnus	*incana*	0.3	0.0	0.2	0.2	0.2	0.1	0.0	0.4	108.5
Equisetum	*fluviatile*	0.3	0.3	0.2	0.4	0.3	0.1	0.1	0.4	50.5
Utricularia	*intermedia*	0.0	0.2	0.5	0.0	0.2	0.2	-0.2	0.5	206.8
Polygonum	*punctatum*	0.0	0.3	0.3	0.0	0.1	0.1	-0.1	0.4	183.7

Table 68. Comparison of cover and richness assessments over four sampling times on twenty repeatledly sampled aquatic 2.0 m quadrats by the same observer over a six day time period in July 2006. One cover metric is a single estimate of all vegetative cover per quadrat (one estimate), and the other is the sum of all individual taxa cover values per quadrat (cover summed). Confidence intervals (CI) are set at 95%.

Times		Total cover (one estimate)	Quadrat Cover (summed)	Quadrat Richness		One estimate cover	Summed cover	Quadrat richness
1	Mean	68.50	70.62	6.30				
	St. deviation	18.72	25.88	1.72	Time	Means	Means	Means
	Standard error	4.18	5.79	0.38	1	68.50	70.62	6.30
	Lowest value	25.00	25.00	3.00	2	70.00	71.12	6.35
	Highest value	100.00	111.30	10.00	3	70.00	78.01	6.95
	Upper Limit CI	77.26	82.73	7.10	4	70.50	71.66	6.85
	Lower Limit CI	59.74	58.50	5.50				
2	Mean	70.00	71.12	6.35	Grand means	69.75	72.85	6.61
	St. deviation	19.53	26.22	2.13	St .dev.	0.87	3.46	0.34
	Standard error	4.37	5.86	0.48	CI Lower	68.37	67.34	6.08
	Lowest value	35.00	28.10	2.00	CI Upper	71.13	78.36	7.15
	Highest value	100.00	113.10	12.00	Minimum % change detectable	1.98	7.56	8.06
	Upper Limit CI	79.14	83.39	7.35				
	Lower Limit CI	60.86	58.85	5.35				
3	Mean	70.00	78.01	6.95				
	St. deviation	18.42	44.21	1.99				
	Standard error	4.12	9.89	0.44				
	Lowest value	35.00	26.00	2.00				
	Highest value	100.00	168.30	11.00				
	Upper Limit CI	78.62	98.70	7.88				
	Lower Limit CI	61.38	57.31	6.02				
4	Mean	70.50	71.66	6.85				
	St. deviation	17.98	24.07	2.11				
	Standard error	4.02	5.38	0.47				
	Lowest value	40.00	35.10	2.00				
	Highest value	100.00	117.20	12.00				
	Upper Limit CI	78.92	82.92	7.84				

Table 69. Comparisons of frequency of occurrence for all individual taxa as sampled by one observer on repeatedly sampled 2.0 m aquatic quadrats over a six day period, July 2004 (N = 20, 1 m x 1 m quadrats for each each time period).

		Time 1	**Time 2**	**Time 3**	**Time 4**	**Totals all times**
Genus	**species**	**Frequency of 20 Quadrats**				
Bidens	*beckii*	17	14	16	15	62
Ceratophyllum	*demersum*	18	17	19	18	72
Chara	sp.	2	4	6	6	18
Elodea	*canadensis*	12	10	12	12	46
Lemna	*trisulca*	19	19	19	19	76
Myriophyllum	spp.	12	17	18	15	62
Najas	*flexilis*	1	4	5	5	15
Nitella	spp.	1	1	0	1	3
Nymphaea	*odorata*	2	2	1	2	7
Potamogeton	*foliosus*	11	10	12	15	48
Potamogeton	*richardsonii*	0	0	1	1	2
Potamogeton	*spirillus*	5	5	3	4	17
Potamogeton	*vaseyi*	2	1	2	1	6
Potamogeton	*zosteriformis*	1	1	2	1	5
Ranunculus	*longirostris*	1	1	1	1	4
Sagittaria	*rosette*	2	2	2	2	8
Utricularia	*vulgaris*	0	0	1	0	1
Vallisneria	*americana*	20	19	19	19	77
totals all taxa		126	127	139	137	529

Percent detection accuracy was again calculated by the formula (80 - total the number of misses)/80 x 100 (see peatland section above for a more complete explanation), and it varied from a low of 77.5% for *Chara* spp. to 100% (Table 70). The mean percent detection accuracy was 91.2% similar to that of the repeated peatland observations.

Estimates of Cover by Taxa: Cover was estimated each time period over the 20 quadrats, and estimates of the mean per quadrat cover was calculated for all 18 taxa for each of the four sampling times (Table 71). Five taxa had raw cover values consistently (each time) greater than 5%, including *Vallisneria americana, Sagittaria* (rosette form), *Lemna trisulca*, *Ceratophyllum demersum*, and *Bidens beckii.* As with the peatland taxa, variance (reported as standard deviation from the mean) increased with increasing cover.

We again looked at the variance surrounding the grand means, offering estimates of "estimated minimal detection percent" for all taxa (Table 72) and comparisons of the variance associated with cover and relative importance values.

Vallisneria americana had the greatest percent cover, with a grand mean of 31.4%, a confidence interval ranging from 25.6 to 37.3% (Table 72), and a minimal detection of change at 18.7% (the percent the confidence interval surrounds the mean). This suggests that observing a difference in cover greater than this from one time to the next may suggest real change. As with the peatland

Table 70. Frequency of occurrence and consistency of observations of all taxa recorded in twenty, 2.0 m aquatic quadrats each sampled four separate times (80 quadrats total). All twenty quadrats were sampled by the same observer each time.

Genus	species	Frequency per 80 quadrats	Of the twenty quadrats repeatedly sampled, number of quadrats when taxa on list was found (once, twice, etc.):						Estimated % accuracy*
			1	2	3	4	0	# quadrats seen at least once	
Bidens	*beckii*	62	2	3	2	12	1	19	82.5
Ceratophyllum	*demersum*	72			4	15	1	19	95.0
Chara	sp.	18	3	4	1	1	11	9	77.5
Elodea	*canadensis*	46	2	3	2	8	5	15	82.5
Lemna	*trisulca*	76				19	1	19	100.0
Myriophyllum	spp.	62	2	1	6	10	1	19	82.5
Najas	*flexilis*	15	1	1	4		14	6	88.8
Nitella	spp.	3			1		19	1	98.8
Nymphaea	*odorata*	7			1	1	18	2	98.8
Potamogeton	*foliosus*	48	3	2	3	8	4	16	80.0
Potamogeton	*richardsonii*	2	2				18	2	92.5
Potamogeton	*spirillus*	17	3	2	2	1	12	8	81.3
Potamogeton	*vaseyi*	6	3		1		16	4	87.5
Potamogeton	*zosteriformis*	7			1	1	18	2	98.8
Ranunculus	*longirostris*	4				1	19	1	100.0
Sagittaria	*rosette*	8				2	18	2	100.0
Utricularia	*vulgaris*	1	1				19	1	96.3
Vallisneria	*americana*	79			1	19	0	20	98.8
								Mean	91.2

* estimated by assuming that four sampling times without noticing a taxon indicates it is not present in the quadrat, and if it was seen at least once it was present in the quadrat (# times seen/ # times possibly seen x 100

Table 71. Comparisons of percent cover and estimations of variance for all taxa as sampled by a single observer on repeatedly sampled 2.0 m aquatic quadrats over a six day period, July 2004 (N = 20, 1 m x 1 m quadrats at each time period). Confidence intervals (CI) are set at 95%.

Genus	**species**	**Time 1**	**Time 2**	**Time 3**	**Time 4**	**Time 1**	**Time 2**	**Time 3**	**Time 4**	**Time 1**	**Time 2**	**Time 3**	**Time 4**	**Time 1**	**Time 2**	**Time 3**	**Time 4**
		Mean Percent Cover				**Standard error**				**CI Upper limits**				**CI lower limits**			
Bidens	*beckii*	10.9	12.0	11.8	9.9	4.4	5.3	5.1	4.4	20.1	23.0	22.4	19.0	1.7	0.9	1.1	0.7
Ceratophyllum	*demersum*	8.6	8.5	7.6	7.4	3.5	2.6	2.4	3.0	15.8	13.9	12.7	13.6	1.3	3.1	2.5	1.1
Chara	sp.	0.7	0.4	0.3	0.1	1.1	0.5	0.3	0.1	3.0	1.4	0.8	0.3	-1.7	-0.7	-0.3	-0.1
Elodea	*canadensis*	1.3	1.8	2.1	1.3	0.9	1.2	1.9	0.5	3.3	4.3	6.1	2.4	-0.7	-0.6	-2.0	0.2
Lemna	*trisulca*	8.1	5.4	5.5	8.2	1.8	1.6	1.5	1.8	11.8	8.8	8.6	11.9	4.4	2.0	2.4	4.4
Myriophyllum	spp.	2.9	2.7	2.8	1.9	0.6	0.8	0.7	0.7	4.2	4.4	4.2	3.3	1.6	1.0	1.4	0.5
Najas	*flexilis*	0.1		0.1	0.1			0.1	0.1			0.3	0.3			-0.1	-0.1
Nitella	spp.		0.1				0.0				0.1				0.1		
Nymphaea	*odorata*	0.1	0.1			0.1	0.1			0.4	0.4			-0.2	-0.3		
Potamogeton	*foliosus*	2.5	2.7	3.2	2.7	1.9	2.8	3.2	2.0	6.5	8.5	10.0	7.0	-1.6	-3.2	-3.6	-1.5
Potamogeton	*richardsonii*			0.0	0.0			0.0	0.0			0.0	0.0			0.0	0.0
Potamogeton	*spirillus*	0.0	0.1	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.3	0.0	0.0	0.0	-0.1	0.0	0.0
Potamogeton	*vaseyi*	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.1	0.0	0.0
Potamogeton	*zosteriformis*	2.0	1.8	2.4	1.3		0.0	6.8	0.0		1.8	16.7	1.3		1.8	-11.9	1.3
Ranunculus	*longirostris*	0.1	0.0	0.0	0.0		0.0	0.0	0.0		0.0	0.0	0.0		0.0	0.0	0.0
Sagittaria	*rosette*	5.3	6.5	5.8	7.0	8.7	4.9	5.7	4.9	23.5	16.7	17.6	17.2	-13.0	-3.7	-6.1	-3.2
Utricularia	*vulgaris*			0.1				0.0				0.1				0.1	
Vallisneria	*americana*	28.2	29.3	36.5	31.9	6.8	7.4	8.3	7.8	42.5	44.7	53.8	48.1	13.8	13.8	19.1	15.7

Table 72. Estimated minimal detection limits on raw percent cover for all taxa as sampled by one observer on repeatedly sampled 2.0 m aquatic quadrats over a six day period, July 2006 (N = 20, 1 m x 1 m quadrats for each each time period). Taxa sorted by overall percent cover. Confidence intervals (CI) are set at 95%.

Genus	species	Time 1	Time 2	Time 3	Time 4	Grand mean	St. dev.	CI lower	CI upper	% Estimated minimal detection
		Mean Percent Cover								
Bidens	*beckii*	10.92	11.95	11.76	9.85	11.12	0.96	9.60	12.64	13.70
Ceratophyllum	*demersum*	8.55	8.50	7.60	7.36	8.00	0.61	7.03	8.98	12.16
Chara	sp.	0.65	0.36	0.27	0.12	0.35	0.22	-0.01	0.70	102.42
Elodea	*canadensis*	1.33	1.82	2.08	1.31	1.63	0.38	1.03	2.24	36.83
Lemna	*trisulca*	8.11	5.37	5.52	8.16	6.79	1.56	4.31	9.26	36.48
Myriophyllum	spp.	2.90	2.72	2.82	1.87	2.58	0.48	1.81	3.34	29.60
Najas	*flexilis*	0.10	0.00	0.07	0.07	0.06	0.04	-0.01	0.13	112.50
Nitella	spp.	0.00	0.05	0.00	0.00	0.01	0.03	-0.03	0.05	318.20
Nymphaea	*odorata*	0.06	0.06	0.00	0.00	0.03	0.03	-0.02	0.08	183.71
Potamogeton	*foliosus*	2.46	2.67	3.21	2.73	2.76	0.32	2.26	3.27	18.38
Potamogeton	*richardsonii*	0.00	0.00	0.01	0.01	0.00	0.00	0.00	0.01	183.71
Potamogeton	*spirillus*	0.03	0.07	0.02	0.02	0.03	0.03	-0.01	0.07	124.01
Potamogeton	*vaseyi*	0.01	0.05	0.01	0.01	0.02	0.02	-0.01	0.05	177.91
Potamogeton	*zosteriformis*	2.00	1.75	2.40	1.25	1.85	0.48	1.08	2.62	41.39
Ranunculus	*longirostris*	0.10	0.01	0.01	0.01	0.03	0.05	-0.05	0.10	262.86
Sagittaria	*rosette*	5.25	6.50	5.75	7.00	6.13	0.78	4.89	7.36	20.19
Utricularia	*vulgaris*	0.00	0.00	0.05	0.00	0.01	0.03	-0.03	0.05	318.20
Vallisneria	americana	28.16	29.25	36.45	31.90	31.44	3.69	25.56	37.31	18.69

taxa, the estimated minimal detection percents vary with taxa and their distributional patterns from greater than 100% for many lesser taxa, to as low as 12.1 % for *Ceratophyllum demersum*. In general we can assume that low abundance taxa will have to as much as double (100%) in cover from one sampling time to the next before real change can be inferred, while the top five most abundant taxa by cover have minimal detection rates that vary from 12.2% (*Ceratophyllum*) to 36.5% (*Lemna*).

Estimates of Relative Importance Value (IV) by Taxa: Similar calculations designed to estimate minimal detection were undertaken for relative importance value (Table 73). Detection limits are greater for cover compared to IV, especially for the top five most abundant taxa (e.g. *Vallisneria americana* 18.7% for cover vs. 6.0% for IV, *Sagittaria* 20.2% vs. 19.2%, *Lemna trisulca* 36.5% vs. 17.6%, *Ceratophyllum demersum* 12.2% vs. 9.6%, and *Bidens beckii* with 13.7% for cover vs. 10.8% for IV. Again, as with the peatland taxa, relative importance value that reflects both frequency of occurrence and cover may be a better metric to follow, as it is associated with lower variance in most cases.

Table 73. Estimated minimal detection limits of relative importance values (IV) for all individual taxa as sampled by one observer on repeated visits to 2.0 m aquatic quadrats over a six day period, July 2006. (N = 20, 1 m x 1 m quadrats for each each time period). Importance values are relativized over the 20 quadrats each time period, and confidence intervals (CI) are set at 95%.

Genus	species	Time 1	Time 2	Time 3	Time 4	Mean Rel. IV	Standard deviation	CI upper limit	CI lower limit	% Estimated minimal detection
		Importance Values								
Bidens	*beckii*	14.48	13.91	13.29	12.35	13.51	0.91	14.96	12.06	10.75
Ceratophyllum	*demersum*	13.20	12.67	11.71	11.71	12.32	0.74	13.50	11.14	9.56
Chara	sp.	1.25	1.82	2.33	2.27	1.92	0.50	2.71	1.13	41.28
Elodea	*canadensis*	5.70	5.21	5.65	5.29	5.47	0.25	5.86	5.07	7.21
Lemna	*trisulca*	13.28	11.25	10.37	12.62	11.88	1.32	13.98	9.79	17.62
Myriophyllum	spp.	6.82	8.61	8.28	6.78	7.62	0.96	9.15	6.09	20.05
Najas	*flexilis*	0.47	1.59	1.84	1.87	1.44	0.66	2.50	0.39	73.07
Nitella	spp.	0.40	0.43	0.00	0.37	0.30	0.20	0.62	-0.02	106.87
Nymphaea	*odorata*	0.83	0.83	0.36	0.74	0.69	0.22	1.04	0.34	51.25
Potamogeton	*foliosus*	6.10	5.81	6.37	7.38	6.42	0.68	7.50	5.33	16.86
Potamogeton	*richardsonii*	0.00	0.00	0.36	0.37	0.18	0.21	0.52	-0.15	183.72
Potamogeton	*spirillus*	2.00	2.02	1.09	1.47	1.65	0.45	2.36	0.93	43.42
Potamogeton	*vaseyi*	0.80	0.43	0.73	0.37	0.58	0.21	0.92	0.24	58.65
Potamogeton	*zosteriformis*	1.81	1.62	2.26	1.24	1.73	0.42	2.41	1.06	38.93
Ranunculus	*longirostris*	0.47	0.40	0.36	0.37	0.40	0.05	0.48	0.32	19.19
Sagittaria	*rosette*	4.51	5.36	4.41	5.61	4.97	0.60	5.93	4.01	19.33
Utricularia	*vulgaris*	0.00	0.00	0.39	0.00	0.10	0.20	0.41	-0.21	318.20
Vallisneria	*americana*	27.87	28.04	30.20	29.19	28.83	1.09	30.56	27.10	6.00

Shoreline Intra-observer Bias

Overall Means: As with the previous two habitat types, confidence intervals surrounding both cover means at the four times suggest there were no differences among the times (Table 74). The mean values for the field estimated cover varied from 71.5% at time two to 67.5% at time four. The overall estimated cover mean was 69.5 (all times), and confidence intervals bracketing these four means fell between 65.4 and 73.6, suggesting the minimal amount of cover change that can be detected is 5.9%. The mean and variance associated with summed cover was greater than the one estimate of cover, with minimal detection limits of 13.9% above and below the 93.7% mean. Here in the shoreline it is apparent that multiple taxa overlap, and the sum of their cover is greater than the single estimate.

Species richness per quadrat is greater and more variable on the shoreline compared to the other two habitat types, varying between 10.6 and 14.6 (95% confidence intervals), suggesting a 15.9% minimum detection value (Table 74).

Comparisons of frequency: Fifty-three taxa were sampled over the 20 quadrats during four time periods (Table 75), and eight taxa were recorded in over half of the total 80 quadrats. Thirteen

Table 74. Comparisons of total estimated cover (one estimate of all taxa's cover per quadrat), the sum of all individual taxa cover, and quadrat richness as sampled by one observer on repeated visits to shoreline quadrats over a six day period, July 2006. (N = 20, 1 m x 1 m quadrats at each time period). Confidence intervals (CI) are set at 95%.

		Total Cover (estimated)	**Quadrat Cover (summed)**	**Quadrat Richness**		**One estimate cover**	**Summed cover**	**Quadrat richness**
Time 1	**Mean**	70.5	87.5	11.3	**Time**	**Means**	**Means**	**Means**
	Standard deviation	10.5	21.3	2.8	1	70.5	87.5	11.3
	Standard error	2.3	4.8	0.6	2	71.5	93.5	13.1
	Upper Limit CI	75.3	97.3	12.5	3	68.5	101.5	12.9
	Lower Limit CI	65.7	77.7	10.0	4	67.5	92.3	13.1
Time 2	**Mean**	71.5	93.5	13.1	**Grand means**	69.50	93.70	12.58
	Standard deviation	7.8	20.3	2.5	**St .dev.**	1.83	5.80	0.89
	Standard error	1.7	4.5	0.6	**CI Lower**	65.39	80.65	10.58
	Upper Limit CI	75.1	102.8	14.2	**CI Upper**	73.61	106.75	14.57
	Lower Limit CI	67.9	84.1	11.9	**Minimum % change detectable**	5.91	13.93	15.88
Time 3	**Mean**	68.5	101.5	12.9				
	Standard deviation	6.9	16.8	2.6				
	Standard error	1.5	3.8	0.6				
	Upper Limit CI	71.7	109.2	14.1				
	Lower Limit CI	65.3	93.8	11.7				
Time 4	**Mean**	67.5	92.3	13.1				
	Standard deviation	6.2	17.2	2.6				
	Standard error	1.4	3.8	0.6				
	Upper Limit CI	70.3	100.2	14.3				
	Lower Limit CI	64.7	84.4	11.9				

Table 75. Comparisons of frequency of occurrence for all individual taxa as sampled by one observer on repeated visits to shoreline quadrats over a six day period, July 2006.

Genus	Species	Time 1	Time 2	Time 3	Time 4	Totals all times (of 80)
		Frequency of 20 quadrats				
Abies	*balsamea*	1	2	3	4	10
Acer	*rubrum*	2	3	1	2	8
Acorus	*calamus*	2	3	2	1	8
Amphicarpa	*bractea*	1	4	5	5	15
Aster	spp.	14	16	17	15	62
Bidens	spp.	0	1	1	1	3
Calamagrostis	*canadensis*	19	19	19	18	75
Cardamine	sp.	0	0	1	1	2
Carex	*(ovales)*	8	8	6	8	30
Carex	*crinita*	1	1	1	1	4
Carex	*lacustris*	4	4	6	6	20
Carex	*retrorsa*	1	1	1	1	4
Carex	spp.	12	11	14	10	47
Cicuta	*bulbifera*	3	5	3	2	13
Cornus	*canadensis*	1	1	1	1	4
Cornus	*stolonifera*	4	3	4	2	13
Eleocharis	*acicularis*	0	2	4	0	6
Equisetum	*sylvaticum*	11	14	14	13	52
Fragaria	*virginiana*	1	1	1	1	4
Fraxinus	spp.	1	4	3	5	13
Galium	*trifidum*	3	5	3	3	14
Impatiens	*capensis*	0	0	0	1	1
Iris	*versicolor*	2	2	2	2	8
Lathyrus	*palustris*	4	3	2	3	12
Leersia	*oryzoides*	3	3	4	2	12
Lycopodium	*annotinum*	1	1	1	1	4
Lycopus	spp.	12	14	13	14	53
Lysimachia	*ciliata*	4	5	4	4	17
Lysimachia	spp.	14	15	12	15	56
moss	spp.	2	3	0	0	5
Myrica	*gale*	3	3	3	3	12
Phalaris	*arundinacea*	2	1	1	3	7
Pinus	*strobus*	9	11	11	11	42
Poa	*palustris*	9	12	14	15	50
Polygonum	*coccineum*	9	9	8	9	35
Polygonum	*punctatum*	4	7	7	7	25
Pyrola	*elliptica*	1	1	1	1	4
Ranunculus	*pensylvanicus*	4	5	5	7	21
Rosa	sp.	2	2	2	2	8
Sagittaria	*cuneata*	3	6	8	6	23
Scirpus	*cyperinus*	8	8	7	8	31
Scirpus	*fluviatilis*	3	3	3	3	12
Scutellaria	*galericulata*	3	3	5	3	14
Scutellaria	*lateriflorus*	5	7	6	8	26
Sium	*suave*	9	8	9	12	38
Sparganium	*eurycarpum*	8	8	9	9	34
Stachys	*palustris*	3	4	3	4	14
Stellaria	*longifolia*	2	3	2	2	9
Thelypteris	*palustris*	1	1	1	1	4
Toxicodendron	*radicans*	2	1	1	1	5
Trifolium	sp.	1	1	1	1	4
Typha	*x glauca*	2	2	2	3	9
Viola	sp.	1	1	1	1	4

taxa were seen the same number of times each sampling period (with occurrences only in the 4 times column in Table 76), and twelve of those (with the exception of *Scirpus fluviatilis*) were found in the same quadrats each time. For example, *Myrica gale* was found in the same 3 quadrats in each of the four repeated sampling times (Tables 75 and 76).

Percent detection accuracy was calculated by the formula (80 - total the number of misses)/80 x 100 (see peatland section above for a more complete explanation), and there were only four taxa with accuracy scores less than 80%. These taxa include *Carex* (ovales group) at 72.5%, *Carex* spp. (78.75%), *Lysimachia* spp. 75%, and *Sium suave* at 77.5% (Table 76). The mean percent accuracy was 90.7%, similar that of the repeated peatland observations.

Estimates of Cover by Taxa: Cover was estimated each time period over the 20 quadrats, and estimates of the mean per quadrat cover was reported for the top twenty most abundant taxa by cover taxa across the four sampling times (Table 77). Only two taxa had raw cover values consistently (each time) greater than 10%, including *Calamagrostis canadensis* and *Pinus strobus,* while four more had cover values consistently greater than 3%, *including Carex* spp. (both *Carex utriculata* and *Carex vesicaria), Sparganium eurycarpum, Myrica gale,* and *Scirpus cyperinus.* As with the other habitat types, the variance about the means across all 80 quadrats was considerable, especially for the abundant taxa. For example, *Calamagrostis* estimates (taking the extremes of the reported 95% confidence intervals) varied from a low of 20.97% to as high as 44.35%, while the over hanging *Pinus* varied from as low as 1.83% to as high as 21.99%.

Looking at the variance surrounding the grand means again offers estimates of “estimated minimal detection percent” for all taxa (Table 78). This allows a comparison of the variance associated with cover and relative importance value.

Calamagrostis canadensis had the greatest percent cover, with a grand mean of 31.3% and 95% confidence intervals ranging from 27.7 to 34.9% (Table 78), and with a minimal detection of 11.5% (the percent the confidence interval surrounds the mean). As with the taxa in the peatlands and 2.0 m transects, the estimated minimal detection percents vary with taxa and their distributional patterns from greater than 100% for many lesser taxa to as low as 8.5 % for *Scirpus cyperinus*. Of the taxa with grand means greater than 3.0%, the detection limits vary from *Scirpus*’ 8.5% to as much as 44.3% for *Poa palustris*.

Estimates of Relative Importance Value (IV) by Taxa: Similar calculations designed to estimate minimal detection were undertaken for relative importance value (Table 79). Using IV did not reduce (compared to raw cover) the detection limits for all of the top five taxa, for example *Calamagrostis canadensis* had minimal detection estimates of 11.5% for cover (Table 78) and 17.7% for relative IV (Table 79). On the other hand, *Pinus strobus*, *Carex* spp., and *Sparganium eurycarpum* all had less variance (and lower detection limits) using relative importance value as a metric. As with the peatland and the 2.0 M transects, detection limits increase with decreasing overall abundance. For many of the less abundant taxa, increases of 50% or more may be required to suggest real change.

Table 76. Frequency of occurrence and consistency of observations of all shoreline taxa in 20 quadrats each sampled four separate times (80 quadrats total). All twenty quadrats sampled by the same observer each time.

Genus	species	Frequency per 80 quadrats	Of the twenty quadrats repeatedly sampled, number of quadrats when taxa on list was found (once, twice, etc.):					Total # quadrats seen at least once	Estimated % percent accuracy
			1	2	3	4	0		
Abies	*balsamea*	10	1	1	1	1	16	4	92.5
Acer	*rubrum*	8	1	2	1		16	4	90
Acorus	*calamus*	8	2	1		1	16	4	90
Amphicarpa	*bractea*	15		1	3	1	15	5	93.75
Aster	*spp.*	62	2	3	2	12	1	19	82.5
Bidens	*spp.*	3			1		19	1	98.75
Calamagrostis	*canadensis*	75	1		2	17	0	20	93.75
Cardamine	sp.	2		1			19	1	97.5
Carex	*(ovales)*	30	4	4	2	3	7	13	72.5
Carex	*crinita*	4				1	19	1	100
Carex	*lacustris*	20	5		1	3	11	9	80
Carex	*retrorsa*	4				1	19	1	100
Carex	spp.	47	3	2	4	7	4	16	78.75
Cicuta	*bulbifera*	13	4	1	1	1	13	7	81.25
Cornus	*canadensis*	4				1	19	1	100
Cornus	*stolonifera*	13	2		1	2	15	5	91.25
Eleocharis	*acicularis*	6	2	2			16	4	87.5
Equisetum	*sylvaticum*	52	1	2	5	8	4	16	85
Fragaria	*virginiana*	4				1	19	1	100
Fraxinus	spp.	13	1	1	2	1	15	5	91.25
Galium	*trifidum*	14	3	2	1	1	13	7	82.5
Impatiens	*capensis*	1	1				19	1	96.25
Iris	*versicolor*	8				2	18	2	100
Lathyrus	*palustris*	12	1	2	1	1	15	5	90
Leersia	*oryzoides*	12	2	1		2	15	5	90
Lycopodium	*annotinum*	4				1	19	1	100
Lycopus	spp.	53	1	1	2	11	5	15	91.25
Lysimachia	*ciliata*	17	1			4	15	5	96.25
Lysimachia	spp.	56	3	3	5	8	1	19	75
moss	spp.	5	3	1			16	4	86.25
Myrica	*gale*	12				3	17	3	100
Phalaris	*arundinacea*	7	3			1	16	4	88.75
Pinus	*strobus*	42	1	1	1	9	8	12	92.5
Poa	*palustris*	50	1	2	3	9	5	15	87.5
Polygonum	*coccineum*	35	2	3	1	6	8	12	83.75
Polygonum	*punctatum*	25	1	3	6		10	10	81.25

Genus	species	Frequency per 80 quadrats	Of the twenty quadrats repeatedly sampled, number of quadrats when taxa on list was found (once, twice, etc.):					Total # quadrats seen at least once	Estimated % percent accuracy
			1	2	3	4	0		
Pyrola	*elliptica*	4				1	19	1	100
Ranunculus	*pensylvanicus*	21	3	3		3	11	9	81.25
Rosa	sp.	8				2	18	2	100
Sagittaria	*cuneata*	23	2		3	3	12	8	88.75
Scirpus	*cyperinus*	31	2	2	3	4	9	11	83.75
Scirpus	*fluviatilis*	12	1	2	1	1	15	5	90
Scutellaria	*galericulata*	14	4	1		2	13	7	82.5
Scutellaria	*lateriflorus*	26		4	2	3	11	9	87.5
Sium	*suave*	38	2	5	2	5	6	14	77.5
Sparganium	*eurycarpum*	34	1	1	1	7	10	10	92.5
Stachys	*palustris*	14			2	2	16	4	97.5
Stellaria	*longifolia*	9	3		2		15	5	86.25
Thelypteris	*palustris*	4				1	19	1	100
Toxicodendron	*radicans*	5	1			1	18	2	96.25
Trifolium	sp.	4				1	19	1	100
Typha	*x glauca*	9	1			2	17	3	96.25
Viola	sp.	4				1	19	1	100
								Mean	90.71

Table 77. Comparisons of percent cover and estimation of variance for the top 20 taxa (ranked by overall cover) as sampled by a single observer on repeated visits to shoreline quadrats over a six day period, July 2006. (N = 20, 1 m x 1 m quadrats at each time period). Confidence intervals (CI) are set at 95%.

		Time 1	**Time 2**	**Time 3**	**Time 4**	**Time 1**	**Time 2**	**Time 3**	**Time 4**	**Time 1**	**Time 2**	**Time 3**	**Time 4**	**Time 1**	**Time 2**	**Time 3**	**Time 4**
Genus	**Species**	**Mean Percent Cover**				**St. dev.**				**CI lower limits**				**CI upper limits**			
Calamagrostis	*canadensis*	34.20	30.90	31.40	28.70	21.72	20.35	18.98	16.57	24.07	21.41	22.55	20.97	44.33	40.39	40.25	36.43
Pinus	*strobus*	10.85	12.50	12.35	10.10	19.34	20.34	15.65	15.00	1.83	3.01	5.05	3.10	19.87	21.99	19.65	17.10
Carex	spp.	4.10	3.90	5.50	4.35	8.75	4.55	6.39	5.37	0.02	1.78	2.52	1.84	8.18	6.02	8.48	6.86
Sparganium	*eurycarpum*	4.30	3.85	4.40	3.30	9.65	8.31	10.66	6.67	-0.20	-0.03	-0.57	0.19	8.80	7.73	9.37	6.41
Myrica	*gale*	3.45	3.65	3.30	4.15	20.66	16.01	17.09	17.21	-6.19	-3.82	-4.67	-3.88	13.09	11.12	11.27	12.18
Scirpus	*cyperinus*	3.75	3.35	3.55	3.75	9.71	6.97	8.76	7.67	-0.78	0.10	-0.54	0.17	8.28	6.60	7.64	7.33
Poa	*palustris*	2.05	3.70	4.25	3.75	6.46	5.20	4.68	3.78	-0.96	1.27	2.07	1.99	5.06	6.13	6.43	5.51
Carex	*lacustris*	1.75	1.60	3.15	2.65	11.00	5.94	11.33	7.28	-3.38	-1.17	-2.13	-0.74	6.88	4.37	8.43	6.04
Carex	*(ovales)*	0.90	1.25	2.90	3.35	2.38	2.23	6.19	5.68	-0.21	0.21	0.01	0.70	2.01	2.29	5.79	6.00
Polygonum	*coccineum*	2.80	1.90	1.75	1.80	9.09	3.19	2.92	3.00	-1.44	0.41	0.39	0.40	7.04	3.39	3.11	3.20
Lycopus	spp.	1.65	2.05	2.45	1.75	3.05	1.77	2.39	1.83	0.23	1.22	1.34	0.90	3.07	2.88	3.56	2.60
Abies	*balsamea*	1.00	1.50	2.80	2.45		7.07	12.06	12.01		-1.80	-2.82	-3.15		4.80	8.42	8.05
Lysimachia	spp.	1.55	2.45	1.70	1.85	1.63	2.43	1.90	1.64	0.79	1.31	0.81	1.08	2.31	3.59	2.59	2.62
Aster	spp.	1.41	2.15	2.00	1.85	1.40	1.74	1.37	1.13	0.75	1.34	1.36	1.33	2.06	2.96	2.64	2.37
Sium	*suave*	0.85	1.25	1.60	1.75	1.27	2.64	2.65	2.11	0.26	0.02	0.36	0.77	1.44	2.48	2.84	2.73
Fraxinus	spp.	1.25	0.80	1.45	1.70		4.00	13.28	6.22		-1.07	-4.74	-1.20		2.67	7.64	4.60
Iris	*versicolor*	0.75	1.35	1.50	1.25	0.71	2.12	0.00	3.54	0.42	0.36	1.50	-0.40	1.08	2.34	1.50	2.90
Equisetum	*sylvaticum*	0.85	1.10	1.25	1.30	0.69	0.51	0.70	1.47	0.53	0.86	0.92	0.61	1.17	1.34	1.58	1.99
Stachys	*palustris*	1.00	1.10	0.95	1.35	2.31	3.00	4.73	4.99	-0.08	-0.30	-1.25	-0.98	2.08	2.50	3.15	3.68
Sagittaria	*cuneata*	0.35	1.45	1.20	1.20	1.53	4.12	2.14	2.10	-0.36	-0.47	0.20	0.22	1.06	3.37	2.20	2.18

Table 78. Estimated minimal detection limits on raw percent cover for all taxa as sampled by one observer on repeated visits to shoreline quadrats over a six day period, July 2006 (N = 20, 1 m x 1 m quadrats for each each time period). Taxa sorted by overall percent cover, and confidence intervals (CI) are set at 95%.

Genus	species	Time 1	Time 2	Time 3	Time 4	Grand mean	St. dev.	CI lower	CI upper	% Estimated minimal detection
		Mean Percent Cover								
Calamagrostis	*canadensis*	34.2	30.9	31.4	28.7	31.30	2.26	27.70	34.90	11.5
Pinus	*strobus*	10.85	12.5	12.35	10.1	11.45	1.17	9.59	13.31	16.2
Carex	spp.	4.1	3.9	5.5	4.35	4.46	0.72	3.32	5.60	25.5
Sparganium	*eurycarpum*	4.3	3.85	4.4	3.3	3.96	0.50	3.16	4.76	20.2
Myrica	*gale*	3.45	3.65	3.3	4.15	3.64	0.37	3.05	4.23	16.2
Scirpus	*cyperinus*	3.75	3.35	3.55	3.75	3.60	0.19	3.30	3.90	8.5
Poa	*palustris*	2.05	3.7	4.25	3.75	3.44	0.96	1.91	4.96	44.3
Carex	*lacustris*	1.75	1.6	3.15	2.65	2.29	0.74	1.11	3.46	51.4
Carex	*(ovales)*	0.9	1.25	2.9	3.35	2.10	1.21	0.18	4.02	91.4
Polygonum	*coccineum*	2.8	1.9	1.75	1.8	2.06	0.50	1.27	2.85	38.2
Lycopus	spp.	1.65	2.05	2.45	1.75	1.98	0.36	1.40	2.55	29.0
Abies	*balsamea*	1	1.5	2.8	2.45	1.94	0.83	0.61	3.26	68.3
Lysimachia	spp.	1.55	2.45	1.7	1.85	1.89	0.39	1.26	2.52	33.3
Aster	spp.	1.405	2.15	2	1.85	1.85	0.32	1.34	2.36	27.6
Sium	*suave*	0.85	1.25	1.6	1.75	1.36	0.40	0.72	2.00	46.8
Fraxinus	spp.	1.25	0.8	1.45	1.7	1.30	0.38	0.69	1.91	46.6
Iris	*versicolor*	0.75	1.35	1.5	1.25	1.21	0.33	0.70	1.73	42.6
Equisetum	*sylvaticum*	0.85	1.1	1.25	1.3	1.13	0.20	0.80	1.45	28.6
Stachys	*palustris*	1	1.1	0.95	1.35	1.10	0.18	0.82	1.38	25.7
Sagittaria	*cuneata*	0.35	1.45	1.2	1.2	1.05	0.48	0.28	1.82	72.9
Carex	*retrorsa*	0.75	1	1	1.25	1.00	0.20	0.68	1.32	32.5
Lysimachia	*ciliata*	0.55	1.05	0.9	1.2	0.93	0.28	0.48	1.37	47.9
Cornus	*stolonifera*	0.95	0.75	1.45	0.4	0.89	0.44	0.19	1.59	78.6
Scutellaria	*lateriflorus*	0.55	0.9	0.9	0.8	0.79	0.17	0.52	1.05	33.4
Carex	*crinita*	0.5	0.5	1.25	0.75	0.75	0.35	0.19	1.31	75.0
Scirpus	*fluviatilis*	0.5	0.7	0.7	0.5	0.60	0.12	0.42	0.78	30.6
Typha	*x glauca*	0.6	0.6	0.5	0.35	0.51	0.12	0.32	0.70	36.7
Acer	*rubrum*	1.05	0.85	0.05	0.055	0.50	0.52	-0.33	1.34	166.5
Leersia	*oryzoides*	0.3	0.8	0.5	0.2	0.45	0.26	0.03	0.87	93.5
Polygonum	*punctatum*	0.25	0.45	0.6	0.45	0.44	0.14	0.21	0.67	52.2
Stellaria	*longifolia*	0.2	0.4	0.4	0.7	0.43	0.21	0.10	0.75	77.2
Ranunculus	*pensylvanicus*	0.2	0.35	0.45	0.5	0.38	0.13	0.16	0.59	56.1
Scutellaria	*galericulata*	0.25	0.25	0.405	0.25	0.29	0.08	0.17	0.41	42.7
Amphicarpa	*bractea*	0.05	0.3	0.4	0.4	0.29	0.17	0.02	0.55	91.4
Phalaris	*arundinacea*	0.35	0.3	0.15	0.3	0.28	0.09	0.14	0.41	50.1
Trifolium	sp.	0.2	0.3	0.3	0.3	0.28	0.05	0.20	0.35	28.9

Genus	species	Time 1	Time 2	Time 3	Time 4	Grand mean	St. dev.	CI lower	CI upper	% Estimated minimal detection
		Mean Percent Cover								
Lathyrus	*palustris*	0.2	0.25	0.15	0.25	0.21	0.05	0.14	0.29	35.8
Galium	*trifidum*	0.155	0.25	0.25	0.15	0.20	0.06	0.11	0.29	44.5
Rosa	sp.	0.105	0.15	0.3	0.2	0.19	0.08	0.06	0.32	70.6
Cicuta	*bulbifera*	0.25	0.205	0.2	0.055	0.18	0.08	0.04	0.31	75.9
moss	*spp.*	0.3	0.35	0	0	0.16	0.19	-0.14	0.46	184.8
Acorus	*calamus*	0.15	0.25	0.15	0.05	0.15	0.08	0.02	0.28	86.6
Viola	sp.	0.05	0.15	0.2	0.1	0.13	0.06	0.02	0.23	82.2
Toxicodendron	*radicans*	0.105	0.05	0.2	0.1	0.11	0.06	0.01	0.21	87.6
Pyrola	*elliptica*	0.1	0.1	0.1	0.15	0.11	0.02	0.07	0.15	35.4
Eleocharis	*acicularis*	0	0.15	0.2	0	0.09	0.10	-0.08	0.25	187.4
Thelypteris	*palustris*	0.05	0.05	0.05	0.1	0.06	0.03	0.02	0.10	63.6
Fragaria	*virginiana*	0.005	0.05	0.05	0.1	0.05	0.04	-0.01	0.11	120.5
Bidens	spp.	0	0.05	0.1	0.05	0.05	0.04	-0.01	0.11	129.9
Cornus	*canadensis*	0.005	0.05	0.05	0.05	0.04	0.02	0.00	0.07	92.4
Lycopodium	*annotinum*	0.005	0.05	0.05	0.05	0.04	0.02	0.00	0.07	92.4
Cardamine	sp.	0	0	0.05	0.05	0.03	0.03	-0.02	0.07	183.7
Impatiens	*capensis*	0	0	0	0.1	0.03	0.05	-0.05	0.10	318.2

Table 79. Estimated minimal detection limits of relative importance values (IV) for all individual taxa as sampled by one observer on repeated visits to shoreline quadrats over a six day period, July 2006 (N = 20, 1 m x 1 m quadrats for each each time period). Importance values are relativized over the 20 quadrats each time period. Taxa sorted by overall percent cover, and confidence intervals (CI) are set at 95%.

Genus	Species	Time 1	Time 2	Time 3	Time 4	Grand Mean	St. dev.	CI lower limit	CI upper limit	% estimated minimal detection
		Mean Importance Value								
Calamagrostis	*canadensis*	23.76	20.05	19.07	18.85	20.43	2.28	16.81	24.06	17.7
Pinus	*strobus*	8.198	8.725	8.167	7.493	8.15	0.50	7.34	8.95	9.9
Carex	spp.	5.009	5.79	6.497	6.033	5.83	0.62	4.84	6.82	17.0
Sparganium	*eurycarpum*	4.234	3.541	3.872	3.442	3.77	0.36	3.20	4.34	15.1
Myrica	*gale*	2.637	2.508	2.194	2.799	2.53	0.26	2.13	2.94	16.1
Scirpus	*cyperinus*	3.92	3.274	3.074	3.502	3.44	0.36	2.86	4.02	16.8
Poa	*palustris*	3.171	4.202	4.745	4.789	4.23	0.75	3.03	5.42	28.3
Carex	*lacustris*	1.888	1.597	2.688	2.538	2.18	0.52	1.35	3.01	38.0
Carex	*(ovales)*	2.292	2.15	2.565	3.285	2.57	0.50	1.77	3.38	31.2
Polygonum	*coccineum*	3.599	2.683	2.377	2.629	2.82	0.53	1.97	3.67	30.2
Lycopus	spp.	3.609	3.689	3.669	3.521	3.62	0.08	3.50	3.74	3.3
Abies	*balsamea*	0.793	1.173	1.947	2.062	1.49	0.61	0.52	2.47	65.1
Lysimachia	spp.	3.996	4.089	3.11	3.759	3.74	0.44	3.04	4.44	18.8
Aster	spp.	3.914	4.113	4.205	3.759	4.00	0.20	3.68	4.32	8.0
Sium	*suave*	2.486	2.15	2.493	3.154	2.57	0.42	1.90	3.24	26.0

Genus	Species	Time 1	Time 2	Time 3	Time 4	Grand Mean	St. dev.	CI lower limit	CI upper limit	% estimated minimal detection
		Mean Importance Value								
Fraxinus	spp.	0.936	1.169	1.282	1.84	1.31	0.38	0.70	1.92	46.7
Iris	*versicolor*	0.873	1.093	1.118	1.045	1.03	0.11	0.86	1.21	17.0
Equisetum	*sylvaticum*	2.93	3.181	3.267	3.094	3.12	0.14	2.89	3.35	7.3
Stachys	*palustris*	1.238	1.329	1.036	1.467	1.27	0.18	0.98	1.55	22.7
Sagittaria	*cuneata*	0.867	1.887	2.106	1.753	1.65	0.54	0.79	2.52	52.4
Carex	*retrorsa*	0.651	0.72	0.682	0.861	0.73	0.09	0.58	0.88	20.3
Lysimachia	*ciliata*	1.203	1.488	1.201	1.385	1.32	0.14	1.09	1.54	17.1
Cornus	*stolonifera*	1.432	0.957	1.472	0.584	1.11	0.42	0.44	1.78	60.4
Scutellaria	*lateriflorus*	1.425	1.778	1.58	1.904	1.67	0.21	1.33	2.01	20.1
Carex	*crinita*	0.508	0.453	0.805	0.59	0.59	0.15	0.34	0.84	41.8
Scirpus	*fluviatilis*	0.952	0.93	0.913	0.822	0.90	0.06	0.81	1.00	10.0
Typha	*x glauca*	0.787	0.691	0.625	0.741	0.71	0.07	0.60	0.82	15.5
Acer	*rubrum*	1.044	1.01	0.214	0.397	0.67	0.42	-0.01	1.34	101.1
Leersia	*oryzoides*	0.838	0.984	1.004	0.476	0.83	0.24	0.44	1.21	47.1
Polygonum	*punctatum*	1.032	1.537	1.621	1.531	1.43	0.27	1.00	1.86	29.9
Stellaria	*longifolia*	0.559	0.77	0.576	0.747	0.66	0.11	0.49	0.84	26.6
Ranunculus	*pensylvanicus*	1.003	1.113	1.169	1.558	1.21	0.24	0.83	1.59	31.7
Scutellaria	*galericulata*	0.809	0.689	1.146	0.687	0.83	0.22	0.49	1.18	41.4
Amphicarpa	*bractea*	0.251	0.901	1.144	1.136	0.86	0.42	0.19	1.53	77.9
Phalaris	*arundinacea*	0.644	0.346	0.263	0.714	0.49	0.22	0.14	0.84	71.4
Trifolium	sp.	0.336	0.346	0.337	0.346	0.34	0.01	0.33	0.35	2.5
Lathyrus	*palustris*	1.003	0.689	0.453	0.687	0.71	0.23	0.35	1.07	50.8
Galium	*trifidum*	0.755	1.06	0.691	0.633	0.78	0.19	0.48	1.09	38.5
Rosa	sp.	0.504	0.451	0.527	0.476	0.49	0.03	0.44	0.54	10.8
Cicuta	*bulbifera*	0.809	1.036	0.667	0.397	0.73	0.27	0.30	1.15	58.5
moss	spp.	0.616	0.743	0	0	0.34	0.40	-0.29	0.97	185.3
Acorus	*calamus*	0.53	0.689	0.453	0.211	0.47	0.20	0.15	0.79	67.4
Viola	sp.	0.251	0.265	0.288	0.238	0.26	0.02	0.23	0.29	13.1
Toxicodendron	*radicans*	0.504	0.212	0.288	0.238	0.31	0.13	0.10	0.52	68.1
Pyrola	*elliptica*	0.279	0.239	0.239	0.265	0.26	0.02	0.22	0.29	12.6
Eleocharis	*acicularis*	0	0.451	0.856	0	0.33	0.41	-0.33	0.98	200.6
Thelypteris	*palustris*	0.251	0.212	0.214	0.238	0.23	0.02	0.20	0.26	13.1
Fragaria	*virginiana*	0.225	0.212	0.214	0.238	0.22	0.01	0.20	0.24	8.6
Bidens	spp.	0	0.212	0.239	0.211	0.17	0.11	-0.01	0.34	106.8
Cornus	*canadensis*	0.225	0.212	0.214	0.211	0.22	0.01	0.21	0.23	4.8
Lycopodium	*annotinum*	0.225	0.212	0.214	0.211	0.22	0.01	0.21	0.23	4.8
Cardamine	sp.	0	0	0.214	0.211	0.11	0.12	-0.09	0.30	183.7
Impatiens	*capensis*	0	0	0	0.238	0.06	0.12	-0.13	0.25	318.2

Inter-observer Bias (Multiple Observer Variability)

Interpreting the results from the intensive quadrat-based sampling (Vegetative Change section) requires an estimate of the variability associated with it. One source of variability, within observer, or intra-observer bias, was addressed above. In what follows we address sources of variability in how different observers view the same resource. This includes inter-observer bias in species identification and visual estimates of cover (e.g. due, in part, to differences in experience) and differences among sampling techniques (e.g. shoreline transects are sampled by walking whereas the deeper aquatic transects require canoe and/or diving with a mask and snorkel).

Methods

We assessed inter-observer bias in 1 m x 1 m quadrats in three different habitats using peatland sampling (above mean high water in peatland habitat), aquatic sampling (at depths of 1.25 meters), and shoreline sampling (at mean high water [MHW], with saturated soil to water depths up to 0.25 m). To estimate variability among individuals, four observers sampled the same vegetation at very close to the same time period. Twenty 1 m x 1 m quadrats were placed along shoreline (0.0 m), aquatic (1.25 m), and peatland transects. The twenty quadrat frames were *kept in the same location* during the duration of sampling (1-2 days for each transect) and observed by multiple individuals. Aquatic sampling was done with a mask and snorkel and weighted quadrats were sunk to the sediment's surface and re-located by floats. We also tested for differences in field experience by breaking the observers into two groups, experienced wetland assessors (the authors) and trained assessors (Northland College undergraduate student assistants). Inexperienced observers received 3-4 days of instruction, including species identification (of all taxa they would likely observe) and, through practice sessions, calibration of cover estimates prior to sampling. Observers are referred to by initials, where JM and AH are experienced (the authors), RE and RA recently trained in 2004, and RE and RW recently trained in 2005. Deep Slu and Lost Bay, both on Namakan Lake, were the locations for the shoreline and aquatic transects, which were sampled in 2006, while the peatland transects were sampled in 2005 in an area just below Kohler Bay on Namakan Lake.

Results

Raw data for all inter-observer error assessment was entered into digital form, printed out, and error checked by comparison with field notebooks and included in Meeker and Harris (2008), along with the waypoint locations and maps of the sites.

Peatland Inter-observer Bias

In addition to cover and frequency, as was measured in all of the intensively sampled sites (Intensive Sampling section), we also estimated *Typha* stem density as a means to monitor change in peatland habitat (Extensive Sampling section). In this assessment of inter-observer bias, we found no significant differences (using 95% confidence intervals) in the estimated mean number of stems of *Typha*, which varied from 3.3 to 3.8 stems per m^2, and while estimates of dead stem density varied more, the differences were not significant (Table 80).

Table 80. Comparisons among observers for quadrat richness, *Typha* stem density (live and dead), total cover (one estimate), and total summed cover of all taxa in peatland habitat over the same twenty quadrats, July 2005. Confidence intervals are set at 95%.

	Typha Stems live				**Typha Stems dead**				**Richness per quadrat**				**Cover (one estimate)**				**Cover (summed all taxa)**			
	AH	JM	RA	RE	AH	JM	RA	RE	AH	JM	RA	RE	AH	JM	RA	RE	AH	JM	RA	RE
Q01	2	1	1	1	3	0	1	3	14	12	10	11	50	60	40	60	63.6	64.1	49.2	77.1
Q02	2	3	2	2	9	4	6	7	9	10	8	10	65	55	40	60	80.3	66.2	38.3	78.2
Q03	4	4	4	4	6	6	10	7	16	13	11	11	65	65	45	75	46.6	83.3	42.1	94.1
Q04	7	6	5	6	8	10	8	7	11	13	10	10	60	65	65	85	45.3	78.4	69.2	98.1
Q05	6	6	5	5	11	10	5	7	12	16	11	12	65	70	60	85	69.4	97.4	90.1	108.0
Q06	4	3	2	4	6	7	3	3	12	11	10	13	35	55	40	75	41.4	84.2	71.1	93.2
Q07	6	5	5	8	10	7	3	8	12	11	10	12	80	55	60	70	124.3	96.1	73.0	91.0
Q08	0	0	0	0	0	2	0	2	11	10	10	9	60	65	40	80	67.2	91.1	77.1	105.0
Q09	3	2	2	2	3	6	4	2	13	14	11	12	75	70	75	80	107.5	87.2	82.1	98.2
Q10	2	2	2	2	8	7	5	6	14	14	10	11	70	65	65	60	132.5	55.2	78.1	74.1
Q11	3	4	2	2	9	8	6	3	10	11	13	10	85	45	40	75	65.3	51.0	49.2	79.1
Q12	10	13	12	8	13	12	16	8	13	14	11	15	55	70	55	90	60.4	71.4	79.0	125.1
Q13	6	4	6	4	10	7	14	7	14	13	13	13	50	50	60	70	61.4	61.1	95.0	92.0
Q14	5	5	3	5	3	4	4	3	14	12	12	14	60	65	55	90	73.5	98.1	69.0	114.0
Q15	5	5	4	3	19	6	10	5	11	11	11	14	75	70	50	90	76.4	88.0	67.1	113.1
Q16	1	1	1	1	10	6	5	6	15	15	13	14	45	55	55	90	74.5	63.3	58.0	98.0
Q17	3	3	3	3	4	2	2	1	13	12	12	13	50	40	50	75	44.5	55.1	95.0	87.0
Q18	2	2	2	2	14	6	7	4	12	12	10	14	70	60	80	85	84.3	90.0	91.0	94.2
Q19	2	1	2	2	1	2	0	1	13	15	13	13	65	55	65	70	68.4	79.3	80.1	75.1
Q20	3	2	2	3	8	9	5	5	13	14	10	16	75	60	80	80	86.4	76.2	96.0	88.4
Mean	3.8	3.6	3.3	3.4	7.8	6.1	5.7	4.8	12.6	12.7	11.0	12.4	62.8	59.8	56	77.3	73.7	76.8	72.5	94.2
St.Dev.	2.4	2.8	2.6	2.2	4.7	3.1	4.2	2.4	1.7	1.7	1.4	1.9	12.6	8.5	13.1	10.1	24.6	15.1	17.6	14.0
CI lower	2.7	2.3	2.0	2.3	5.6	4.6	3.7	3.6	11.8	11.8	10.3	11.5	56.9	55.8	49.9	72.6	62.2	69.8	64.3	87.6
CI upper	4.9	4.9	4.5	4.4	9.9	7.5	7.7	5.9	13.4	13.5	11.6	13.2	68.6	63.7	62.1	81.9	85.1	83.9	80.7	100.7

Overal Mean by experience

	Typha Stems live		**Typha Stems dead**		**Richness per quadrat**		**Cover (one estimate)**		**Cover (summed all taxa)**	
	Exp.	**In-exp.**	**Exp.**	**In-exp.**	**Exp.**	**In-exp.**	**Exp.**	**In-exp.**	**Exp.**	**In-exp.**
Mean	3.70	3.30	6.90	5.23	12.63	11.65	61.25	66.63	75.25	83.32
St.Dev.	2.57	2.37	3.99	3.42	1.69	1.76	10.73	15.79	20.20	19.15
CI lower	2.88	2.54	5.62	4.13	12.08	11.09	57.82	61.58	68.79	77.20
CI upper	4.52	4.06	8.18	6.32	13.17	12.21	64.68	71.67	81.70	89.44

Mean species richness (per m^2) in the same quadrats showed significant differences, and varied from a mean low of 11.0 to a high of 12.7, with the two higher estimates by the experienced observers. Combining the estimates into two groups (experienced observers with a mean of 12.63 and recently trained observers with a mean of 11.65), still showed significant differences (Table 80).

Mean cover (one estimate) ranged between 56.0 and 77.3, with the high estimate significantly greater than the other three. These values were generally less than the sum of all individual taxon's estimates, which varied from 72.5 to 94.2 (Table 80). One observer (RE), estimated summed cover at significantly greater levels, suggesting that relative cover may be a better metric.

Thirty-three taxa were recorded over the 20 quadrats by the four observers (Table 81), although there was not agreement for a number of them. For example, neither experienced observer recorded *Carex lasiocarpa*, *Hypericum canadense*, *Euthamia graminifolia*, *Iris versicolor* and *Sium suave*, which were recorded by at least one of the recently trained observers. All of these were at low abundance levels, and some of these were most likely misidentifications, as observer RA likely recorded *Carex diandra* as C. *lasiocarpa* and *Triadenum fraseri* as *Hypericum canadense*.

Some taxa were very frequently recorded and found by at least one observer in every quadrat (second column from the right in Table 82) some were very abundant and apparently easy to recognize (e.g. *Potentilla palustris* and *Carex lacustris*), found in every quadrat by all four observers. Other taxa were moderately frequent but consistently found (e.g. *Calla palustris*, found in the same nine quadrats by each observer), while some are apparently more difficult to spot. This difficulty was estimated, as we did with the intra-observer sampling, by computing a percent accuracy.

Of the twenty quadrats that were repeatedly sampled by four observers, we calculated the number of times that individual taxa were found by only one observer, by two observers, by three, or by all four observers (Table 82). With this information we calculated a percent detection accuracy by assuming: 1) if a taxon was not seen in a quadrat by all four observers it was not present, and 2) if it was seen at least once *by an experienced observer* then it was present. (Since the experienced observer was not likely to mis-identify taxa, if a taxon was only found once by them it was assumed to have been overlooked the other three times, if it was found twice, it was assumed to have been missed the other two times, etc.) Our percent accuracy was calculated by the formula (80 - total the number of misses)/80 x 100, where 80 is the total number of possible quadrats, or four observers x twenty quadrats each. For example whenever *Calla* occurred in a quadrat, it was easily spotted, found in 9 quadrats, and recognized each time, hence no misses, and this results in an estimated accuracy of 100%. Other taxa had low accuracies, and five taxa had accuracies less than 75%. These include *Sphagnum* moss, *Acorus calamus*, *Carex diandra*, *Galium* spp., and *Triadenum fraseri* (all either overlooked or mis-identified). The mean accuracy was 90.3 %, similar to the single observer measure for peatlands of 90.0%.

Table 81. Comparison among observers in their estimates of mean raw cover and frequency for all taxa in the same twenty quadrats in peatlands, July 2005. Taxa sorted by overall cover. 'Upper' and 'lower' indicate the ranges of the 95% confidence intervals. Bolded taxa and values indicate significant differences among observers for taxa with means greater than 1%.

			AH	AH	AH	AH	AH	JM	JM	JM	JM	JM	RA	RA	RA	RA	RA	RE	RE	RE	RE	RE	Gr.
	Genus	**species**	**Mn.**	**SE**	**Upper**	**Lower**	**Freq.**	**Mn.**	**SE**	**Upper**	**Lower**	**Freq.**	**Mn.**	**SE**	**Upper**	**Lower**	**Freq.**	**Mn.**	**SE**	**Upper**	**Lower**	**Freq.**	**Mean**
1	*Carex*	*lacustris*	24.45	3.11	30.93	17.97	20	27.20	3.43	34.36	20.04	20	21.95	1.89	25.90	18.00	20	26.75	2.47	31.90	21.60	20	24.13
2	*Potentilla*	*palustris*	8.70	1.37	11.55	5.85	20	13.00	1.83	16.83	9.17	20	10.70	1.56	13.97	7.43	20	14.35	1.45	17.38	11.32	20	13.82
3	***Carex***	***rostrata***	**12.65**	1.98	16.78	8.52	19	7.40	1.36	10.25	4.55	18	**5.50**	1.09	7.78	3.22	17	10.45	2.29	15.22	5.68	15	8.98
4	*Typha*	*latifolia*	6.15	1.33	8.93	3.37	19	9.65	1.92	13.65	5.65	19	5.95	1.26	8.59	3.31	19	10.10	1.88	14.02	6.18	19	7.62
5	**moss**	**spp.**	8.76	2.91	14.84	2.68	18	6.10	1.41	9.04	3.16	19	**10.26**	2.73	15.95	4.56	19	**2.80**	0.84	4.54	1.06	15	7.44
6	*Calamagrostis*	*canadensis*	6.95	2.26	11.66	2.24	18	3.51	0.99	5.57	1.44	16	4.61	1.20	7.12	2.09	15	7.31	1.43	10.28	4.33	20	5.67
7	*Calla*	*palustris*	1.16	0.44	2.07	0.24	9	3.15	1.34	5.94	0.36	9	2.90	1.50	6.03	-0.23	9	4.45	1.51	7.59	1.31	9	2.82
8	***Lysimachia***	***thyrsiflora***	**1.51**	0.22	1.97	1.05	19	1.60	0.22	2.06	1.14	19	2.65	0.28	3.24	2.06	20	**3.50**	0.47	4.48	2.52	20	2.51
9	***Utricularia***	***intermedia***	**0.39**	0.13	0.65	0.13	14	1.57	0.57	2.75	0.39	13	2.02	0.68	3.43	0.61	13	**2.69**	0.72	4.19	1.18	19	1.61
10	*Acorus*	*calamus*	0.74	0.21	1.18	0.29	15	1.55	0.41	2.41	0.69	14	1.10	0.32	1.76	0.44	10	2.05	0.72	3.54	0.56	10	1.44
11	*Polygonum*	*amphibium*	0.57	0.18	0.95	0.18	10	1.40	0.30	2.03	0.77	13	0.90	0.30	1.52	0.28	9	1.65	0.53	2.77	0.53	8	1.40
12	*Sphagnum*	spp.	0.30	0.14	0.59	0.01	13	0.24	0.11	0.48	0.00	11	0.05	0.05	0.15	-0.05	1	3.56	1.33	6.33	0.78	19	0.88
13	*Salix*	spp.	0.20	0.16	0.52	-0.12	2	0.90	0.55	2.05	-0.25	3	0.75	0.75	2.32	-0.82	1	0.50	0.50	1.54	-0.54	1	0.63
14	*Campanula*	*aparinoides*	0.13	0.05	0.22	0.03	16	0.44	0.11	0.66	0.22	16	0.93	0.17	1.28	0.58	19	1.16	0.23	1.64	0.68	15	0.56
15	*Spiraea*	*alba*	0.50	0.50	1.54	-0.54	1	0.30	0.30	0.93	-0.33	1	0.25	0.25	0.77	-0.27	1	0.75	0.75	2.32	-0.82	1	0.56
16	*Carex*	*lasiocarpa*											1.40	0.38	2.19	0.61	12						0.28
17	*Galium*	spp.	0.08	0.05	0.18	-0.02	7	0.24	0.09	0.42	0.06	12	0.02	0.01	0.03	0.00	3	0.73	0.14	1.02	0.44	18	0.22
18	*Equisetum*	spp.	0.06	0.05	0.16	-0.04	3	0.10	0.07	0.24	-0.04	2	0.05	0.05	0.15	-0.05	1	0.36	0.18	0.73	-0.02	5	0.18
19	*Carex*	*diandra*	0.29	0.14	0.58	0.00	11	0.46	0.20	0.87	0.04	6											0.15
20	*Hypericum*	*canadense*											0.20	0.12	0.44	-0.04	3	0.35	0.22	0.81	-0.11	3	0.11
21	*Rumex*	*orbiculatus*	0.02	0.01	0.03	0.00	3	0.11	0.07	0.25	-0.04	3	0.16	0.08	0.33	-0.02	4	0.10	0.10	0.31	-0.11	1	0.11
22	*Triadenum*	*fraseri*	0.03	0.01	0.05	0.01	6	0.21	0.09	0.40	0.01	5											0.10
23	*Epilobium*	spp.						0.21	0.16	0.53	-0.12	3						0.11	0.10	0.31	-0.10	2	0.08
24	*Scirpus*	*cyperinus*						0.30	0.18	0.67	-0.07	3											0.06
25	*Scutellaria*	*galericulata*	0.01	0.01	0.02	0.00	2	0.10	0.07	0.24	-0.04	2	0.01	0.01	0.02	-0.01	1	0.15	0.08	0.32	-0.02	3	0.06
26	*Cicuta*	spp.	0.01	0.01	0.02	-0.01	1	0.05	0.05	0.15	-0.05	1						0.15	0.15	0.46	-0.16	1	0.05
27	*Viola*	spp.	0.02	0.01	0.03	0.00	3	0.06	0.05	0.16	-0.04	3											0.05
28	*Euthamia*	*graminifolia*											0.10	0.10	0.31	-0.11	1						0.03
29	*Aster*	spp.	0.01	0.01	0.02	-0.01	1											0.10	0.10	0.31	-0.11	1	0.02
30	*Iris*	*versicolor*																0.06	0.05	0.16	-0.05	2	0.01
31	*Sium*	*suave*											0.05	0.05	0.15	-0.05	1						0.01
32	*Thelypteris*	*palustris*	0.01	0.01	0.02	-0.01	1	0.01	0.01	0.02	-0.01	1											0.00
33	*Carex*	*brunnescens*	0.01	0.01	0.02	-0.01	1	0.01	0.01	0.02	-0.01	1											0.00

Table 82. Frequency of occurrence and consistency of observations for all peatland taxa sampled in 20 quadrats by each of four observers (four observers, 20 quadrats each = 80 quadrats total).

Genus	**species**	**Frequency per 80 quadrats**	**Of the twenty quadrats sampled by different observers, number of times when taxa on list was found:**					**Total # quadrats seen at least once**	**Estimated % percent accuracy**
			By only one obs.	**By two obs.**	**By three obs.**	**By all four obs.**	**Never seen**		
Acorus	*calamus*	49	3	6	2	7	2	18	73.75
Aster	spp.	2	2				18	2	95
Calamagrostis	*canadensis*	69		5	1	14	0	20	86.25
Calla	*palustris*	36				9	11	9	100
Campanula	*aparinoides*	66	1	2	7	10	0	20	85
Carex	*brunnescens*	3	1	1			18	2	93.75
Carex	*diandra*	16	6	5			9	11	65
Carex	*lacustris*	80				20	0	20	100
Carex	*lasiocarpa*	12	12				8	12	100
Carex	*rostrata*	69	1	1	2	15	1	19	91.25
Cicuta	spp.	3			1		19	1	98.75
Epilobium	spp.	5	3	1			16	4	88.75
Equisetum	spp.	11	2		3		15	5	93.75
Euthamia	*graminifolia*	1	1				19	1	98.75
Galium	spp.	40	7	5	5	2	1	19	70
Hypericum	*canadense*	6	2	2			16	4	92.5
Iris	*versicolor*	2	2				18	2	97.5
Lysimachia	*thyrsiflora*	78			2	18	0	20	97.5
moss	spp.	71	1	1	4	14	0	20	91.25
Polygonum	*amphibium*	40	3	2	3	6	6	14	80
Potentilla	*palustris*	80				20	0	20	100
Rumex	*orbiculatus*	11	1		2	1	16	4	96.25
Salix	*pyrifolia*	7	3			1	16	4	88.75
Scirpus	*cyperinus*	3	3				17	3	88.75
Scutellaria	*galericulata*	8		1	2		17	3	95
Sium	*suave*	2		1			19	1	96.25
Sphagnum	spp.	42	6	6	8		0	20	65
Spiraea	*alba*	1	1				19	1	100
Thelypteris	*palustris*	2		1			19	1	97.5
Triadenum	*fraseri*	11	3	4			13	7	78.75
Typha	*latifolia*	76				19	1	19	100
Utricularia	*intermedia*	62	4	2	2	12	0	20	87.5
Viola	spp.	6	2	2			16	4	87.5
								Mean	90.3

There was total agreement as to the ranking of the top eight taxa (ordered by mean cover) when looking at the four observers' estimates for both cover (Table 81) and for mean relative cover (Table 83). For both metrics the top eight taxa were the same across observers. However, there was not any agreement as to the *order* of the top three taxa for either metric. Taxa with mean cover values greater than 1.0% that showed significant differences among observers for both cover and relative cover (bolded inTables 81 and 83) include *Carex rostrata* (AH>RA), non-*Sphagnum* moss spp. (RA>RE), *Lysimachia* (AH<RE), and *Utricularia intermedia* (AH<RE).

Although relative cover is a metric calculated after sampling, it did not (in this case) reduce variance among observers in their estimates of abundance of individual species.

Aquatic Inter-observer Bias

Mean species richness (per m^2) over the same quadrats showed significant differences among observers (AH<RE,Table 84) and varied from a mean low of 6.35 to a high of 7.80. Combining the estimates into two groups (experienced observers with a mean of 6.6 and recently trained observers with a mean of 7.6), also showed significant differences at the 95% confidence interval (Table 84).

Mean cover (one estimate) ranged between 79.5 and 89.9, with the two experienced observers most disparate (AH>JM). As with the other habitat types, the single estimate values were less than the sum of all individual taxon's estimates, which varied from 80.0 to 109.3 (Table 84). There were differences here as well (JM<the other three observers), again suggesting that relative cover may be a better metric to monitor individual taxa's abundances over time.

Fifteen taxa were recorded over the 20 quadrats by the four observers (Table 85), although not all taxa were seen by every observer. For example neither experienced observer recorded *Ceratophyllum demersum*, although it was recorded by the other two observers. Unlike the shoreline and peatland habitats, the "call" as to who was correct here is more difficult to judge, as visibility is more of a problem.

As in the peatland quadrats, we calculated a percent accuracy for aquatics by determining the number of times that individual taxa were found by only one observer, by two observers, by three, or by all four observers (Table 86). Taxa that had low accuracies include *Eleocharis acicularis* (67.5%) and *Elatine minima* (68.8%), both small and difficult to detect. The overall average accuracy was 87.6%.

There was total agreement as to which taxa comprised the top seven (ordered by means) for both mean raw and relative cover but little agreement as to their order (Tables 85 and 87). All but one observer (RW) saw *Vallisneria americana* and *Potamogeton pusillus* as the two most abundant.

Only one taxon, *Lemna trisulca*, showed significant differences among observers for both cover and relative cover (RW>the other observers, Tables 85 and 87). This taxon was usually seen laying on the substrate surface when it was abundant and difficult to sort out visually from periphyton coating other species.

Table 83. Comparison among observers in their estimates of mean relative cover for all taxa in the same twenty quadrats sampled in peatland habitat, July 2005. Taxa sorted by overall cover. "Upper" and "lower" indicate the ranges of the 95% confidence intervals. Bolded taxa and values indicate significant differences among observers for taxa with means greater than 1%.

Peatland		**AH**	**AH**	**AH**	**AH**	**JM**	**JM**	**JM**	**JM**	**RA**	**RA**	**RA**	**RA**	**RE**	**RE**	**RE**	**RE**	**overall**
Genus	**species**	**Mn.**	**SE**	**Upper**	**Lower**	**Mn.**	**SE**	**Upper**	**Lower**	**Mn.**	**SE**	**Upper**	**Lower**	**Mn.**	**SE**	**Upper**	**Lower**	**means**
Carex	*lacustris*	33.61	3.90	41.79	25.42	33.75	3.36	40.80	26.70	32.32	3.36	39.37	25.27	28.88	2.85	34.86	22.90	32.14
Potentilla	*palustris*	12.22	1.67	15.72	8.72	16.04	1.80	19.82	12.26	14.62	1.82	18.43	10.81	15.65	1.65	19.12	12.19	14.63
Carex	***rostrata***	**17.12**	2.64	22.65	11.58	9.31	1.70	12.87	5.75	**6.77**	1.15	9.19	4.35	10.69	2.15	15.21	6.18	10.97
Typha	*latifolia*	8.85	1.66	12.34	5.36	12.22	2.48	17.43	7.02	8.39	1.65	11.86	4.92	10.23	1.71	13.83	6.64	9.93
moss	**spp.**	9.95	2.89	16.00	3.89	7.36	1.52	10.55	4.17	**12.28**	2.89	18.34	6.21	**2.97**	0.90	4.86	1.08	8.14
Calamagrostis	*canadensis*	9.51	3.12	16.05	2.96	4.72	1.74	8.37	1.07	6.66	1.67	10.16	3.16	7.90	1.69	11.44	4.35	7.20
Calla	*palustris*	1.77	0.66	3.15	0.38	3.95	1.55	7.21	0.69	4.17	1.97	8.30	0.04	4.52	1.46	7.58	1.47	3.60
Lysimachia	***thyrsiflora***	2.33	0.36	3.09	1.57	**2.13**	0.33	2.82	1.43	**4.02**	0.53	5.12	2.91	3.73	0.46	4.69	2.76	3.05
Utricularia	***intermedia***	**0.58**	0.20	1.00	0.15	2.01	0.64	3.36	0.67	2.75	0.83	4.48	1.02	**2.80**	0.75	4.38	1.22	2.04
Acorus	*calamus*	1.07	0.30	1.70	0.43	1.86	0.37	2.64	1.09	1.49	0.42	2.36	0.61	2.29	0.85	4.06	0.52	1.68
Polygonum	*amphibium*	0.81	0.28	1.39	0.22	1.89	0.38	2.68	1.09	1.33	0.45	2.27	0.38	1.82	0.57	3.01	0.63	1.46
Sphagnum	**spp.**	0.56	0.27	1.13	-0.01	0.35	0.16	0.69	0.01	**0.10**	0.10	0.31	-0.11	**3.65**	1.26	6.30	1.00	1.17
Campanula	*aparinoides*	0.19	0.07	0.35	0.04	0.56	0.14	0.86	0.26	1.28	0.24	1.78	0.78	1.18	0.22	1.65	0.71	0.80
Salix	spp.	0.44	0.37	1.20	-0.33	1.07	0.62	2.38	-0.24	1.05	1.05	3.27	-1.16	0.54	0.54	1.66	-0.59	0.77
Spiraea	*alba*	0.38	0.38	1.17	-0.41	0.54	0.54	1.68	-0.60	0.32	0.32	0.99	-0.35	1.01	1.01	3.13	-1.11	0.56
Carex	*lasiocarpa*									1.69	0.44	2.60	0.78					0.42
Galium	spp.	0.12	0.07	0.27	-0.03	0.30	0.11	0.54	0.06	0.02	0.01	0.04	0.00	0.77	0.15	1.08	0.46	0.30
Carex	*diandra*	0.31	0.13	0.58	0.03	0.53	0.22	1.00	0.07									0.21
Equisetum	spp.	0.08	0.06	0.20	-0.05	0.12	0.08	0.30	-0.05	0.07	0.07	0.22	-0.08	0.38	0.20	0.80	-0.04	0.16
Hypericum	*canadense*									0.26	0.16	0.60	-0.08	0.31	0.19	0.71	-0.10	0.14
Rumex	*orbiculatus*	0.02	0.01	0.05	0.00	0.15	0.10	0.37	-0.06	0.23	0.13	0.50	-0.03	0.08	0.08	0.25	-0.09	0.12
Triadenum	*fraseri*	0.05	0.02	0.08	0.01	0.30	0.14	0.58	0.01									0.09
Epilobium	spp.					0.23	0.16	0.57	-0.12					0.12	0.11	0.36	-0.12	0.09
Scirpus	*cyperinus*					0.33	0.21	0.77	-0.11									0.08
Scutellaria	*galericulata*	0.01	0.01	0.04	-0.01	0.13	0.09	0.32	-0.06	0.01	0.01	0.03	-0.01	0.17	0.10	0.37	-0.03	0.08
Cicuta	spp.	0.00	0.00	0.01	-0.01	0.06	0.06	0.18	-0.06					0.15	0.15	0.47	-0.17	0.05
Euthamia	*graminifolia*									0.11	0.11	0.33	-0.12					0.03
Aster	spp.	0.01	0.01	0.02	-0.01									0.09	0.09	0.29	-0.10	0.02
Viola	spp.	0.02	0.01	0.03	0.00	0.08	0.07	0.21	-0.06									0.02
Iris	*versicolor*													0.07	0.07	0.21	-0.07	0.02
Sium	*suave*									0.06	0.06	0.19	-0.07					0.02
Thelypteris	*palustris*	0.01	0.01	0.03	-0.01	0.01	0.01	0.02	-0.01									0.00
Carex	*brunnescens*	0.01	0.01	0.02	-0.01	0.01	0.01	0.02	-0.01									0.00

Table 84. Comparisons among observers in quadrat richness, total cover (one estimate), and total summed cover of all taxa in aquatic habitat (1.25 m) over the same twenty quadrats, July 2006. AH and JM = experienced observers, and confidence intervals (CI) are set at 95%.

	Richness per quadrat				**Total Cover (one estimate)**				**Total Cover (summed all taxa)**			
	AH	**JM**	**RE**	**RW**	**AH**	**JM**	**RE**	**RW**	**AH**	**JM**	**RE**	**RW**
	6	5	6	6	70	60	70	70	95.1	108	106.1	89
	4	3	5	7	97	90	85	95	99	55.1	90	108.3
	6	7	7	7	85	80	80	70	84.1	57	86	125.1
	6	7	7	5	90	80	85	80	90.1	90	95.1	98
	5	7	7	6	95	70	90	85	105.1	81	113	109.1
	6	8	9	8	95	85	90	80	94	91.1	116.1	142.1
	6	6	8	9	90	80	85	80	97.1	77	96.1	102.2
	9	10	11	8	80	90	85	65	88.2	94.1	95.2	92.1
	7	8	11	6	80	65	75	75	83.2	85.1	93.3	84
	8	9	11	8	95	80	85	90	127.1	98	97.1	149.1
	7	8	7	8	95	90	90	70	109.1	80.1	103.1	103.2
	7	6	7	7	100	85	90	85	136.1	68	132.1	153.1
	4	7	7	9	100	90	90	80	101	87	96	84.1
	7	5	7	8	95	90	90	80	108.3	80	100.2	81.1
	5	6	6	5	100	90	90	85	107.1	71	104.1	125.1
	8	6	8	9	85	75	80	70	88.2	68	70.1	104.2
	5	7	7	8	90	80	80	85	143	73.1	115	118.1
	7	5	8	10	85	65	70	75	104.2	65.1	99.3	105.3
	7	8	9	9	90	70	90	85	102.1	83.2	97.2	110.1
	7	7	8	6	80	75	75	75	86.1	87	82.1	103
Mean	6.35	6.75	7.80	7.45	89.85	79.50	83.75	79.00	102.41	79.95	99.36	109.32
St.Dev.	1.31	1.59	1.67	1.43	8.11	9.58	6.86	7.71	16.54	13.50	13.36	20.82
CI lower	5.74	6.01	7.02	6.78	86.06	75.01	80.54	75.39	94.67	73.63	93.11	99.57
CI upper	6.96	7.49	8.58	8.12	93.64	83.99	86.96	82.61	110.15	86.26	105.61	119.06
		Cover	Cover				Cover	Cover				
	Rich	One est.	summed			Rich	One est.	summed				
Overall means experienced					**Overall means in-experienced**							
Mean	6.55	91.18	84.68		**Mean**	7.63	104.34	81.38				
St dev.	1.45	18.75	10.21		**St dev.**	1.55	17.98	7.59				
CI lower	6.09	85.19	81.41		**CI lower**	7.13	98.59	78.95				
CI upper	7.01	97.17	87.94		**CI upper**	8.12	110.08	83.80				

Table 85. Comparison of raw cover means among observers for all taxa in the same twenty quadrats sampled in aquatic habitat (1.25m), July 2006. Taxa are ordered by overall mean cover and bolded taxa and values indicate significant differences among observers. “Upper” and “lower” indicate the ranges of the 95% confidence intervals.

Genus	**Species**	**AH Mn.**	**AH St.Dev.**	**AH Upper**	**AH Lower**	**AH Freq.**	**JM Mn.**	**JM St.Dev.**	**JM Upper**	**JM Lower**	**JM Freq.**	**RW Mn.**	**RW St.Dev.**	**RW Upper**	**RW Lower**	**RW Freq.**	**RE Mn.**	**RE St.Dev.**	**RE Upper**	**RE Lower**	**RE Freq.**	**overall mean**
Vallisneria	*americana*	30.3	40.1	49.1	11.5	19	20.4	23.9	31.6	9.2	18	20.7	25.6	32.7	8.6	18	27.7	35.5	44.3	11.0	19	24.8
Potamogeton	*pusillus*	29.4	34.6	45.5	13.2	16	20.8	23.9	31.9	9.6	17	18.5	28.7	31.9	5.0	17	27.4	31.6	42.2	12.6	18	24.0
Sagittaria	*rosette*	13.8	27.1	26.5	1.1	10	6.9	12.9	12.9	0.8	8	19.2	25.1	30.9	7.4	15	11.1	21.2	21.0	1.2	10	12.7
Lemna	*trisulca*	8.5	9.5	13.0	4.1	17	**3.7**	6.1	6.5	0.8	18	**26.6**	27.9	39.7	13.5	19	7.1	7.6	10.6	3.5	19	11.5
Myriophyllum	spp.	8.6	11.6	14.1	3.2	19	13.9	12.5	19.7	8.1	19	8.8	9.0	13.0	4.6	20	11.2	11.5	16.5	5.8	20	10.6
Elodea	*canadensis*	6.1	8.0	9.8	2.3	17	6.0	7.9	9.7	2.2	17	6.2	8.7	10.3	2.1	17	5.7	6.7	8.9	2.6	18	6.0
Bidens	*beckii*	4.5	13.5	10.8	-1.8	14	5.8	9.1	10.0	1.5	17	6.2	12.6	12.1	0.3	14	6.0	13.1	12.1	-0.2	19	5.6
Potamogeton	*richardsonii*	1.0	2.8	2.3	-0.3	5	1.2	2.2	2.2	0.2	7	2.0	4.1	3.9	0.1	5	1.5	2.9	2.8	0.1	7	1.4
Najas	*flexilis*	0.1	0.2	0.2	-0.1	1	1.1	2.4	2.2	-0.1	7	0.1	0.4	0.3	-0.1	3	1.3	2.4	2.4	0.2	9	0.6
Eleocharis	*acicularis*	0.2	0.7	0.5	-0.2	1	0.1	0.2	0.2	0.0	2	0.9	2.3	2.0	-0.2	9	0.2	0.9	0.6	-0.2	2	0.3
Elatine	*minima*	0.0	0.0	0.0	0.0	4	0.1	0.2	0.2	0.0	2	0.1	0.3	0.3	0.0	10	0.0	0.0	0.1	0.0	7	0.1
Nymphaea	*odorata*					0	0.1	0.4	0.3	-0.1	1					0	0.2	0.7	0.5	-0.2	1	0.1
Chara	spp.	0.0	0.0	0.0	0.0	3	0.2	0.7	0.5	-0.2	1					0	0.1	0.2	0.2	0.0	3	0.1
Ceratophyllum	*demersum*					0					0	0.1	0.2	0.2	0.0	2	0.1	0.4	0.3	-0.1	2	0.0
Ranunculus	*longirostris*	0.0	0.0	0.0	0.0	1	0.1	0.2	0.2	-0.1	1					0	0.0	0.0	0.0	0.0	2	0.0

Table 86. Frequency of occurrence and consistency of observations for all aquatic taxa sampled in 20 quadrats by each of four observers (four observers, each with 20 quadrats = 80 quadrats total).

			Of the twenty quadrats sampled by different observers, number of times when taxa on list was found:						
Genus	**species**	**Frequency per 80 quadrats**	**By only one obs.**	**By two obs.**	**By three obs.**	**By all four obs.**	**Never seen**	**Total # quadrats seen at least once**	**Estimated % percent accuracy**
Bidens	*beckii*	64		3	6	10	1	19	85.0
Ceratophyllum	*demersum*	4		2			18	2	95.0
Chara	spp.	7		2	1		17	3	93.8
Elatine	*minima*	23	6	2	3	1	8	12	68.8
Eleocharis	*acicularis*	14	8	1		1	10	10	67.5
Elodea	*canadensis*	69	1	2		16	1	19	91.3
Lemna	*trisulca*	73			3	16	1	19	96.3
Myriophyllum	spp.	78		1		19	0	20	97.5
Najas	*flexilis*	20	4	6		1	9	11	70.0
Nymphaea	*odorata*	2		1			19	1	97.5
Potamogeton	*pusillus*	68	1		5	13	1	19	90.0
Potamogeton	*richardsonii*	24	1	2	1	4	12	8	90.0
Ranunculus	*longirostris*	4		2			18	2	95.0
Sagittaria	rosette	43	4	1	3	7	5	15	78.8
Vallisneria	*americana*	74		1		18	1	19	97.5
								Mean	87.6

Table 87. Comparison of relative cover means among observers for all taxa in the same twenty quadrats sampled in aquatic habitat (1.25 m), July 2006. Taxa are ordered by overall mean cover and bolded taxa and values indicate significant differences among observers. “Upper” and “lower” indicate the ranges of the 95% confidence intervals (CI).

		AH	AH	AH	AH	JM	JM	JM	JM	RW	RW	RW	RW	RE	RE	RE	RE	overall
Genus	**Species**	**Mn.**	**SE**	**Upper**	**Lower**	**Mn.**	**SE**	**Upper**	**Lower**	**Mn.**	**SE**	**Upper**	**Lower**	**Mn.**	**SE**	**Upper**	**Lower**	**mean**
Vallisneria	*americana*	27.23	8.03	43.98	10.47	25.75	6.80	39.95	11.55	19.24	5.64	31.02	7.46	26.63	7.46	42.20	11.07	24.71
Potamogeton	*pusillus*	31.07	8.19	48.17	13.97	26.86	7.28	42.05	11.66	17.26	6.05	29.89	4.62	27.97	7.37	43.34	12.60	25.79
Sagittaria	rosette	12.80	5.44	24.16	1.44	8.60	3.56	16.04	1.17	17.73	5.07	28.32	7.14	11.22	4.70	21.02	1.41	12.59
Lemna	*trisulca*	8.06	1.85	11.91	4.21	**4.21**	1.44	7.21	1.21	**22.69**	4.85	32.81	12.57	7.00	1.62	10.38	3.61	10.49
Myriophyllum	spp.	8.52	2.65	14.05	2.98	17.04	3.29	23.90	10.17	7.84	1.71	11.40	4.28	11.48	2.73	17.19	5.77	11.22
Elodea	*canadensis*	6.20	2.02	10.41	1.99	7.86	2.59	13.25	2.46	5.81	1.88	9.74	1.88	6.42	2.09	10.79	2.05	6.57
Bidens	*beckii*	4.76	3.17	11.38	-1.87	6.54	1.93	10.57	2.51	6.13	3.07	12.53	-0.28	5.85	2.75	11.59	0.12	5.82
Potamogeton	*richardsonii*	1.11	0.74	2.66	-0.43	1.47	0.59	2.70	0.23	2.03	0.96	4.03	0.03	1.50	0.68	2.91	0.09	1.53
Najas	*flexilis*	0.06	0.06	0.18	-0.06	1.24	0.58	2.46	0.03	0.12	0.11	0.34	-0.11	1.38	0.58	2.59	0.17	0.70
Eleocharis	*acicularis*	0.17	0.17	0.53	-0.18	0.06	0.05	0.17	-0.05	0.97	0.56	2.14	-0.20	0.22	0.21	0.65	-0.22	0.35
Elatine	*minima*	0.02	0.01	0.04	0.00	0.06	0.05	0.17	-0.05	0.13	0.06	0.26	0.00	0.04	0.01	0.06	0.01	0.06
Nymphaea	*odorata*	0.00	0.00	0.00	0.00	0.11	0.11	0.34	-0.12	0.00	0.00	0.00	0.00	0.13	0.13	0.40	-0.14	0.06
Chara	spp.	0.02	0.01	0.03	0.00	0.15	0.15	0.47	-0.17	0.00	0.00	0.00	0.00	0.06	0.05	0.17	-0.04	0.06
Ceratophyllum	*demersum*	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.05	0.05	0.15	-0.05	0.09	0.09	0.27	-0.09	0.04
Ranunculus	*longirostris*	0.00	0.00	0.02	-0.01	0.05	0.05	0.16	-0.06	0.00	0.00	0.00	0.00	0.01	0.01	0.03	0.00	0.02

Shoreline Inter-observer Bias

In general the more experienced observers noted more taxa in the shoreline quadrats; they estimated between 7.95 and 8.20 taxa per 1 m x 1 m quadrat compared to values of between 7.00 and 7.80 for the less experienced observers (Table 88). However, even when the data was combined into two groups (experienced vs. inexperienced) there was no significant difference in overall mean richness (95% confidence intervals).

There were, however, significant differences among observers in both the single estimate of cover and the summed cover of all taxa. For the single estimate of cover these differences showed no relationship with experience and ranged from 60.8 to 75.8. The same was true for summed cover, ranging from 71.2 to 129.0.

Forty-nine taxa were recorded over the 20 quadrats by the four observers, although forty-one was the most recorded by any one observer (Table 89). Experienced observers generally saw more taxa overall (41 and 40 vs. 33 and 33). Most of the taxa in disagreement were at low abundances overall, though two had considerable cover (*Pinus strobus*) or frequency (*Spirea alba*) and were missed by RA. *Pinus* was usually represented by overhanging branches and easily overlooked, whereas *Spirea* was likely miss-identified as *Salix* spp. Other taxa, such as *Eleocharis acicularis*, *Potentilla norvegica*, and *Lycopodium annotinum* were seen by both experienced observers but missed by the other two, while a number of taxa were seen by only one of the experienced observers (but at low numbers). Only one species (*Poa palustris*) was seen somewhat regularly (frequency=7) by a single experienced observer.

Only four taxa were found at frequencies greater than 50% (of 80 quadrats total, Table 90), including *Calamagrostis canadensis*, *Myrica gale*, *Lysimachia* spp., and non-*Sphagnum* moss, compared to seven in the peatland habitat.

Again, we calculated a percent accuracy, this time for shorelines by determining the number of times that individual taxa were found by only one observer, by two observers, by three, or by all four observers (Table 90). Taxa that had low accuracies include *Eleocharis acicularis* (found eight times by experienced observers only), non-*Sphagnum* moss, and *Poa palustris*, recorded seven times by one experienced observer (AH). Overall, the percent accuracy was greater here than in the peatlands (mean= 92.8%, Table 90), but this metric was not designed to compare across habitat types, due to the assumption that if a taxon was infrequent, found only twice for example, it was assumed to be correctly determined the 78 other possibilities (20 quadrats x four observers), and many infrequent taxa will bring up the mean.

Though observers agreed on the top three taxa by mean raw cover and mean relative cover (*Myrica gale*, *Calamagrostis canadensis*, and *Alnus incana*) (Tables 91 and 92), there was not agreement as to their order.

Of the top fifteen taxa by mean cover, there was only one significant difference among observers, with AH>RE for *Calamagrostis canadensis* (Table 91), though not if measured by relative cover (Table 92).

Table 88. Comparisons among observers in quadrat richness, total cover (one estimate), and total summed cover of all taxa in shoreline habitat over the same twenty quadrats, July 2005. Confidence intervals (CI) are set at 95%.

	Richness per quadrat					**Total Cover (one estimate)**					**Total Cover (summed all taxa)**			
	AH	**JM**	**RA**	**RE**		**AH**	**JM**	**RA**	**RE**		**AH**	**JM**	**RA**	**RE**
Q01	7	5	4	3		90	80	75	70		103.2	84.1	98	69
Q02	11	10	6	9		70	70	70	70		174.2	78.2	85	88.1
Q03	11	8	6	8		65	65	60	60		142.3	76.1	76.1	65
Q04	8	11	9	10		90	75	70	75		120.1	104.3	112.1	93.2
Q05	6	5	6	3		75	85	65	70		215.1	93	151	75
Q06	10	12	11	12		70	60	65	45		105	55.3	72.1	50.1
Q07	7	7	7	7		70	85	50	65		177	101	98	70
Q08	9	12	6	12		100	95	95	80		136.1	109	112	104
Q09	6	6	5	5		85	90	100	80		89.2	79	105	88
Q10	8	7	7	6		90	80	80	45		123.1	73	88.1	59
Q11	7	9	8	10		60	85	65	55		168.2	87	125	70
Q12	9	10	12	11		90	70	75	55		134.3	93	118.2	84.1
Q13	9	8	7	6		85	85	70	70		131.3	94.2	87.1	82
Q14	8	8	5	8		75	85	80	60		122.1	110	129	89
Q15	7	6	8	7		60	80	95	65		167.1	97	168.1	79
Q16	7	8	6	7		30	60	95	35		12.3	65	113	26.2
Q17	10	9	8	10		45	65	60	45		81.4	73	101.1	34.1
Q18	6	4	6	5		12	45	33	35		63.2	37	42	21
Q19	8	7	6	11		70	75	100	70		176.1	74	111	105
Q20	10	7	7	6		85	80	100	65		139.2	109	65	72
Mean	8.20	7.95	7.00	7.80		70.85	75.75	75.15	60.75		129.03	84.61	102.85	71.19
St.Dev.	1.61	2.26	1.95	2.76		21.79	12.17	18.26	13.70		46.19	19.08	28.98	23.52
CI lower	7.45	6.89	6.09	6.51		60.65	70.05	66.60	54.34		107.41	75.68	89.28	60.18
CI upper	8.95	9.01	7.91	9.09		81.05	81.45	83.70	67.16		150.64	93.54	116.41	82.20
Overall means experienced						**Overall means in-experienced**								
		Cover	Cover					Cover	Cover					
	Rich	One est.	summed				Rich	One est.	summed					
Mean	8.08	73.30	106.82				7.40	67.95	87.02					
St.dev.	1.94	17.60	41.50				2.39	17.52	30.59					
CI lower	7.46	67.68	93.55				6.63	62.35	77.24					
CI upper	8.69	78.92	120.08				8.17	73.55	96.79					

Table 89. Comparison among observers in their estimates of total raw cover and frequency for all taxa in the same twenty, 1 m x 1 m quadrats sampled on shorelines, July 2005. Taxa sorted by overall cover.

		AH	**AH**	**JM**	**JM**	**RA**	**RA**	**RE**	**RE**
Genus	**species**	**Cover**	**freq.**	**Cover**	**freq.**	**Cover**	**freq.**	**Cover**	**freq.**
Myrica	*gale*	664	17	493	15	560	16	446	16
Calamagrostis	*canadensis*	782.2	20	444	18	569	18	367.1	18
Alnus	*incana*	437	9	305	10	453.1	9	189	10
moss	spp.	121.4	16	57	11	147	14	34	7
Pinus	*strobus*	225	3	39	3			55	3
Chamaedaphne	*calyculata*	70	1	65	1	75	2	60	1
Spiraea	*alba*	73.1	6	48	5			34	5
Potentilla	*palustris*	23.1	8	52	10	31	6	30	8
Lysimachia	spp.	19.1	12	22.1	10	55	14	30	12
Polygonum	*amphibium*	26.1	5	35	5	33	3	26	6
Salix	spp.	13	3	4	1	32	2	42	7
Carex	*rostrata/vesicaria*	7	2	23	8	25	7	17	8
Equisetum	spp.	7.2	7	10.2	8	10.1	5	15	11
Onoclea	*sensibilis*	8	1	2	1	6	1	20	1
Eleocharis	*acicularis*	24.2	4	7.1	4				
Lycopus	spp.	3.1	3	9.1	7	9	5	10	6
Populus	*tremuloides*	18	2	10	2	3	1		
Phalaris	*arundinaceae*	6	1	12	3	7	4	4.1	4
Campanula	*aparinoides*	2	2	8	4	4.3	6	11	6
Triadenum	*fraseri*			8	4	3	3	8	5
Scirpus	*cyperinus*	12	3	2	1	1	1	2.1	2
Aster	spp.	8.1	3	3.1	3	5	1		
Galium	spp.	5.2	5	5.1	4	5	2		
Fraxinus	spp.	7	3	4	1			3	1
Sium	*suave*	2.2	3	3	2	5.1	4	3	3
Cornus	*sericea*	4	1	3	1	4	2	2	1
Trientalis	*borealis*	0.1	1	4	1	4	2	3	1
Poa	*palustris*	7.2	7						
Glyceria	*grandis*			1	1	0.1	1	6	4
Maianthemum	*canadensis*	0.1	1	3	2	2	2	1	1
Acorus	*calamus*	1	1	1	1	1	1	2	1
Lathyrus	*palustris*	0.1	1	2	1	2	1		
Sagittaria	*latifolia*	1	1	2	1	1	1		
Acer	*rubrum*	1.1	2	1	1			1	1
Carex	spp.	0.1	1			2	2		
Carex	*tenera (ovales)*	1	1			0.1	1	1	1
Thelypteris	*palustris*	0.1	1			1	1	1	1
Cicuta	spp.			0.2	2	1	1	0.2	2
Potentilla	*norvegica*	0.2	2	1.1	2				
Lycopodium	*annotinum*	0.1	1	1	1			0.1	1
Carex	*canescens*			1	1				
Ranunculus	*reptans*			1	1				
Agrostis	spp.			0.1	1			0.1	1
Stachys	*palustris*			0.1	1			0.1	1
Cornus	*canadensis*	0.1	1						
Impatiens	*capensis*					0.1	1		
Linnaea	*borealis*	0.1	1						
Scutellaria	*latifolia*	0.1	1						
Seedling	unknown	0.1	1						
	Total taxa by observer		41		40		33		33

Table 90. Frequency of occurrence and consistency of observations for all shoreline taxa sampled in 20 quadrats by each of four observers (four observers, each with 20 quadrats = 80 quadrats total).

Genus	species	Frequency per 80 quadrats	Of the twenty quadrats sampled by different observers, number of times where taxa on list was found: By only one obs.	By two obs.	By three obs.	By all four obs.	Never seen	Total # quadrats seen at least once	Estimated % percent accuracy
Acer	*rubrum*	4	1		1		18	2	95.0
Acorus	*calamus*	4				1	19	1	100.0
Agrostis	spp.	2		1			19	1	97.5
Alnus	*incana*	38			2	8	10	10	97.5
Aster	spp.	7	2	1	1		16	4	88.8
Calamagrostis	*canadensis*	74		2	2	16	0	20	92.5
Campanula	*aparinoides*	18	6	1	2	1	10	10	85.0
Carex	*canescens*	1	1				19	1	96.3
Carex	spp.	3	3				17	3	93.8
Carex	*rostrata/vesicaria*	25		1	5	2	12	8	91.3
Carex	*tenera (ovales)*	3			1		19	1	98.8
Chamaedaphne	*calyculata*	5	1			1	18	2	98.8
Cicuta	spp.	5	1	2			17	3	93.8
Cornus	*canadensis*	1	1				19	1	96.3
Cornus	*sericea*	5	2		1		17	3	96.3
Eleocharis	*acicularis*	8	4	2			14	6	80.0
Equisetum	spp.	31	2	3	1	5	9	11	88.8
Fraxinus	spp.	5	2		1		17	3	91.3
Galium	spp.	11	2	3	1		14	6	83.8
Glyceria	*grandis*	6	4	1			15	5	92.5
Impatiens	*capensis*	1	1				19	1	98.8
Lathyrus	*palustris*	3			1		19	1	98.8
Linnaea	*borealis*	1	1				19	1	96.3
Lycopodium	*annotinum*	3			1		19	1	98.8
Lycopus	spp.	21	1	1	2	3	13	7	91.3
Lysimachia	spp.	48	2	4	2	8	4	16	85.0
Maianthemum	*canadensis*	6			2		18	2	97.5
moss	spp.	48	4	3	6	5	2	18	72.5
Myrica	*gale*	65		1	1	15	3	17	96.3
Onoclea	*sensibilis*	4				1	19	1	100.0
Phalaris	*arundinaceae*	12	3	1	1	1	14	6	92.5
Pinus	*strobus*	9			3		17	3	96.3
Poa	*palustris*	7	7				13	7	73.8
Polygonum	*amphibium*	19		1	3	2	14	6	93.8
Populus	*tremuloides*	5		1	1		18	2	96.3
Potentilla	*norvegica*	4	2	1			17	3	90.0
Potentilla	*palustris*	32	2	2	2	5	9	11	87.5
Ranunculus	*reptans*	1	1				19	1	96.3
Sagittaria	*latifolia*	3			1		19	1	98.8
Salix	spp.	13	4	3	1		12	8	83.8
Scirpus	*cyperinus*	7	3			1	16	4	91.3
Scutellaria	*latifolia*	1	1				19	1	96.3
Seedling	unknown	1	1				19	1	96.3
Sium	*suave*	12	5		1	1	13	7	90.0
Spiraea	*alba*	16	1		5		14	6	90.0
Stachys	*palustris*	2		1			19	1	97.5
Thelypteris	*palustris*	3			1		19	1	98.8
Triadenum	*fraseri*	12	2	2	2		14	6	90.0
Trientalis	*borealis*	5	2		1		17	3	93.8
								mean	92.8

Table 91. Comparison among observers in their estimates of mean raw cover for the fifteen most abundant taxa in the same twenty shoreline quadrats, July 2005. Taxa are sorted by overall cover, and bolded taxa and values indicate significant differences among observers. "Lower" and "upper" indicate the ranges of the 95% confidence intervals (CI).

		AH	**AH**	**AH**	**AH**	**JM**	**JM**	**JM**	**JM**	**RA**	**RA**	**RA**	**RA**	**RE**	**RE**	**RE**	**RE**	
Genus	**species**	**Mean**	**Stdev.**	**Lower**	**Upper**	**Mean**	**Stdev.**	**Lower**	**Upper**	**Mean**	**Stdev.**	**Lower**	**Upper**	**Mean**	**Stdev.**	**Lower**	**Upper**	**Total cover all obs.**
Myrica	*gale*	33.2	32.1	18.2	48.2	24.7	24.6	13.2	36.1	28.0	26.4	15.6	40.4	22.3	23.2	11.4	33.2	27.04
Calamagrostis	***canadensis***	**39.1**	26.0	26.9	51.3	22.2	21.7	12.1	32.3	28.5	23.6	17.4	39.5	**18.4**	17.3	10.2	26.5	27.03
Alnus	*incana*	21.9	29.5	8.0	35.7	15.3	19.3	6.2	24.3	22.7	32.4	7.5	37.8	9.5	12.0	3.8	15.1	17.30
moss	spp.	6.1	7.7	2.5	9.7	2.9	4.4	0.8	4.9	7.4	8.8	3.2	11.5	1.7	3.6	0.0	3.4	4.49
Pinus	*strobus*	11.3	28.5	-2.1	24.6	2.0	5.8	-0.8	4.7	0.0	0.0	0.0	0.0	2.8	7.2	-0.6	6.1	3.99
Chamaedaphne	*calyculata*	3.5	15.7	-3.8	10.8	3.3	14.5	-3.6	10.1	3.8	13.7	-2.6	10.1	3.0	13.4	-3.3	9.3	3.38
Spiraea	*alba*	3.7	8.5	-0.3	7.6	2.4	5.9	-0.4	5.2	0.0	0.0	0.0	0.0	1.7	3.8	-0.1	3.5	1.94
Potentilla	*palustris*	1.2	2.0	0.2	2.1	2.6	3.7	0.9	4.3	1.6	3.0	0.1	3.0	1.5	2.2	0.5	2.5	1.70
Lysimachia	spp.	1.0	1.1	0.4	1.5	1.1	1.4	0.4	1.8	2.8	3.1	1.3	4.2	1.5	1.6	0.7	2.3	1.58
Polygonum	*amphibium*	1.3	3.5	-0.3	2.9	1.8	3.9	-0.1	3.6	1.7	5.6	-1.0	4.3	1.3	2.8	0.0	2.6	1.50
Salix	spp.	0.7	1.8	-0.2	1.5	0.2	0.9	-0.2	0.6	1.6	5.7	-1.1	4.3	2.1	4.7	-0.1	4.3	1.14
Carex	*rostrata/vesicaria*	0.4	1.1	-0.2	0.9	1.2	1.9	0.3	2.0	1.3	2.1	0.2	2.3	0.9	1.2	0.3	1.4	0.90
Equisetum	spp.	0.4	0.7	0.0	0.7	0.5	0.8	0.1	0.9	0.5	1.1	0.0	1.0	0.8	0.8	0.4	1.1	0.53
Onoclea	*sensibilis*	0.4	1.8	-0.4	1.2	0.1	0.4	-0.1	0.3	0.3	1.3	-0.3	0.9	1.0	4.5	-1.1	3.1	0.45
Eleocharis	*acicularis*	1.2	4.5	-0.9	3.3	0.4	0.9	-0.1	0.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.39

Table 92. Comparison among four observers in their estimates of mean relative cover for the fifteen most abundant taxa in the same twenty quadrats sampled along shoreline habitat, July 2005. Taxa sorted by overall cover. Bolded taxa and means indicate significant differences in observer estimates. “Lower” and “upper” indicate the ranges of the 95% confidence intervals (CI).

		AH	**AH**	**AH**	**AH**	**JM**	**JM**	**JM**	**JM**	**RA**	**RA**	**RA**	**RA**	**RE**	**RE**	**RE**	**RE**
Genus	**species**	**Mn**	**Stdev**	**Lower**	**Upper**	**Mn**	**Stdev**	**Lower**	**Upper**	**Mn**	**Stdev**	**Lower**	**Upper**	**Mn**	**Stdev**	**Lower**	**Upper**
Myrica	*gale*	24.3	24.8	12.7	35.9	27.6	27.3	14.8	40.3	27.4	26.1	15.2	39.6	27.8	27.0	15.2	40.4
Calamagrostis	*canadensis*	27.6	19.0	18.7	36.5	25.0	23.7	13.9	36.1	28.7	23.9	17.5	39.9	24.5	22.2	14.1	34.9
Alnus	*incana*	17.6	26.3	5.3	30.0	20.3	27.9	7.3	33.3	20.7	29.2	7.0	34.4	18.5	24.1	7.2	29.8
moss	spp.	7.0	11.5	1.6	12.4	3.3	5.3	0.8	5.8	6.8	8.3	2.9	10.6	3.1	5.9	0.3	5.8
Pinus	*strobus*	6.9	17.4	-1.2	15.0	2.5	7.5	-1.0	6.0					3.1	8.0	-0.6	6.9
Chamaedaphne	*calyculata*	3.9	17.5	-4.3	12.1	4.1	18.4	-4.5	12.7	3.3	12.8	-2.7	9.3	3.4	15.2	-3.7	10.5
Spiraea	*alba*	2.9	6.5	-0.2	5.9	2.7	6.5	-0.3	5.8	0.0	0.0	0.0	0.0	2.4	5.4	-0.2	4.9
Potentilla	*palustris*	0.8	1.4	0.2	1.5	2.9	4.1	1.0	4.8	1.4	2.7	0.2	2.7	1.9	2.7	0.6	3.2
Lysimachia	spp.	0.8	1.1	0.3	1.3	1.6	2.2	0.5	2.6	2.8	3.2	1.3	4.3	2.2	2.1	1.2	3.2
Polygonum	*amphibium*	0.9	2.5	-0.2	2.0	2.1	4.4	0.1	4.2	2.1	7.4	-1.3	5.6	1.6	3.4	0.0	3.2
Salix	spp.	0.4	0.9	-0.1	0.8	0.3	1.2	-0.3	0.8	1.2	3.9	-0.6	3.0	2.9	6.5	-0.1	5.9
Carex	*rostrata/vesicaria*	0.2	0.8	-0.1	0.6	1.3	2.2	0.3	2.4	1.4	2.4	0.3	2.5	1.1	1.5	0.4	1.8
Equisetum	spp.	0.6	1.8	-0.2	1.5	0.7	1.1	0.1	1.2	0.6	1.5	-0.1	1.3	1.3	1.9	0.4	2.1
Onoclea	*sensibilis*	0.3	1.3	-0.3	0.9	0.1	0.5	-0.1	0.3	0.3	1.1	-0.3	0.8	1.2	5.3	-1.3	3.7
Eleocharis	*acicularis*	0.7	2.7	-0.5	2.0	0.6	1.6	-0.1	1.3								

Similarity Comparisons in all Habitat Types

Similarity index values measuring the percent similarity among observers in presence and absence of species on a quadrat basis were calculated for all three habitat types (Table 93). The index used, often indicated by the formula 2w/(a + b)*100, varies from 0%, no shared species among observers, to 100% , or total agreement as to the species present within a quadrat. Each observer-to-observer similarity listed in Table 93 is a mean of 20 quadrat comparisons.

In general observers agreed more in their floristic assessments of the aquatic and peatland habitats, with overall mean similarities of 85.6% and 81.6% respectively, with less similarity seen at the quadrat level in the shorelines (69.6%). This is likely due to a greater species pool in the shorelines, as more taxa are subject to omission.

We expected more similarity among experienced observers, but this was only significant in the case of the peatland quadrats (with experienced similarities, AH to JM at 87.2% > RA to RE at 79.8%).

Table 93. Summary of taxonomic presence /absence similarity comparisons among observers at three different habitat types. AH and JM were experienced samplers, others received training prior to the assessment. Similarilty index used = 2w/(a+b). Bolded comparisons are among experienced samplers, and confidence intervals (CI) are set at 95%

Shoreline similarities			**Means**	**St. dev.**	**CI lower**	**CI upper**
	compare shoreline AH to JM		72.8%	9.9%	68.2%	77.5%
	compare shoreline AH to RA		66.6%	12.5%	60.7%	72.4%
	compare shoreline AH to RE		64.9%	10.1%	60.2%	69.6%
	compare shoreline JM to RA		69.4%	12.6%	63.6%	75.3%
	compare shoreline JM to RE		76.7%	8.9%	72.5%	80.8%
	compare shoreline RA to RE		67.3%	9.0%	63.2%	71.5%
	Summary shoreline similarities		Mean	st.dev.	CI lower	CI upper
		Overall values	69.6%	11.1%	67.6%	71.6%
Peatland similarities			**Means**	**St. dev.**	**CI lower**	**CI upper**
	compare peatland AH to JM		87.2%	1.7%	90.7%	83.7%
	compare peatland AH to RA		80.6%	1.3%	83.2%	77.9%
	compare peatland AH to RE		82.4%	1.6%	85.7%	79.1%
	compare Peatland JM to RA		79.0%	1.6%	82.3%	75.7%
	compare peatland JM to RE		80.8%	1.6%	84.1%	77.4%
	compare peatland RA to RE		79.8%	1.3%	82.5%	77.2%
	Summary peatland similarities		Mean	st.dev.	CI lower	CI upper
		Overall values	81.6%	7.1%	80.4%	82.9%
Aquatic similarities			**Means**	**St. dev.**	**CI lower**	**CI upper**
	Compare aquatic AH to JM		85.3%	7.0%	82.0%	88.6%
	Compare aquatic AH to RE		89.8%	8.0%	86.0%	93.5%
	Compare aquatic AH to RW		83.6%	10.5%	78.7%	88.5%
	Compare aquatic JM to RE		91.7%	7.8%	88.1%	95.3%
	Compare aquatic JM to RW		80.3%	10.4%	75.4%	85.2%
	Compare aquatic RE to RW		82.7%	7.8%	79.1%	86.3%
	Summary aquatic similarities		Mean	st.dev.	CI lower	CI upper
		Overall values	85.6%	9.4%	83.9%	87.3%

Placement Bias

We have called placement bias the variability inherent in different random placement of quadrats along a transect and the relationship between this placement and the investigation of the minimum number of sub-samples (in this case quadrats) needed to produce reliable estimates. We did this investigation in the same habitat types that we tested in observer bias, including peatlands, aquatic segments, and shoreline segments.

Methods

Field Methods

To assess variability among the different random placement of sampling frames, transects were placed along segments of shoreline (Deep Slu in Namakan Lake 0.0 m contour, approximately 250 m long), deep aquatic habitat (Deep Slu 2.0 m contour, approximately 300 m long), and peatland habitat (NAM US1, 50 m long). Each transect was assessed by a single observer, JM for shoreline and peatlands and AH for aquatic, to minimize observer bias (above), and the cover of all taxa observed were recorded for each of fifty, 1 m x 1 m quadrats. We used the same quadrat methodology as described in the intensive and peatland sections.

Along the shoreline segments we randomly placed one quadrat in each 5 m segment, and hence sampled about 20% of the whole habitat (50/250). For the aquatic segment we sampled about 16% of the total (50/300), and in peatland we sampled every quadrat along a 50 m transect struck in a portion of the total peatland. In all cases our intuition suggests that 50 quadrats (thus 16-20% of the whole) is excessive, but we wanted to determine empirically how our chosen number of quadrats (20 in the peatland and intensive site analyses) fared against both smaller (10-15) and larger (25 and up) sample sizes.

The raw quadrat data for all the placement bias sampling is included in Meeker and Harris (2008), along with the waypoint locations and maps of the sites used.

Analyses

For each habitat type, we first ordered the quadrats 1-50 in the manner they were sampled, and from that pool of quadrat data ran 10 separate sub-sampling trials by randomly choosing among the 50 quadrats and creating progressively larger sample sizes. We did this with the goal of determining how variability in estimates of mean cover changes with increasing sample size. For example in one trial, quadrat number 22 could have been chosen as the first quadrat, followed by quadrat 17, quadrat 8, quadrat 33, and quadrat 46. At this point, after only five quadrats, the mean for each taxa of that one trial was computed, then five more quadrats were chosen for a total of 10, then five more for a total of 15, and so on for 20, 25, and up to the total of all of the 50 quadrats that were sampled. Once 10 trials were completed, a reporting for each taxa of the variability of the estimated means using progressively more quadrats was determined. In each case we can then compare the high and low mean estimates using variable number of quadrats with that of the pseudo “true” mean (the mean of all 50 quadrats).

Results

The total and mean cover, frequency, and relative cover for all taxa over all 50 quadrats in the peatland, aquatic, and shoreline transects are summarized in Tables 94 to 96 respectively.

Peatland Placement Assessment

Twenty-six taxa were recorded in the peatland community, and nine taxa were found in greater than 90% of all the quadrats (with frequencies of 45 and more, Table 94). Five taxa had mean cover values (over all 50 quadrats) of 9% and greater, and accounted for 80.1% of all relative cover (Table 94).

In addition to looking at the abundance of individual taxa, we looked at changes in variability with sample size in five composite metrics (Table 97), including total cover (single estimate), summed cover (all taxa), *Typha* stem densities (live and dead), and quadrat richness. In most cases standard deviation begins to level off at sample sizes of 20-25 quadrats. For example using only five quadrats per sample resulted in total cover (one estimate) means varying from a high of 76 to a low of 65, while using 25 quadrats the spread was less (71.6 to 68.6%), while standard deviation dropped from 3.36 (5 quadrats) to 0.94 (25 quadrats).

Changes in variability about the means using increasing sample sizes were calculated for the twelve most abundant taxa by total cover (Table 98). The most abundant taxon, *Carex lacustris*, had low and high estimates of 14.0 to 25.4% using five quadrats (compared to the pseudo "true" mean of 19.3%), while by increasing sample size to 20 quadrats the variability is reduced to a range of 17.1 and 21.7%, or about 11-12% around the 50 quadrat mean of 19.3. Some taxa, even though they were fairly abundant, had greater variability, such as seen with *Carex utriculata*. Using the 20 quadrat sample, this sedge had extreme estimates of 9.7 to 18.3 below and above the 50 quadrat sample mean (13.1), or 26 to 40 % above and below this mean.

Typha is a taxa that VNP has an interest in monitoring, and these trials advocate that if 20 quadrats are used then differences in abundance over two time periods need to exceed about 25% to suggest a real change (13.1 and 7.9 are about 25% above and below the 10.2 50-quadrat mean).

Aquatic Placement Assessment

Sixteen taxa were recorded in the aquatic transect, and only three taxa had mean cover values (per quadrat) greater than 2% (Table 95). Overall the aquatic habitat had a low per quadrat cover (Table 99) as assessed by both a single estimate (22.1%, using 50 quadrats, Table 99) and summed for all taxa (24.9%).

Wild celery (*Vallisneria americana*) was the most abundant aquatic taxa, averaging 13.3% per 1 m^2 over all 50 quadrats (Table 100). Using 20 quadrats, the extreme estimates of the mean cover for *Vallisneria* over the ten trials ranged between 9.8 and 17.6%, or about 26-32% around a mean of 13.3 using all 50 quadrats. The "true means" of all the other taxa were less than 5% per 1 m x 1 m quadrat, a patchily vegetated site. Yet the utilization of 20 quadrats noted the presence of all taxa in all trials except one (*Bidens beckii*), in only 1 of the 10 trials. (Using twenty quadrats one estimate of *Bidens* cover was 0.0, see Table 100)

Shoreline Placement Assessment
Fifty-two taxa were recorded in the shoreline community, but only two taxa (*Calamagrostis canadensis* and *Myrica gale*) had frequencies greater than 80% (occurring in 40 or more quadrats, Table 96). These two taxa, with the addition of *Alnus incana*, were the only taxa with per quadrat cover values greater than 10%. Seven taxa accounted for 82.1% of all relative cover (Table 96).

Estimates of percent cover over all 50 quadrats varied from 75.6% (single estimate) to 91% (summed) (Table 101). Using a 20 quadrat sample to estimate summed cover resulted in low and high estimates of 84.3 and 96%, or only 6-8% around the "true" mean.

Using only five quadrats, the estimated mean cover of *Myrica gale* varied from 6.8% (the lowest estimate of the 10 trials) to 36% (the highest estimate of the 10 trials), with a standard deviation (for the 10 trials) of 8.9 (Table 102). This variability declined to 6.2 using 10 quadrats, to 5.0 using 15 quadrats, and to 4.7 using 20 quadrats. At 20 quadrats, the number used in our intensively sampled sites, the estimation of the mean cover for *Myrica gale* varied between 23.8 and 37.5, compared with the 30.6 mean using all 50 quadrats. Hence by using 20 quadrats, the extreme estimates of *Myrica* cover (the low and high) can be expected to be about 23% above and below the 'true' mean (37.6 is about 23% greater than 30.6).

Using 20 quadrats, the extreme mean estimates for *Calamagrostis canadensis* varied between 13.0 and 20.7, or about 25% around the 50 quadrat mean of 17.9%.

(The estimates of the trial means converge at the "true" mean of 17.9, with no variance at 50, as the same 50 quadrats are used for each trial.)

For almost all taxa, it appears that the use of 20 quadrats occurs at or beyond the inflection point if a graph of standard deviation were to be viewed. These data suggest that 15-25 quadrats provide a fair estimate of the abundance in shoreline transects for most taxa. Of the taxa shown in Table 102, white pine (*Pinus strobus*) was an exception. It was the patchiest, found at fairly high cover values in individual quadrats, but occurring only in 8 of 50 quadrats (Table 96), and with even 20 quadrats, one randomization suggested a mean cover of 0.0, although this was an extreme case.

Table 94. Total and mean cover, frequency, and relative cover for all taxa sampled in 50 quadrats used to test placement bias in a peatland habitat adjacent to Namakan Lake, July 20, 2006.

	Alphabetical Order					**Ordered by Cover**				**Cumulative relative Cover**
			Total Cover	**Freq.**				**mean cover**	**Relative Cover**	
	Genus	**species**				**Genus**	**species**			
1	*Acorus*	*calamus*	22.2	18		*Carex*	*lacustris*	19.3	24.5	24.5
2	*Alnus*	*incana*	44	4		*Carex*	*utriculata*	13.1	16.6	41.0
3	*Calamagrostis*	*canadensis*	545	50		*Calamagrostis*	*canadensis*	10.9	13.8	54.8
4	*Calla*	*palustris*	91	20		*Typha*	*latifolia*	10.2	12.9	67.7
5	*Campanula*	*aparinoides*	30.4	38		*Potentilla*	*palustris*	9.8	12.4	80.1
6	*Carex*	*lasiocarpa*	27.5	24		*Sphagnum*	spp.	3.3	4.1	84.3
7	*Carex*	*lacustris*	965	50		*Calla*	*palustris*	1.8	2.3	86.6
8	*Carex*	*utriculata*	653	49		*moss*	spp.	1.8	2.3	88.8
9	*Epilobium*	*leptophyllum*	8.4	12		*Spirea*	*alba*	1.1	1.4	90.3
10	*Galium*	sp.	8.4	12		*Salix*	spp.	1.1	1.4	91.7
11	*Iris*	*versicolor*	6	1		*Lysimachia*	spp.	1.1	1.4	93.1
12	*Lysimachia*	spp.	55.4	42		*Polygonum*	*amphibium*	1.0	1.3	94.4
13	*moss*	spp.	88.8	37		*Alnus*	*incana*	0.9	1.1	95.5
14	*Polygonum*	*amphibium*	52.1	21		*Campanula*	*aparinoides*	0.6	0.8	96.3
15	*Potentilla*	*palustris*	490	50		*Triadenum*	*fraseri*	0.6	0.7	97.0
16	*Rumex*	sp.	1	1		*Carex*	*lasiocarpa*	0.6	0.7	97.7
17	*Salix*	spp.	56	5		*Acorus*	*calamus*	0.4	0.6	98.3
18	*Scirpus*	*cyperinus*	10	3		*Scutellaria*	sp.	0.3	0.4	98.6
19	*Scutellaria*	sp.	14.1	12		*Thelypteris*	*palustris*	0.3	0.3	99.0
20	*Sphagnum*	spp.	162.9	45		*Scirpus*	*cyperinus*	0.2	0.3	99.2
21	*Spirea*	*alba*	57	4		*Epilobium*	*leptophyllum*	0.2	0.2	99.4
22	*Thelypteris*	*palustris*	13	3		*Galium*	sp.	0.2	0.2	99.6
23	*Triadenum*	*fraseri*	28	17		*Viola*	sp.	0.1	0.2	99.8
24	*Typha*	*latifolia*	508	50		*Iris*	*versicolor*	0.1	0.2	99.9
25	*Utricularia*	*intermedia*	1	1		*Rumex*	sp.	0.0	0.0	100.0
26	*Viola*	sp.	6.1	5		*Utricularia*	*intermedia*	0.0	0.0	100.0
		Totals	3944					78.9	100.0	

Table 95. Total and mean cover, frequency, and relative cover for all taxa sampled in 50 quadrats used to test placement bias in aquatic habitat, Deep Slu, Namakan Lake, July 2004.

	Alphabetical Order					**Ordered by Cover**				**Cumulative relative Cover**
			Total Cover	**Freq.**				**mean cover**	**Rel. Cover**	
	Genus	**species**				**Genus**	**species**			
1	*Bidens*	*beckii*	5.4	7		*Vallisneria*	*americana*	13.3	53.4	53.4
2	*Ceratophyllum*	*demersum*	78.1	30		*Myriophyllum*	spp.	3.6	14.3	67.7
3	*Elodea*	*canadensis*	44	31		*Najas*	*flexilis*	2.7	10.8	78.5
4	*Isoetes*	spp.	20.7	16		*Ceratophyllum*	*demersum*	1.6	6.3	84.8
5	*Juncus*	*pelocarpus*	0.1	1		*Potamogeton*	*richardsonii*	1.2	4.7	89.5
6	*Myriophyllum*	spp.	178	30		*Elodea*	*canadensis*	0.9	3.5	93.0
7	*Najas*	*flexilis*	134	34		*Potamogeton*	*vaseyi*	0.8	3.3	96.3
8	*Nitella*	spp.	4.3	5		*Isoetes*	spp.	0.4	1.7	98.0
9	*Nymphaea*	*odorata*	9.6	12		*Nymphaea*	*odorata*	0.2	0.8	98.8
10	*Potamogeton*	*gramineus*	3	1		*Bidens*	*beckii*	0.1	0.4	99.2
11	*Potamogeton*	*richardsonii*	58.3	23		*Nitella*	spp.	0.1	0.3	99.5
12	*Potamogeton*	*spirillus*	0.1	1		*Potamogeton*	*gramineus*	0.1	0.2	99.8
13	*Potamogeton*	*vaseyi*	41.4	30		*Ranunculus*	*longirostris*	0.0	0.1	99.9
14	*Potamogeton*	*zosteriformis*	1.1	2		*Potamogeton*	*zosteriformis*	0.0	0.1	100.0
15	*Ranunculus*	*longirostris*	1.4	5		*Juncus*	*pelocarpus*	0.0	0.0	100.0
16	*Vallisneria*	*americana*	664.1	50		*Potamogeton*	*spirillus*	0.0	0.0	100.0
		Totals	1244					24.9		

Table 96. Total and mean cover, frequency, and relative cover for all taxa sampled in 50 quadrats used to test placement bias, in shoreline habitat at Deep Slu, Namakan Lake, July 2004.

	Alphabetical Order		**Total Cover**			**Ordered by Cover**		**Mean Cover**	**Rel. Cover**	**Cum. Rel. Cover**
	Genus	**species**		**Freq.**		**Genus**	**species**			
1	*Acer*	*rubrum*	1.2	3		*Myrica*	*gale*	30.6	33.7	33.7
2	*Acorus*	*calamus*	1.0	1		*Calamagrostis*	*canadensis*	17.9	19.6	53.3
3	*Agrostis*	*hyemalis*	0.1	1		*Alnus*	*incana*	11.7	12.9	66.2
4	*Alnus*	*incana*	586.0	23		*Pinus*	*strobus*	4.4	4.8	71.0
5	*Asclepias*	*incarnata*	3.0	2		*moss*	spp.	4.2	4.7	75.7
6	*Aster*	spp.	12.1	8		*Spiraea*	*alba*	3.1	3.4	79.1
7	*Calamagrostis*	*canadensis*	894.0	47		*Potentilla*	*palustris*	2.7	3.0	82.1
8	*Campanula*	*aparinoides*	29.2	16		*Carex*	*rostrata*	2.5	2.8	84.9
9	*Carex*	*canescens*	9.0	2		*Scirpus*	*cyperinus*	1.4	1.5	86.4
10	*Carex*	*lacustris*	2.0	1		*Chamaedaphne*	*calyculata*	1.3	1.4	87.8
11	*Carex*	*ovales group*	3.0	2		*Polygonum*	*amphibium*	1.2	1.3	89.1
12	*Carex*	*rostrata*	127.0	28		*Lysimachia*	spp.	1.1	1.3	90.4
13	*Carex*	spp.	8.0	2		*Equisetum*	spp.	0.8	0.9	91.3
14	*Chamaedaphne*	*calyculata*	65.0	1		*Triadenum*	*fraseri*	0.8	0.9	92.2
15	*Cicuta*	spp.	4.4	7		*Lycopus*	*uniflorus*	0.7	0.8	92.9
16	*Cornus*	*sericea*	7.0	2		*Lysimachia*	*terrestris*	0.7	0.7	93.7
17	*Eleocharis*	*acicularis*	12.2	8		*Salix*	spp.	0.7	0.7	94.4
18	*Equisetum*	spp.	42.3	24		*Campanula*	*aparinoides*	0.6	0.6	95.1
19	*Fraxinus*	spp.	7.0	2		*Phalaris*	*arundinaceae*	0.4	0.5	95.5
20	*Galium*	spp.	21.4	15		*Galium*	spp.	0.4	0.5	96.0
21	*Glyceria*	*borealis*	1.0	1		*Glyceria*	*grandis*	0.4	0.4	96.4
22	*Glyceria*	*grandis*	18.0	7		*Poa*	*palustris*	0.3	0.4	96.8
23	*Juncus*	*filiformis*	4.0	2		*Sagittaria*	*latifolia*	0.3	0.3	97.1
24	*Lathyrus*	*palustris*	2.0	1		*Eleocharis*	*acicularis*	0.2	0.3	97.3
25	*Lycopodium*	spp.	1.0	1		*Aster*	spp.	0.2	0.3	97.6
26	*Lycopus*	spp.	35.1	17		*Populus*	*tremuloides*	0.2	0.2	97.8
27	*Lysimachia*	*terrestris*	34.0	13		*Carex*	*canescens*	0.2	0.2	98.0
28	*Lysimachia*	spp.	57.1	22		*Potentilla*	*norvegica*	0.2	0.2	98.2
29	*Maianthemum*	*canadense*	3.0	2		*Carex*	spp.	0.2	0.2	98.4
30	*moss*	spp.	212.0	37		*Sium*	*suave*	0.2	0.2	98.5
31	*Myrica*	*gale*	1532.0	43		*Cornus*	*sericea*	0.1	0.2	98.7
32	*Onoclea*	*sensibilis*	6.0	4		*Fraxinus*	spp.	0.1	0.2	98.8
33	*Phalaris*	*arundinaceae*	22.0	6		*Onoclea*	*sensibilis*	0.1	0.1	99.0
34	*Pinus*	*strobus*	219.0	8		*Potamogeton*	*pusillus*	0.1	0.1	99.1
35	*Poa*	*palustris*	16.1	10		*Rosa*	*palustris*	0.1	0.1	99.2
36	*Polygonum*	*amphibium*	60.0	12		*Cicuta*	spp.	0.1	0.1	99.3
37	*Populus*	*tremuloides*	10.0	2		*Juncus*	*filiformis*	0.1	0.1	99.4
38	*Potamogeton*	*pusillus*	6.0	2		*Ranunculus*	*reptans*	0.1	0.1	99.5
39	*Potentilla*	*norvegica*	8.1	5		*Trientalis*	*borealis*	0.1	0.1	99.6
40	*Potentilla*	*palustris*	137.0	27		*Asclepias*	*incarnata*	0.1	0.1	99.6
41	*Ranunculus*	*reptans*	4.0	3		*Carex*	*ovales* group	0.1	0.1	99.7
42	*Rosa*	*palustris*	5.0	2		*Maianthemum*	*canadense*	0.1	0.1	99.8
43	*Rumex*	spp.	1.0	1		*Carex*	*lacustris*	0.0	0.0	99.8
44	*Sagittaria*	*latifolia*	13.0	4		*Lathyrus*	*palustris*	0.0	0.0	99.9
45	*Salix*	spp.	34.0	2		*Acer*	*rubrum*	0.0	0.0	99.9
46	*Scirpus*	*cyperinus*	68.0	14		*Acorus*	*calamus*	0.0	0.0	99.9
47	*Scutellaria*	*galericulata*	1.0	1		*Glyceria*	*borealis*	0.0	0.0	99.9
48	*Sium*	*suave*	8.0	6		*Lycopodium*	spp.	0.0	0.0	100.0
49	*Spiraea*	*alba*	155.0	11		*Rumex*	spp.	0.0	0.0	100.0
50	*Stachys*	*palustris*	0.1	1		*Scutellaria*	*galericulata*	0.0	0.0	100.0
51	*Triadenum*	*fraseri*	39.1	18		*Agrostis*	*hyemalis*	0.0	0.0	100.0
52	*Trientalis*	*borealis*	4.0	1		*Stachys*	*palustris*	0.0	0.0	100.0
		Totals	4550.5	481						

Table 97. Analysis of variability in total estimated cover, summed cover (all taxa), quadrat richness, and stem density of live and dead *Typha* sampled along a peatland transect by changing sample size (# of 1 m x 1 m quadrats). Ten different trials were analyzed, and for each trial sub-sets of 50 quadrats were randomly chosen. For each factor the mean, standard deviation, highest estimate, and lowest estimate is reported with increasing number of quadrats contributing to the estimate. (20 is the number of quadrats we have used to date for the intensively studied sites, and these values are bolded for comparisons.)

Values after stated number of quadrats:	**5**	**10**	**15**	**20**	**25**	**30**	**35**	**40**	**45**	**50**
Total Quadrat Cover (estimated)										
Mean	71	70	70	**70**	70	70	70	70	70	70
St. Dev.	3.4	2.1	1.6	**1.2**	0.9	0.9	0.8	0.5	0.4	0
Highest estimate of mean (one trial)	76	73	74	**72**	72	72	71	71	71	70
Lowest estimate of mean (one trial)	65	67	69	**69**	69	69	69	70	70	70
Quadrat Cover (summed)										
Mean	79.4	79.5	78.7	**79.0**	79.0	78.6	78.9	78.9	78.8	78.9
St. Dev.	7.9	5.3	3.5	**2.7**	2.5	1.9	1.3	1.2	0.7	0.0
Highest estimate of mean (one trial)	96.3	87.1	83.9	**83.4**	82.4	81.5	81.5	80.7	79.5	78.9
Lowest estimate of mean (one trial)	71.3	72.6	72.9	**75.5**	75.3	75.9	77.2	76.7	77.6	78.9
***Typha* stems live**										
Mean	3.7	3.7	3.6	**3.6**	3.6	3.6	3.6	3.6	3.6	3.6
St. Dev.	0.7	0.6	0.5	**0.5**	0.4	0.3	0.2	0.2	0.1	0.0
Highest estimate of mean (one trial)	5.2	4.8	4.3	**4.3**	4.2	4.1	3.9	3.8	3.8	3.6
Lowest estimate of mean (one trial)	3.0	2.8	2.9	**3.0**	3.0	3.2	3.3	3.3	3.5	3.6
***Typha* stems dead**										
Mean	2.8	2.6	2.6	**2.6**	2.6	2.6	2.6	2.6	2.6	2.6
St. Dev.	0.5	0.4	0.3	**0.2**	0.2	0.1	0.1	0.1	0.1	0.0
Highest estimate of mean (one trial)	3.6	3.4	3.0	**3.0**	2.9	2.8	2.7	2.7	2.7	2.6
Lowest estimate of mean (one trial)	2.2	2.2	2.1	**2.3**	2.4	2.4	2.4	2.5	2.5	2.6
Quadrat Richness										
Mean	12	12	12	**12**	11	11	11	11	11	11
St. Dev.	0.9	0.6	0.5	**0.3**	0.3	0.2	0.2	0.1	0.1	0
Highest estimate of mean (one trial)	13	12	12	**12**	12	12	12	12	12	11
Lowest estimate of mean (one trial)	11	11	11	**11**	11	11	11	11	11	11

Table 98. Analysis of variability in the estimated mean percent cover values (per 1 m x 1 m quadrat) for the twelve most abundant taxa along a peatland transect by changing sample size (# of quadrats). Ten different trials were analyzed, and for each trial sub-sets of the 50 quadrats were randomly chosen. For each taxon the standard deviation, highest estimate, and lowest estimate is reported with increasing number of quadrats contributing to the estimate. (20 is the number of quadrats we have used to date for the intensively studied sites, and is bolded for comparisons.)

Values after stated number of quadrats:	**5**	**10**	**15**	**20**	**25**	**30**	**35**	**40**	**45**	**50**
Carex lacustris										
St. Dev. of 10 random trials	3.9	2.8	1.8	**1.8**	1.2	1.0	0.9	0.7	0.4	0.0
Highest estimate of mean cover (one trial)	25.4	25.7	22.7	**21.7**	20.7	20.5	20.5	20.0	19.8	19.3
Lowest estimate of mean cover (one trial)	14.0	16.1	17.4	**17.1**	17.4	17.8	18.0	17.9	18.7	19.3
Carex utriculata										
St. Dev. of 10 random trials	5.5	4.5	3.9	**3.1**	2.5	2.2	1.7	1.0	0.6	0.0
Highest estimate of mean cover (one trial)	23.0	20.0	19.7	**18.3**	16.3	15.3	14.8	14.5	13.6	13.1
Lowest estimate of mean cover (one trial)	7.6	7.7	8.9	**9.7**	10.0	9.7	9.9	11.6	12.2	13.1
Calamagrostis canadensis										
St. Dev. of 10 random trials	5.2	3.7	3.3	**3.0**	2.4	1.8	1.2	0.9	0.4	0.0
Highest estimate of mean cover (one trial)	20.0	16.1	15.7	**15.7**	14.2	13.2	12.7	12.4	11.7	10.9
Lowest estimate of mean cover (one trial)	3.6	5.4	6.7	**7.0**	7.6	8.5	9.1	9.5	10.4	10.9
Typha latifolia										
St. Dev. of 10 random trials	3.2	2.2	1.7	**1.6**	1.3	1.1	0.8	0.6	0.4	0.0
Highest estimate of mean cover (one trial)	16.4	14.8	12.3	**13.1**	12.2	11.8	11.2	11.0	10.7	10.2
Lowest estimate of mean cover (one trial)	7.2	7.2	7.5	**7.9**	8.0	8.2	9.1	9.2	9.5	10.2
Potentilla palustris										
St. Dev. of 10 random trials	3.7	2.5	1.7	**1.7**	1.3	1.0	0.8	0.6	0.5	0.0
Highest estimate of mean cover (one trial)	17.4	13.4	11.3	**12.7**	11.8	11.2	10.9	10.4	10.3	9.8
Lowest estimate of mean cover (one trial)	5.6	7.4	7.3	**6.9**	7.8	7.9	8.7	8.9	8.7	9.8
***Sphagnum* spp.**										
St. Dev. of 10 random trials	2.4	1.9	1.8	**1.5**	1.3	1.1	0.7	0.5	0.2	0.0
Highest estimate of mean cover (one trial)	8.2	5.7	5.6	**5.3**	4.8	4.8	4.2	3.9	3.5	3.3
Lowest estimate of mean cover (one trial)	0.1	0.7	1.0	**1.5**	1.5	1.6	2.2	2.4	2.8	3.3
Calla palustris										
St. Dev. of 10 random trials	2.0	1.8	1.4	**0.8**	0.5	0.5	0.5	0.5	0.3	0.0
Highest estimate of mean cover (one trial)	5.6	5.3	3.6	**2.7**	2.4	2.7	2.5	2.3	2.0	1.8
Lowest estimate of mean cover (one trial)	0.0	0.1	0.1	**0.6**	0.8	1.2	1.1	1.0	1.0	1.8
moss spp.										
St. Dev. of 10 random trials	1.1	0.8	0.5	**0.5**	0.5	0.3	0.3	0.2	0.1	0.0
Highest estimate of mean cover (one trial)	3.8	3.1	2.6	**2.8**	2.4	2.3	2.1	2.1	2.0	1.8
Lowest estimate of mean cover (one trial)	0.2	0.9	1.2	**1.1**	1.2	1.3	1.3	1.4	1.6	1.8
Spirea alba										
St. Dev. of 10 random trials	1.1	2.1	1.6	**1.3**	1.1	0.9	0.8	0.6	0.4	0.0
Highest estimate of mean cover (one trial)	3.6	5.7	3.8	**2.9**	2.3	1.9	1.6	1.4	1.3	1.1
Lowest estimate of mean cover (one trial)	0.0	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	0.1	1.1
***Salix* spp.**										
St. Dev. of 10 random trials	2.9	1.9	1.5	**1.2**	1.0	0.8	0.6	0.4	0.3	0.0
Highest estimate of mean cover (one trial)	8.2	5.3	3.5	**2.7**	2.2	1.9	1.6	1.4	1.2	1.1
Lowest estimate of mean cover (one trial)	0.0	0.0	0.0	**0.0**	0.0	0.1	0.1	0.2	0.2	1.1
***Lysimachia* spp.**										
St. Dev. of 10 random trials	0.3	0.2	0.2	**0.2**	0.1	0.1	0.1	0.1	0.0	0.0
Highest estimate of mean cover (one trial)	1.4	1.6	1.4	**1.4**	1.3	1.2	1.2	1.2	1.1	1.1
Lowest estimate of mean cover (one trial)	0.6	0.9	0.9	**0.9**	0.9	0.9	1.0	1.0	1.0	1.1
Polygonum amphibium										
St. Dev. of 10 random trials	1.2	0.9	0.9	**0.8**	0.6	0.5	0.4	0.2	0.1	0.0
Highest estimate of mean cover (one trial)	3.4	2.3	2.3	**2.2**	1.8	1.7	1.5	1.3	1.2	1.0
Lowest estimate of mean cover (one trial)	0.0	0.0	0.0	**0.1**	0.2	0.3	0.5	0.7	0.8	1.0

Table 99. Analysis of variability in total estimated cover, summed cover (all taxa), and quadrat richness sampled along an aquatic transect by changing sample size (# of 1 m x 1 m quadrats). Ten different trials were analyzed, and for each trial sub-sets of 50 quadrats were randomly chosen. For each factor the mean, standard deviation, highest estimate, and lowest estimate is reported with increasing number of quadrats contributing to the estimate. (20 is the number of quadrats we have used to date for the intensively studied sites, and is bolded for comparisons.)

Values after stated number of quadrats:	**5**	**10**	**15**	**20**	**25**	**30**	**35**	**40**	**45**	**50**
Total Quadrat Cover (estimated)										
Mean	22.1	21.6	21.9	**22.0**	21.9	21.8	22.0	21.9	21.8	22.1
St. Dev.	10.9	9.4	8.2	**7.2**	6.2	4.6	3.5	2.6	1.2	0.0
Highest estimate of mean (one trial)	43.0	38.0	33.2	**30.0**	30.0	28.9	26.8	26.0	23.8	22.1
Lowest estimate of mean (one trial)	6.4	6.9	10.0	**12.6**	14.8	16.2	17.3	18.1	19.8	22.1
Quadrat Cover (summed)										
Mean	25.0	24.2	24.9	**24.7**	24.7	24.6	24.7	24.7	24.6	24.9
St. Dev.	12.2	10.2	8.9	**7.6**	6.5	4.8	3.8	2.8	1.4	0.0
Highest estimate of mean (one trial)	50.1	42.0	37.9	**33.3**	33.0	32.2	29.8	28.8	26.6	24.9
Lowest estimate of mean (one trial)	9.6	9.5	12.3	**14.6**	16.9	18.5	19.4	20.2	22.1	24.9
Quadrat Richness										
Mean	5.7	5.6	5.6	**5.6**	5.6	5.6	5.6	5.6	5.6	5.6
St. Dev.	0.9	0.8	0.7	**0.5**	0.4	0.3	0.3	0.2	0.1	0.0
Highest estimate of mean (one trial)	6.8	6.6	6.8	**6.6**	6.2	6.0	5.9	5.9	5.8	5.6
Lowest estimate of mean (one trial)	4.6	4.2	4.9	**5.1**	5.0	5.0	5.1	5.3	5.4	5.6

Table 100. Analysis of variability in the estimated percent cover values (per 1 m x 1 m quadrat) for the ten most abundant taxa along an aquatic transect by changing sample size (# of quadrats). Ten different trials were analyzed, and for each trial sub-sets of the 50 quadrats were randomly chosen. For each taxon the standard deviation, highest estimate, and lowest estimate is reported with increasing number of quadrats contributing to the estimate. (20 is the number of quadrats we have used to date for the intensively studied sites, and is bolded for comparisons.)

Values after stated number of quadrats:	**5**	**10**	**15**	**20**	**25**	**30**	**35**	**40**	**45**	**50**
Vallisneria americana										
St. Dev. of 10 random trials	6.5	4.6	3.9	**2.6**	1.5	1.4	1.5	1.6	0.9	0.0
Highest estimate of mean cover (one trial)	25.0	19.8	19.2	**17.6**	15.6	15.9	15.5	15.8	14.4	13.3
Lowest estimate of mean cover (one trial)	2.4	3.4	6.9	**9.8**	11.2	10.6	10.2	10.6	11.8	13.3
Myriophyllum spp.										
St. Dev. of 10 random trials	6.5	5.4	4.3	**3.5**	2.9	2.2	1.9	1.3	0.7	0.0
Highest estimate of mean cover (one trial)	19.8	15.2	10.8	**8.4**	6.8	5.7	5.0	4.5	4.0	3.6
Lowest estimate of mean cover (one trial)	0.0	0.0	0.3	**0.3**	0.3	0.4	0.5	0.6	1.8	3.6
Najas flexilis										
St. Dev. of 10 random trials	3.5	2.3	2.0	**1.7**	1.5	0.9	0.8	0.5	0.4	0.0
Highest estimate of mean cover (one trial)	10.8	6.5	5.8	**5.6**	4.8	4.1	3.6	3.2	3.0	2.7
Lowest estimate of mean cover (one trial)	0.4	0.3	0.5	**0.6**	0.5	1.6	1.4	2.0	1.8	2.7
Ceratophyllum demersum										
St. Dev. of 10 random trials	2.4	1.8	1.5	**1.3**	1.1	0.8	0.6	0.5	0.2	0.0
Highest estimate of mean cover (one trial)	7.0	5.1	4.6	**3.5**	2.9	2.5	2.2	1.9	1.7	1.6
Lowest estimate of mean cover (one trial)	0.0	0.0	0.1	**0.1**	0.3	0.3	0.4	0.8	1.0	1.6
Potamogeton richardsonii										
St. Dev. of 10 random trials	1.0	0.8	0.7	**0.6**	0.5	0.4	0.3	0.2	0.1	0.0
Highest estimate of mean cover (one trial)	3.0	2.3	2.1	**2.0**	1.8	1.8	1.6	1.5	1.3	1.2
Lowest estimate of mean cover (one trial)	0.0	0.0	0.3	**0.3**	0.5	0.6	0.8	0.9	1.0	1.2
Elodea canadensis										
St. Dev. of 10 random trials	1.2	0.9	0.8	**0.6**	0.5	0.4	0.3	0.2	0.1	0.0
Highest estimate of mean cover (one trial)	4.2	2.7	2.0	**1.8**	1.5	1.4	1.2	1.1	1.0	0.9
Lowest estimate of mean cover (one trial)	0.0	0.0	0.1	**0.2**	0.2	0.3	0.4	0.5	0.5	0.9
Potamogeton vaseyi										
St. Dev. of 10 random trials	1.0	0.9	0.8	**0.6**	0.5	0.4	0.4	0.3	0.1	0.0
Highest estimate of mean cover (one trial)	2.6	2.5	2.3	**1.8**	1.5	1.3	1.2	1.0	0.9	0.8
Lowest estimate of mean cover (one trial)	0.0	0.0	0.0	**0.2**	0.2	0.2	0.2	0.3	0.5	0.8
***Isoetes* spp.**										
St. Dev. of 10 random trials	0.7	0.7	0.6	**0.4**	0.3	0.3	0.2	0.2	0.1	0.0
Highest estimate of mean cover (one trial)	2.4	1.8	1.3	**1.0**	0.8	0.7	0.6	0.5	0.5	0.4
Lowest estimate of mean cover (one trial)	0.0	0.0	0.1	**0.1**	0.0	0.0	0.1	0.1	0.2	0.4
Nymphaea odorata										
St. Dev. of 10 random trials	0.2	0.2	0.1	**0.1**	0.1	0.1	0.1	0.0	0.0	0.0
Highest estimate of mean cover (one trial)	0.6	0.5	0.4	**0.4**	0.3	0.3	0.3	0.2	0.2	0.2
Lowest estimate of mean cover (one trial)	0.0	0.0	0.0	**0.1**	0.1	0.1	0.1	0.1	0.1	0.2
Bidens beckii										
St. Dev. of 10 random trials	0.2	0.2	0.1	**0.1**	0.1	0.1	0.1	0.0	0.0	0.0
Highest estimate of mean cover (one trial)	0.4	0.4	0.4	**0.3**	0.2	0.2	0.2	0.1	0.1	0.1
Lowest estimate of mean cover (one trial)	0.0	0.0	0.0	**0.0**	0.0	0.0	0.0	0.0	0.1	0.1

Table 101. Analysis of variability in total estimated cover, summed cover (all taxa), and quadrat richness sampled along a shoreline transect by changing sample size (# of 1 m x 1 m quadrats). Ten different trials were analyzed, and for each trial sub-sets of the 50 quadrats were randomly chosen. For each factor the mean, standard deviation, highest estimate, and lowest estimate is reported with increasing number of quadrats contributing to the estimate. (20 is the number of quadrats we have used to date for the intensively studied sites, and is bolded for comparisons.)

Values after stated number of quadrats:	**5**	**10**	**15**	**20**	**25**	**30**	**35**	**40**	**45**	**50**
Total Quadrat Cover (estimated)										
Mean	75.4	75.8	75.6	**75.5**	75.7	75.5	75.7	75.6	75.6	75.6
St. Dev.	5.6	5.0	4.0	**1.8**	1.3	1.0	1.6	1.3	0.8	0.0
Highest estimate of mean (one trial)	84.0	81.5	82.0	**78.5**	77.8	77.3	78.1	77.9	77.0	75.6
Lowest estimate of mean (one trial)	67.0	66.5	69.7	**72.3**	73.8	74.5	72.9	73.8	74.3	75.6
Quadrat Cover (summed)										
Mean	90.4	91.1	90.6	**90.8**	91.3	90.7	91.1	91.0	90.8	91.0
St. Dev.	6.7	5.4	4.6	**4.1**	3.3	2.5	2.1	1.4	0.5	0.0
Highest estimate of mean (one trial)	97.1	99.3	97.7	**96.0**	96.2	94.9	94.5	93.4	91.6	91.0
Lowest estimate of mean (one trial)	75.0	83.1	83.8	**84.3**	86.7	87.6	88.1	89.1	89.9	91.0
Quadrat Richness										
Mean	9.4	9.6	9.5	**9.6**	9.6	9.6	9.6	9.6	9.6	9.6
St. Dev.	1.5	1.5	1.3	**1.2**	1.0	0.8	0.6	0.4	0.2	0.0
Highest estimate of mean (one trial)	12.0	12.1	11.3	**11.5**	11.0	10.7	10.5	10.2	9.9	9.6
Lowest estimate of mean (one trial)	6.8	7.4	7.7	**8.0**	8.3	8.5	8.8	9.0	9.3	9.6

Table 102. Analysis of variability in the estimated percent cover values (per 1 m x 1 m quadrat) for the eleven most abundant taxa along a shoreline transect by changing sample size (# of quadrats). Ten different trials were analyzed, and for each trial sub-sets of the 50 quadrats were randomly chosen. For each taxon the standard deviation, highest estimate, and lowest estimate is reported with increasing number of quadrats contributing to the estimate. (20 is the number of quadrats we have used to date for the intensively studied sites, and is bolded for comparisons.)

Values after stated number of quadrats:	**5**	**10**	**15**	**20**	**25**	**30**	**35**	**40**	**45**	**50**
Myrica gale										
St. Dev. of 10 random trials	8.9	6.2	5.0	**4.7**	4.3	3.1	2.4	1.7	1.0	0.0
Highest estimate of mean cover (one trial)	36.0	40.5	37.3	**37.5**	38.2	34.7	33.9	32.8	32.0	30.6
Lowest estimate of mean cover (one trial)	6.8	23.1	23.1	**23.8**	23.1	25.7	27.5	27.8	29.3	30.6
Calamagrostis canadensis										
St. Dev. of 10 random trials	6.8	5.6	3.3	**2.3**	2.3	1.5	1.6	1.3	0.9	0.0
Highest estimate of mean cover (one trial)	36.0	28.5	23.9	**20.7**	21.3	21.1	20.5	19.5	18.8	17.9
Lowest estimate of mean cover (one trial)	12.8	11.0	13.3	**13.0**	13.5	16.0	15.1	15.7	15.9	17.9
Alnus incana										
St. Dev. of 10 random trials	9.5	7.4	4.9	**2.7**	1.6	1.8	1.6	1.8	1.1	0.0
Highest estimate of mean cover (one trial)	26.0	23.1	18.3	**16.1**	14.4	14.9	13.9	14.4	13.0	11.7
Lowest estimate of mean cover (one trial)	0.0	1.6	5.0	**6.9**	9.0	9.4	9.6	8.8	9.9	11.7
Pinus strobus										
St. Dev. of 10 random trials	9.1	5.7	4.5	**4.0**	3.0	2.6	1.8	1.6	1.0	0.0
Highest estimate of mean cover (one trial)	29.0	14.5	12.5	**9.4**	7.8	7.3	6.3	5.5	4.9	4.4
Lowest estimate of mean cover (one trial)	0.0	0.0	0.0	**0.0**	1.2	1.0	0.9	1.0	2.0	4.4
Moss spp.										
St. Dev. of 10 random trials	1.5	1.1	0.7	**0.7**	0.7	0.5	0.3	0.3	0.2	0.0
Highest estimate of mean cover (one trial)	7.4	6.2	5.2	**5.3**	5.4	5.0	4.9	4.8	4.6	4.2
Lowest estimate of mean cover (one trial)	1.6	2.4	3.3	**3.2**	3.2	3.4	3.9	3.7	3.9	4.2
Spiraea alba										
St. Dev. of 10 random trials	4.8	3.6	2.5	**1.8**	1.7	1.3	1.1	0.9	0.4	0.0
Highest estimate of mean cover (one trial)	14.0	9.5	6.9	**5.5**	5.7	4.8	4.4	3.9	3.4	3.1
Lowest estimate of mean cover (one trial)	0.0	0.0	0.1	**0.3**	0.5	1.5	1.5	1.5	2.3	3.1
Potentilla palustris										
St. Dev. of 10 random trials	1.8	0.8	0.7	**0.4**	0.4	0.2	0.3	0.2	0.2	0.0
Highest estimate of mean cover (one trial)	6.8	3.8	3.9	**3.4**	3.4	3.1	3.3	3.1	3.0	2.7
Lowest estimate of mean cover (one trial)	1.2	1.4	1.3	**2.2**	2.2	2.6	2.2	2.5	2.4	2.7
Carex rostata										
St. Dev. of 10 random trials	3.2	1.7	1.3	**1.1**	0.9	0.7	0.5	0.3	0.3	0.0
Highest estimate of mean cover (one trial)	10.0	5.8	4.3	**4.1**	3.9	3.5	3.2	3.0	2.8	2.5
Lowest estimate of mean cover (one trial)	0.2	0.9	0.9	**0.9**	1.2	1.7	1.8	1.9	1.9	2.5
Scirpus cyperinus										
St. Dev. of 10 random trials	2.6	1.5	1.1	**0.9**	0.8	0.6	0.5	0.3	0.2	0.0
Highest estimate of mean cover (one trial)	7.8	4.5	3.2	**2.5**	2.5	2.2	1.9	1.7	1.5	1.4
Lowest estimate of mean cover (one trial)	0.0	0.0	0.0	**0.1**	0.2	0.6	0.6	0.7	0.7	1.4
Polygonum amphibium										
St. Dev. of 10 random trials	1.6	1.0	0.8	**0.6**	0.4	0.4	0.4	0.3	0.2	0.0
Highest estimate of mean cover (one trial)	4.2	3.2	2.7	**2.0**	1.6	1.8	1.7	1.5	1.3	1.2
Lowest estimate of mean cover (one trial)	0.0	0.0	0.0	**0.4**	0.6	0.7	0.6	0.7	0.9	1.2
***Lysimachia* spp.**										
St. Dev. of 10 random trials	1.1	0.8	0.6	**0.5**	0.4	0.3	0.3	0.2	0.1	0.0
Highest estimate of mean cover (one trial)	4.0	2.5	2.0	**1.8**	1.6	1.5	1.4	1.3	1.3	1.1
Lowest estimate of mean cover (one trial)	0.0	0.4	0.6	**0.6**	0.6	0.6	0.8	0.8	0.8	1.1

Discussion

For each of the three habitat types, 20 quadrats appeared to provide very adequate estimates of composite metrics such as total cover and richness (Table 97, Table 99, and Table 101for peatland, aquatic, and shoreline transects respectively). Estimates of individual taxa cover were generally adequate using 20 quadrats, especially for the most abundant taxa, or those taxa with mean cover values greater than about 5%. In general, by using 20 quadrats these common taxa varied 20-25% about the "true" means using 50 quadrats, with the exception of some very patchily distributed species. In peatlands, however, since the transects and quadrats are re-locatable (monumented) such that re-sampling may be at the level of individual quadrats, 20 quadrats would be very appropriate. There is some evidence that some taxa, in the aquatic environment especially, could be better served with 25 quadrats, or the addition of 5 more per transect.

Satellite Image Analysis

Satellite image analysis has the potential to monitor changes in vegetation, especially 1) establishment of new wetlands under the new water level regime and 2) *Typha* invasion of other wetlands.

In this section we conduct a preliminary assessment of the potential of using Ikonos multispectral image data to inventory changes in wetland vegetation on Rainy and Namakan lakes and Lac la Croix.

Methods

Source Data

The Ontario Ministry of Natural Resources purchased 11-bit multispectral Ikonos satellite imagery acquired in July and August 2003. The area of coverage includes Lac la Croix, Sand Point Lake, Namakan Lake and all of the South Arm, Redgut Bay, and Rice Bay of Rainy Lake (Figure 31). Metadata is listed below and in Table 103:

- Map Projection: Universal Transverse Mercator
  UTM Specific Parameters
- Datum: NAD83
- Pixel Size: 4.00 meters
- Multispectral (Blue, Green, Red, Near Infrared)

Analysis

A supervised classification of a sample area covering the west end of Rainy Lake (105252_rbg_00) was conducted. Multispec software (Multispec 2001) was used to conduct the analysis.

Voyageurs Park vegetation map polygons were used as training areas (Hop et al. 2001). Training classes included four shoreline wetland communities (Wet Meadow-Fen Mosaic Complex, Midwest Cattail, Leatherleaf – Sweet Gale Shore Fen, and Speckled Alder Swamp) as well as upland forest, water, and cloud (Table 104).

Results

Areas and percentages of the eight classes are provided in Table 104.

Table 103. Ikonos imagery metadata (refer to Figure 31for locations of images).

Image ID	Scan Azimuth (degrees)	Cloud Cover (%)	Acquisition Date/	Time (GMT)	Sun Angle Azimuth	Sun Angle Elevation
000	0.06	12	2003-07-11	17:28	155.0915	61.92616
001	0.06	1	2003-08-16	17:39	165.2908	54.75199
002	180.06	0	2003-08-16	17:39	164.9521	54.55312
003	180.06	0	2003-08-16	17:39	164.9606	54.65121
004	0.05	0	2003-08-16	17:40	164.8130	54.53952

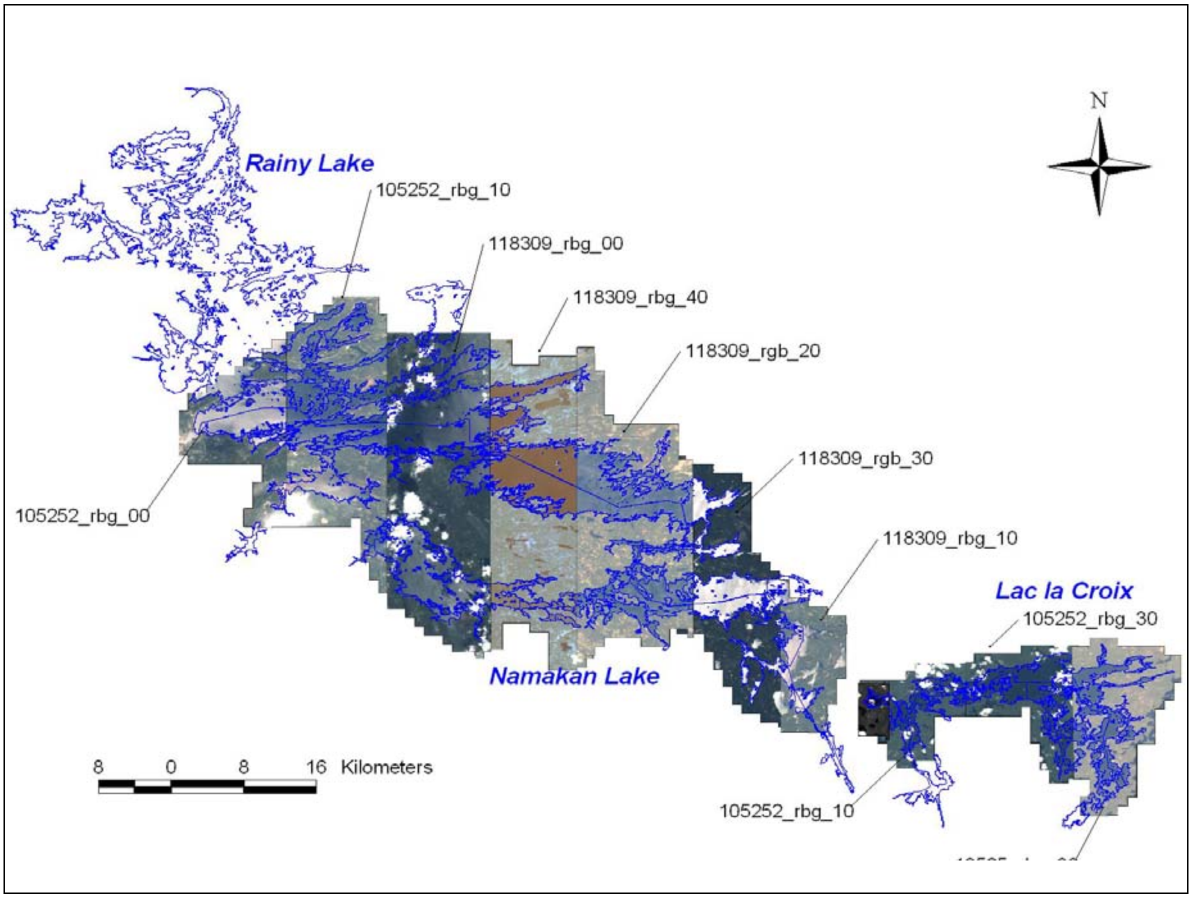


Figure 31. Map of study area showing Ikonos imagery coverage. Labels refer to individual images.

Table 104. Class distribution for selected area (refer to Figure 32).

Class Number	Class Name	Number of Samples	Percent of Area	Area (Hectares)
1	Wet Meadow-Fen Mosaic Complex	376,401	1.93	602.242
2	Midwest Cattail	1,328,628	6.82	2,125.805
3	Leatherleaf – Sweet Gale Shore Fen	196,418	1.01	314.269
4	Water	4,850,975	24.89	7,761.560
5	Forest	4,484,366	23.01	7,174.986
6	Cloud	144,324	0.74	230.918
7	No data	7,402,837	37.98	11,844.539
8	Speckled Alder Swamp	707,091	3.63	1,131.346
	Total	19,491,040	100.00	31,185.664

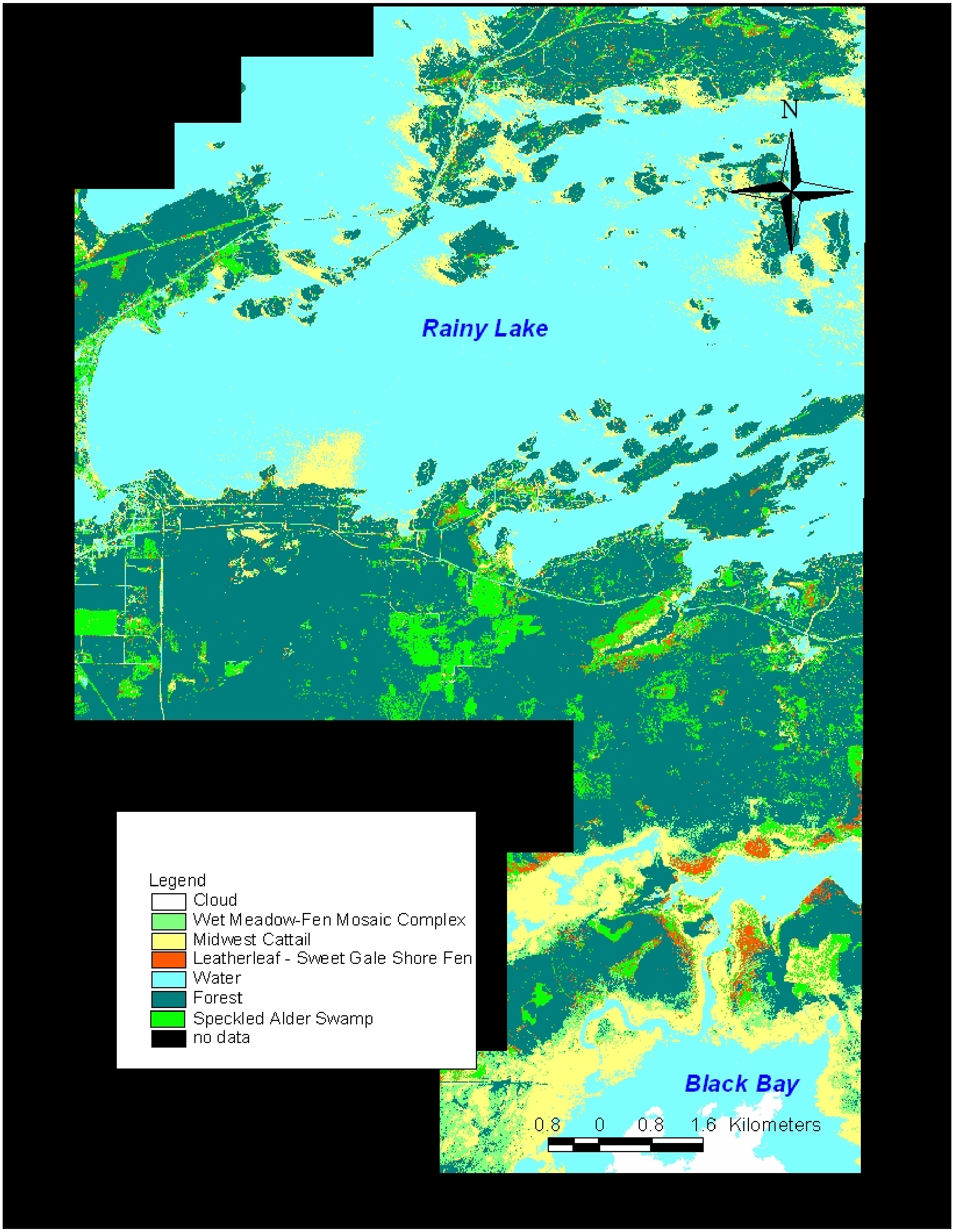


Figure 32. Sample supervised classification of Ikonos data.

A visual inspection of the results suggests that Midwest Cattail polygons mapped by Hop et al. (2001) were often correctly classified in the analysis (Figure 33). However, alder and willow thickets and glare on lake water were frequently misclassified as Midwest Cattail.

Discussion

This preliminary analysis of the Ikonos data shows that it has potential to monitor changes in the shoreline vegetation across the Rainy, Namakan, and Lac la Croix basins. Refinement of the classification and a quantitative check of accuracy are needed.

Ground-truthing data to refine the analyses are available in the form of 1) the Voyageurs vegetation map (Hop et al. 2001), 2) “extensive” shoreline mapping data with the present study, and 3) 1:5000 scale aerial photography acquired for selected wetlands in 2004.

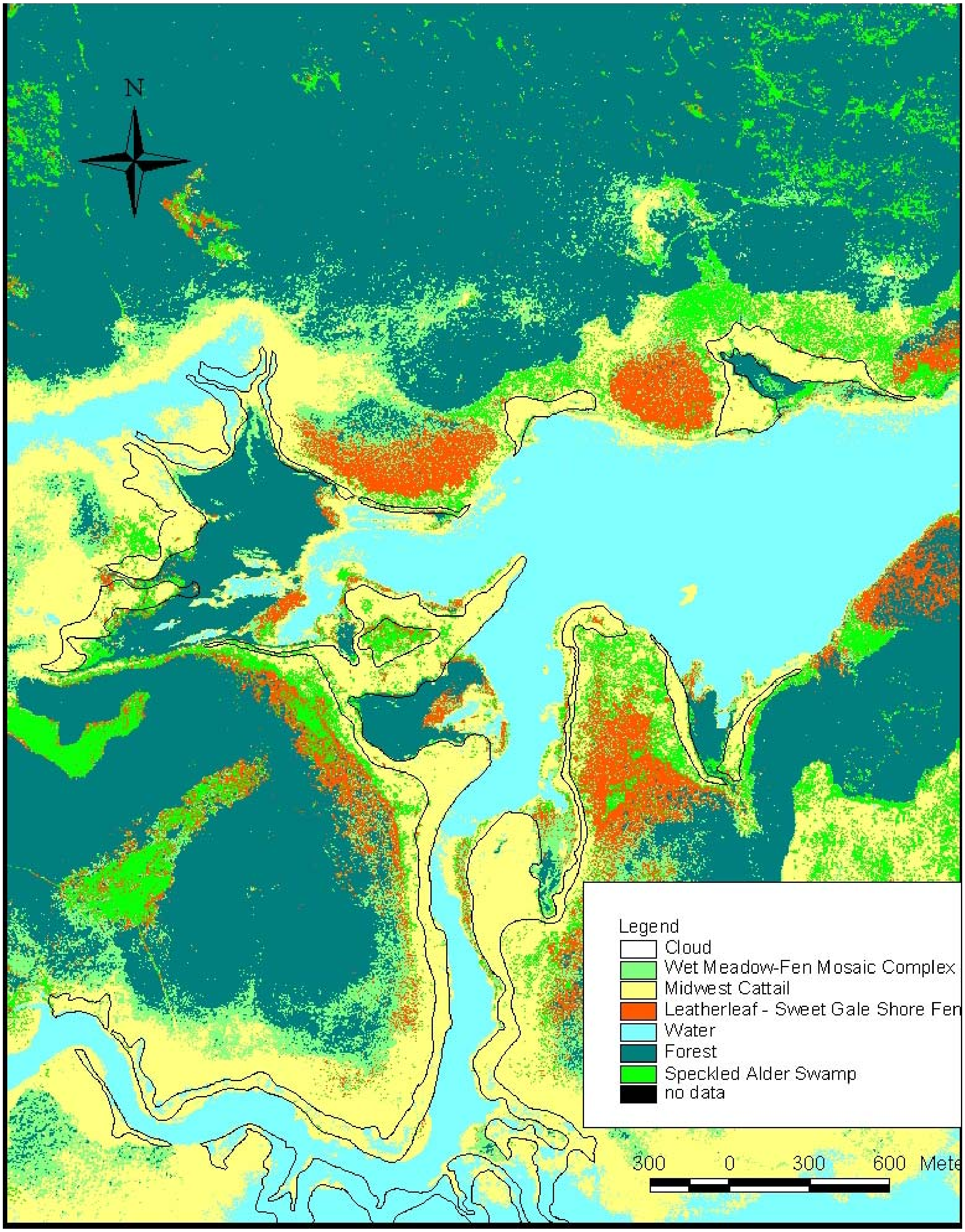


Figure 33. Detail from supervised classification of Ikonos data. Polygons outlined in black were mapped as Midwest Cattail by Hop et al (2001).

Summary and Recommendations

This summary section is organized into two parts. In part one we present the general conclusions concerning how vegetation may be changing in response to rule curve changes and water level management in general. In this process we review the same tasks described in the first six sections of this report. In part two of this section we provide future sampling recommendations as a result of our efforts of estimating bias and variability in vegetative sampling.

General conclusions relative to vegetative response to changes in water level management.

Two of the foremost goals of this study and that of the study reported in Meeker and Harris 2004 were to 1) establish a baseline for sampling vegetation in the future, and 2) concurrently investigate the weight of evidence suggesting how the vegetation in Namakan and Rainy has *already* responded to the rule curve changes established in 2000, and additionally to the adjustments that industry made in water level management prior to 2000.

Background

Regulation of water levels to a strict regime may have degraded the biotic resources of VNP, as suggested by a number of studies conducted during the period 1986-1990 (Kallemeyn et al. 1993). Under the 1970 rule curve, water-level fluctuations on the Namakan Reservoir were more extreme compared to the relative “natural” conditions of non-regulated Lac la Croix, while those on the Rainy Lake basin were less so (Figure 1).

In 1987, as a part of these initial studies, the aquatic vegetation of the three basins was assessed (Meeker and Wilcox 1989; Wilcox and Meeker 1991), and these studies found differences in structure and composition among the three lake systems, especially among deep elevation aquatic macrophytes. Vegetation in the Namakan Reservoir was exclusively dominated by mat-forming species tolerant of extreme drawdowns, while that in Rainy was dominated by dense, erect aquatics; vegetation in Lac la Croix was intermediate to the other two lakes (Figure 2). These vegetative structural differences between the regulated lakes and Lac la Croix were implicated in the degradation of other biota that depend on the vegetation in the regulated lakes (Wilcox and Meeker 1992; Kallemeyn et al.1993).

Industry responsible for the regulation of water levels in the Namakan and Rainy basins responded to the suggested degradation of the biotic resources in 1987-88 by targeting the middle rather than the extremes of the previous rule curves (1970 rules) resulting in a reduction of the extreme fluctuations in the Namakan Reservoir (Figure 3). Following a ruling by the International Joint Commission, a new rule curve was established in 2000 as indicated in Figure 5. This new curve requires industries, in part, to considerably reduce the drawdown in the Namakan Reservoir and establish its annual peak in late May, followed by a gradual decline in water level the rest of the growing months. Comparatively, only minimal changes are required in Rainy Lake.

Of note is the fact that the minimization of these extreme drawdowns in Namakan had already started by the time the 1987 study was conducted and that a reduction of these drawdowns in Namakan continued to occur between 1987 and beginning of the re-sampling reported here

(Figure 3) and in Meeker and Harris, 2004. One focus of this report (and of Meeker and Harris 2004), then, is how has the Namakan Reservoir responded since the 1987 assessment. The bulk of this inquiry focuses on the aquatic macrophyte zone that was once annually de-watered but now is continually submerged, which may offer a more favorable environment for taller (not mat forming) aquatic plants. (This environment is what we have referred to as zone 1 in Figure 6.)

Vegetative response to rule curve changes

To increase the understanding of VNP vegetation dynamics in this present monitoring effort, we relied on two approaches: 1) **an assessment of comparative sampling** (Intensive Sampling section), that is, comparing the eleven sampled sites of Namakan to the ten of both Rainy and Lac la Croix, all sampled since the new rule curve was established; and 2) **an assessment of repeat sampling** of sites over time (Vegetative Change section), using data gathered from the original 1987 vegetation sampling (Wilcox and Meeker 1991). Although the strength of conclusions may be stronger with repeat sampling, there were only two sites sampled in each basin in 1987 sampling. We present each of these two analyses below for both the **shoreline** and combined **aquatic habitats** (1.25 m and 2.0 m).

Shorelines - Comparative study among basins

We demonstrated in Section 1 that shoreline wetland communities of Lac la Croix, Namakan Reservoir, and Rainy Lake differed from each other in species composition. Multivariate analysis (Figure 10) showed that shoreline communities of Rainy Lake are significantly different from the other two basins, with a greater contribution of annuals taxa. In general, there were enough taxa unique to particular basins to suggest that either past or present water level management does differentially influence the shoreline communities. Some taxonomic distributions are noted easily while traveling through the different basins, such as the absence of the aggressive taxa such as the hybrid cattail (*Typha* spp.) in Lac la Croix. Alternatively, the taxa unique to a particular basin include poor fen taxa in Lac la Croix and annuals in Rainy.

Grouping taxa into life form guilds also suggests differences in shoreline vegetation among basins. For example, Lac la Croix is poorly represented by emergent aquatics but has significantly greater facultative wetland herb cover compared to Namakan. The lack of facultative wetland herbs at Namakan again suggests that the effects of the long term reservoir-type management, even though modified in 2000, still exists in the Namakan shoreline vegetation.

On the other hand, while species composition differed, there were little differences in total cover or species richness at the shorelines between the basins, and a few taxa accounted for most of the cover in all basins.

Shorelines - Repeat Sampling in Basins

Just as there is evidence of differences among the basins' shoreline vegetation when comparing recently sampled transects (above), there is also strong evidence for vegetative change over time in the shoreline transects across all the basins. Each basin showed substantial increases (at least a doubling) in the total cover at shoreline (0.0 m) elevations over the 15-16 year period from 1987 to 2002-3. Most of these changes can be attributed to increases in woody cover, including sweet gale (*Myrica gale*), ash spp. (*Fraxinus* spp.), white pine (*Pinus strobus*), meadowsweet (*Spirea alba*) and alder (*Alnus incana*). Accompanying the increases in woody cover, graminoid cover in all three basins showed modest, but non-significant changes, with declines at Lac la Croix and Namakan, and increases in Rainy. This fact suggests that increases in woody taxa have not *yet* reduced abundance of the graminoid guild that may eventually be reduced through shading.

For Namakan and somewhat for Rainy, these results are consistent with the establishment of the new rule curve's annual water level peak in late May followed by gradual decline in water level the rest of the growing months (Figure 5). However, the uniform increase of woody taxa in shorelines across all basins, including Lac la Croix, with a disparate water level history suggests that hydrologic control may not be the only factor influencing change. Only future sampling of the shorelines at each basin will assist in determine whether lake level management or another factor such as climate change is the stronger influence.

Aquatics (1.25 m and 2.0 m Depths) - Comparative study among basins

Although there is no significant difference in total aquatic vegetation cover or species richness per 1 m^2 between the basins, differences in vegetation structure and composition are apparent. Based on multivariate analyses, Lac la Croix, the non-regulated lake, differed significantly from the other two basins at both the 1.25 m depth (Intensive Sampling section, Figure 12) and the 2.0 m depth (Figure 13). This is consistent with the results reported after the 1987 study (Wilcox and Meeker 1991). A major part of these differences (reported from this more recent sampling) are attributed to a greater proportion of tall submergent vegetation, including wild celery (*Vallisneria americana*) found in great abundance at Namakan and Rainy when compared with Lac la Croix at both the 1.25 m and 2.0 m elevations. Also, Rainy Lake continues to be dominated by tall submergents, again supporting Wilcox and Meeker's conclusion that stable water levels promote the dominance of this life form.

In addition Lac la Croix has generally greater vegetation structural diversity compared to the other basins, that is, relative cover is more evenly distributed among the life forms (Figure 11). This also supports the findings of Wilcox and Meeker (1991) who attributed the difference in vegetation structure to the intermediate level of disturbance at Lac la Croix, lacking both the extreme drawdowns of the Namakan Reservoir and the unnaturally stable water levels of Rainy Lake.

There were also taxa uniquely absent or present in each basin (Table 20). In Namakan, for example, several floating leaf taxa, two pondweeds (*Potamogeton robbinsii* and *P. epihydrus*), and a floating leaf burreed (*Sparganium* spp.) have presumably been eliminated from the basin due to extreme reservoir-type management for the 85 years since the creation of the dam.

In sum, comparing the structure and composition of the aquatic vegetation among Namakan (440 quadrats), Rainy (400), and Lac la Croix (400), all sampled since the new rule curve was established (2000), suggests both significant and predictable differences among basins.

Aquatics (1.25 m and 2.0 m Depths) - Repeat Sampling in Basins

Even though the comparative analyses (reported above) suggest there are still differences among the basins' aquatic vegetation, there is strong evidence with the repeat sampling to suggest that the aquatics also appear to have changed considerably within basins since 1987. For example, although the sample size is small (see caveat below), the repeatedly sampled locations at Namakan suggest there is much greater vegetative similarity among the 2002, 2004, and 2006 transects (70% to 89%), as opposed to when any of these newer dates are compared with that of 1987 (48% to 68%). In addition, whereas Wilcox and Meeker (1991) found that Namakan was dominated by rosette and mat-forming species at the 1.25 and 2.0 m depths, this was not observed in the present study. However, Namakan continues to have less emergent and floating leaf cover than the other basins and has significantly fewer overall species than Lac la Croix, suggesting that although this basin may have responded to changes in the rule curve, it still lacks some of the structure of the non-regulated basin.

Unlike Namakan, there were no clear patterns of change in annual extreme water levels that may be affecting vegetative change in either Rainy Lake or Lac la Croix (Figure 3). Additionally, there was only a slight modification in the new rule curve for Rainy. For both of these reasons, there were no expectations suggesting either Rainy or Lac la Croix's recent vegetation sampling (2002-3) should differ from that seen in 1987. However, upon analyses there appear to be vegetative difference between sampling times, and some of these changes are similar to what we reported above for Namakan.

Lac la Croix experienced significant declines in cover from 1987 to 2002 in both of the aquatic transects, which is not easily explained when viewing the hydrograph of annual extremes (Figure 3). This is especially vexing in that Namakan and Rainy both experienced increases in cover over the same time period at both depths, while only Namakan's response is expected due to rule curve modification. We have no one good explanation for this result, unless our sample size was inadequate to get an accurate picture of submergent vegetation in any of the basins. Another possible explanation for disparate response among basins suggests that the taxa pool may influence changes in total cover. For example, at Rainy and to some extent Namakan, much of the increase in aquatic cover was due to taxa that included wild celery (*Vallisneria americana*), floating burreed *(Sparganium* spp.), and variable pondweed (*Potamogeton gramineus*) that are not well represented in Lac la Croix, perhaps acting as a governor of vegetative response in that basin.

Caveat to be noted in repeat sampling assessment

It should be noted that while all basins were experiencing below average water levels during the 1987 sampling, Rainy was lowest (0.7-0.90 m below MHW), Lac la Croix was moderately low (0.3 to 0.5 m down), and Namakan was closest to MHW (0.2 to 0.3 m). It could be, since the 1987 Rainy sampling occurred during an extreme drawdown year (0.7 to 0.9 m), and submergent vegetation would have been stressed, that any comparisons with these data are not well advised. These differences in the initial baseline from which we are making all our comparisons then need to be viewed cautiously. That is, each basin was responding to a different set of hydrological conditions in 1987, and from 1987 to 2002.

It should also be emphasized that the repeat sampling results reported above for both the aquatic and shoreline transects are based on only two sites in each basin, hence over only 40 quadrats for each elevational transect. This was a major critique of the original 1987 sampling (Kallemyen, pers comm.), and during the course of this study we have added 9 more sites in Namakan, and 8 each in Rainy Lake and Lac la Croix for subsequent, more robust monitoring.

Further caution is warranted as all the analyses point to understandable difficulty in sampling the aquatic habitat, such as likely omissions due to loss of visibility in deeper water, and variable identification of the low lying isoetid groups. This suggests that monitoring these habits in the future must take water levels into account and somehow be flexible enough to not sample in extreme years. A good portion of these difficulties can be mitigated through the comparative use of life forms, as we reported here. Another difficulty in assessing the aquatic habitat is its patchy nature. Increasing the number of quadrats (sub-samples) from 20 per transect to 25, as suggested in the Sampling Bias section, would reduce variability in the summaries.

Other explanations for the changes noted include the possibility that regional productivity may be increasing due to factors acting at larger scales, such as climate change or atmospheric deposition. We are not yet capable at this time of choosing among these alternative hypotheses, but since we have increased the number of sites and transects it should provide a more complete picture the next time the sites are re-assessed.

In support of the repeat sampling findings presented here, however, is the fact that the two Namakan sites sampled in 1987 (NAM05 and NAM07), plotted among the other nine sites in the in each of the NMS ordinations (Figures 10, 12, 13 for shoreline, 1.25 m and 2.0 m elevations respectively). That is, these two site sampled in 1987 appear to be representative of the 11 total sites in Namakan.

Peatlands – comparative study among sub-basins (Peatland Assessment section)
The significant differences in vegetation composition of the peatlands among basins and sub-basins supports the suggestion that water regimes have influenced peatland ecology. Ordinations indicated three taxonomic groups that corresponded with well-established ecological terms for three different peatland communities that are known to be generally related to water level fluctuations: 1) *Sphagnum* dominated <u>bogs or poor fens</u> that are intolerant of regular flooding, 2) <u>shore fens</u> dominated by fine leaf sedges that are associated with an intermediate degree of inundation, and 3) <u>sedge meadows</u> dominated by coarse leaf sedges that are associated with regular flooding by lake or stream water.

Although we do not yet have any repeat sampling data, the results of this recent comparative sampling (2004-2005) suggests that peatland types of the VNP region correspond with the pattern of water levels: *Sphagnum* dominated bogs and poor fens are most frequent on Rainy Lake where water level fluctuations are smallest, while shore fens are most frequent on Lac la Croix with intermediate water level fluctuations. However, the picture is complicated by other factors, such as nutrient availability, species pools, and habitat invasibility, which also influence peatland community development and composition. Furthermore, shoreline peatlands on Rainy and Namakan are relatively young since most peatlands existing before the establishment of the dams in 1911-1914 were almost certainly flooded out and may be still changing towards a new equilibrium.

The Typha *(cattail) question*
Typha is much more abundant (about 10 times greater relative cover) in Namakan and Sand Point peatlands than in most Rainy Lake peatlands and is virtually absent in Lac la Croix. This pattern of increased *Typha* abundance in waterbodies with wide range of water level fluctuation is consistent with patterns observed elsewhere (c.f. Weisner 1993). However, these results are inconsistent with the results of the shoreline segments (Shoreline Surveys section), where Sand Point Lake had a relatively low proportion of *Typha* invaded shoreline, suggesting that are differences in factors influencing *Typha* invasions across shoreline and peatland habitats.

In addition, unlike in the analyses of the aquatic vegetation (above), we have no good estimation of the rate or even the direction of change in these peatlands since they were not assessed as part of the 1987 studies. If these peatlands are for the most part grounded (which we suspect), that is, if they do not merely float up and down with changes in water level, the new rule curves should limit *Typha* expansion. That is, the new curves' gradual drawdown in early summer, immediately following the seasonal high water, would theoretically favor grass, sedge and shrub invasion, and not *Typha* expansion, which we had surmised was happening in many sites. This suggests either the new rules curves are not influencing these peatlands appreciably, or that the predicted vegetative response (decrease in *Typha*) has yet to occur.

In summary, we feel the peatland sampling results provide a good snapshot in time of the different non-treed peatland types in the study area and, more importantly, provide a baseline for future monitoring that could begin to answer the *Typha* questions posed above. It should be noted, however, that the comparisons of the Namakan and Rainy sites with Lac la Croix may not be apt, as there were only four sites chosen from Lac la Croix, and these were chosen in a pseudo-random fashion that may not represent the greater Lac la Croix region.

Extensive Site Sampling (Extensive Sampling section)
With this task, extensive sampling, we intended to develop a "quick and dirty" methodology for sampling only the floating and submergent vegetation, particularly on Namakan, and to establish a baseline for future monitoring. Begun as a general component of the 2001-2002 VNP vegetation study (Meeker and Harris 2004), its rationale was to develop a more rapid, more extensive metric focusing on the elevation (2.0 to 2.25 m below MHW) in Namakan where we expected the greatest vegetative response to the new rule curve. For this task on Namakan, we sampled at 31 sites, versus Namakan's 11 intensively sampled sites along elevational transects (Intensive Sampling section). The vegetative predictions relative to the changes in rule curves would suggest that the Namakan sites would increase in macrophyte abundance since the new rule curve indicates that these areas (zone 1) will not be drawn down and exposed to winter/spring dessication and freezing, and that the Rainy aquatics would likely not change as the rule curve modifications in that basin were not significant.

We expected considerable variability in this type of sampling, but thought that it was important to sample at another spatial scale (other than the quadrats along elevational transects). In addition, the goal was to develop one metric, frequency, to assess a lake wide average frequency that could be repeated again at a future time. At the first sampling (2002), Namakan's mean frequency was 39.2%; about 40% of all the 1116 quadrats had at least minimal cover by aquatic taxa. Since we did not resample the sites in this study, we have no previous information to compare with, hence no means to assess vegetative change over time in response to water level changes. We did, however, assess the variability associated with this extensive approach and because of this only recommend future sampling extensive in certain circumstances (see the recommendation portion of this summary below).

Wild Rice (Wild Rice Surveys section)
Verbal accounts and other unpublished sources suggest that wild rice distribution has increased, especially in Kabetogama Lake, relative to its distribution during the extreme drawdowns conditions in the 1960s and 1970s. However, the lack of consistently collected pre- and post-2000 rule curve data preclude any robust comparison of wild rice abundance between these time periods. Similarly, different sampling techniques (due to differences in wild rice distribution) used in Namakan vs. Rainy preclude statistical comparison between basins, now and into the future. We did, however, successfully test sampling techniques unique to each basin and established a baseline for future within-basin monitoring.

Invasive Taxa on Shorelines (Shoreline Surveys section)
Although we do not have any empirical data on the vegetative composition of the shoreline fringe in the 1960s and 1970s, the general wisdom is that invasive taxa increased. Observations by Voyageurs Park Service staff and periodic researchers suggest a noticable increase in the abundance of invasive narrow-leaf cattail (*Typha angustifolia* and the hybrid *T.* x *glauca*) as well as common reed grass (*Phragmites australis*) along shorelines and on the outer edges of shoreline fens, especially in the southern parts of Rainy Lake and the Kabetogama sub-basin.

Preliminary surveys of a portion of the Rainy Lake shoreline completed in 2002 on both the Canadian and US sides indicated that an average of about 6% of 23 shoreline transects in Rainy were invaded by these species (Meeker and Harris 2004). Shoreline assessments were continued and expanded in this study to assess the present shoreline vegetation condition in other areas, including other parts of Rainy, Namakan, Kabetogama, and Sand Point, as well as the Lac la Croix Basin outside of Voyageurs National Park.

Eight sub-basins were recognized, and these sub-basins have considerably different invasive status. The percent of shorelines dominated by *Typha* ranged from as low as 0.2% and 2.9% in Lac la Croix and Sand Point Lake respectively to as high as 99.2% in Black Bay (Rainy Lake). *Phragmites* was in greatest abundance along shorelines in Kabetogama (59.8%) and was uncommon ($\leq$ 13%) in other sub-basins. Only at Sand Point and Lac la Croix is the majority of the shoreline still dominated by native, non-invasive taxa. *Phalaris* was present in substantial amounts (10 to 18%) only in the Rainy Lake sub-basins (North Rainy, South Rainy, and Red Gut Bay).

None of these data necessarily point to water level management as *the* key factor in the presumed increase in these invasives, although reservoir type management (as we saw in Namakan), could easily offer habitat for the establishment phase of *Typha* invasion, and the regularity and minimal fluctuations in Rainy could favor *Typha* once established in a drought year.

In addition, however, the high degree of invasion (>85%) of Black Bay (Rainy Lake) and Kabetogama Lake may be related to nutrient availability. Although in different watersheds, these two sub-basins are in close proximity to each other, and a minor channel of Kabetogama flows into Black Bay for most of the year. Both Kabetogama and Black Bay also are underlain by clay soils and consequently possess higher specific conductivity than other basins in the study area. The degree of invasion appears positively correlated with surface water conductivity (Figure 30).

The percent of invaded shoreline in the study area is higher than that of inland lakes and Lake Superior bays at Isle Royale National Park (1.2% for all invasive species) (Meeker et al. 2007). The difference probably represents an earlier stage of invasion at Isle Royale than at Voyageurs rather than the influence of water level regulation or other habitat attributes (Meeker et al. 2007).

Interestingly, the pattern of *Typha* invasion of the shorelines is different from that of peatlands (Section 3). Peatlands in Sand Point Lake had more *Typha* invasion than the other basins but a low level of invasion (2.9%) of shorelines. This may reflect the different habitat preferences of the native *T. latifolia* (wet soil and very shallow water) vs. *T. angustifolia* and *T.* x *glauca* (deeper water). In this case *T. latifolia* may be prevalent in peatlands and *T. angustifolia* (and hybrid) on shorelines. Although *Typha* hybrids could not be reliably identified in the field, genetic analysis of *Typha* samples from Voyageurs Park indicates that the more isolated sites on inland lakes are mostly pure *T. latifolia*, but that hybrids are widely distributed (Steve Windels, pers. comm.).

Both native (relatively non-invasive) and introduced (invasive) genotypes of *Phragmites* may occur in the study area, but distinguishing the genotypes in the field is very difficult and was not attempted in this study. Subsequent monitoring may determine if *Phragmites* is increasing and genetic analysis or detailed examination of specimens could determine which genotypes are present.

In summary, although increases in invasive shoreline species have been attributed to altered water regimes in other studies, other factors, especially nutrient availability, are apparently also important in the study area.

Summary and recommendations from analyses of Sampling Bias

In our goals to establish long term monitoring recommendations for the Park, we have made inroads in creating a more robust data set from which to monitor vegetative change in Namakan, Rainy, and Lac la Croix. First, as in the intensive site analyses (Intensive Sampling section) discussed earlier, we have greatly increased sample sizes. In addition, a major part of this study was to estimate bias in sampling and to use these estimates to make recommendations for future monitoring. To this end we analyzed bias in three general categories: 1) **Intra-observer bias**, that is, the sampling variability inherent in estimates made by a single, experienced observer repeatedly sampling the same resource, 2) **Inter –observer bias**, how different observers and their experiences in sampling may contribute to variability in results, and 3) what we have called **placement bias**, an attempt to determine the minimum number of quadrats needed to produce reliable information.

Intra-observer bias (Single Observer)

Intra-observer error was estimated for three habitat types, including peatlands, 2.0 m deep aquatic communities, and shoreline communities, as examples of the type of habitats we recommend for monitoring. In each case a single experienced observer sampled the vegetation in 1 m x 1 m quadrats along transects at four successive times during six-day periods. At each time the exact same quadrats were assessed, that is the quadrats remained in place.

Summary Metrics (Single Observer) – cover, richness, Typha count

With single observers we found no significant differences among sampling trials in both cover estimates (a single estimate of cover or the sum of individual taxa), or quadrat richness (1 m^2) and *Typha* stem density count, at any of the three habitat types. For these summary metrics, the minimal detection of change or the amounts of change that must be measured to suggest real change in abundance from one time to the next varied from 2% to 14% for all cover estimates and from 8% (aquatic) to 16% (shoreline) for richness.

To use shoreline richness for an example, these analyses suggest that our estimate of richness, 12.6 taxa per 1 m^2 quadrat, would need to differ by 16% at the next sampling and be either less than 10.6 or greater than 14.6 to be recognized as a real change in quadrat diversity. To use aquatic summed cover as a similar example, our estimate 72.9% would need to differ by 7.6% at the next sampling and be either less than 67.3% or greater than 78.4% to be recognized as a real change in cover. In general, single observers were consistent over time on their estimates of summary metrics.

Individual taxa metrics (Single Observer - frequency, cover, importance value)

We also calculated two measures to gauge how accurately and consistently observers saw and estimated the abundance of individual taxa. One of these measures estimated the *accuracy of detection* and is based on presence/ absence or frequency data. In general, most taxa were observed consistently (90-100% of time), but others were harder to spot (with accuracies as low as 71.3%) due to either small size or similarity to other taxa.

In addition we calculated the *minimal detection of change* (as noted above with the summary measures) for individual taxa and estimated the minimum amount of change necessary to suggest real change in a single observer's assessments. As an example, the most dominant taxa in peatlands, lake sedge (*Carex lacustris*), was estimated to have a mean cover of 21.6% and a minimal detection of change of 11.7% suggesting a future estimate would need to be either less than 19.1% or greater than 24.1% to be recognized as a real change in cover (Table 65). In the aquatic setting, water-marigold (*Bidens beckii*), one of the most dominant taxa by cover, was estimated to have a mean cover of 11.1% and a minimal detection of change of 13.7% suggesting a future estimate would need to be either less than 9.6% or greater than 12.6% to be recognized as a real change in cover (Table 72).

In general, these data suggest for these ideal conditions (a single experienced observer) that change in the abundance of the dominant taxa will be reasonably detectable. However, the second tier taxa, those with less than about 1.5% mean cover, will be harder to track, and some of their abundances would likely have to double or halve before one can comfortably suggest real change (i.e. taxa with minimal detection of change percents at about 50%) (Tables 65, 72, 78).

We recommend that future analyses of change in the abundance of individual taxa focus either on **relative cover** or **relative importance value** (IV). In general, detection of change limits for individual taxa are lower for IV. For example, in the shoreline habitat mean minimal detection of change percent for common taxa using IV is 24.4% as opposed to 37.2% for cover (Table 105), in the aquatic habitat mean minimal detection of change percent for all taxa using IV is 57.9% vs. 111.7% for cover (Table 106), and in the peatland habitat 32.8% for IV vs. 37.8% for cover (Table 107). In all three habitat types, especially the aquatic, variability is reduced by reporting IV. We are reminded that IV, in addition to cover, also reflects frequency of occurrence (simple presence and absence), which is a less subjective measure.

Inter-observer Bias (Multiple Observer Variability)

As opposed to the single observer assessements above, what follows is an assessment of the variability associated with different observers viewing the same resource. As in the single observer sampling, this study utilized 1 m x 1 m quadrats in three different habitats: peatlands, aquatics (at depths of 1.25 meters), and shorelines. The source of variability includes inter-observer bias in species identification and visual estimates of cover (due, in part, to differences in experience) and differences among sampling techniques (e.g., shoreline and peatland transects are sampled by walking whereas the deeper aquatic transects require canoe and/or diving with a mask and snorkel). To estimate variability among individuals, four observers sampled the same vegetation at very close to the same time period. Twenty 1 m x 1 m quadrats were placed along transects and were *kept in the same location* during the duration of sampling (1-2 days for each transect) and observed by multiple individuals.

We also tested for differences in field experience by breaking the observers into two groups, experienced wetland assessors (the authors) and trained assessors (Northland College undergraduate student assistants). Inexperienced observers received 3-4 days of instruction, including species identification of all taxa they would likely observe, and through practice sessions, calibration of cover estimates prior to sampling. As expected, the variability associated with different observers (both experienced and recently trained) viewing the same resource was greater than that of a single experienced observer.

Summary Metrics (Multiple observers – cover, richness, Typha count)

Whereas there were no significant differences in multiple estimates of cover and richness by single observers (noted above), multiple observers' estimates were often significantly different from each other. This was true for both the single estimate of cover, the sum of all individual taxa's cover, and quadrat richness.

These findings suggest that tracking total cover over time, either way it is estimated, may benefit from more calibration of observers' estimates prior to the official sampling, that is calibration should be built into time reserved for monitoring. In our case it was often one observer that was different from the other three, but it did not follow the differences in the observers' level of experience.

Table 105. Metric means and minimal detection of change percents for a single observer over repeated sampling of the shoreline habitat for the twenty most abundant (by cover) taxa. Taxa are ordered by their mean raw cover.

			Taxa Means				**Minimum Detection of Change %**		
	Genus	**species**	**Cover**	**Rel. Cov.**	**Imp. Val.**		**Cover**	**Rel. Cov.**	**Imp. Val.**
1	*Calamagrostis*	*canadensis*	31.30	33.54	20.43		11.5	18.1	17.7
2	*Pinus*	*strobus*	11.45	12.22	8.15		16.2	13.0	9.9
3	*Carex*	*spp.*	4.46	4.75	5.83		25.5	17.1	17.0
4	*Sparganium*	*eurycarpum*	3.96	4.24	3.77		20.2	20.8	15.1
5	*Myrica*	*gale*	3.64	3.90	2.53		16.2	20.8	16.1
6	*Scirpus*	*cyperinus*	3.60	3.86	3.44		8.5	15.6	16.8
7	*Poa*	*palustris*	3.44	3.64	4.23		44.3	38.0	28.3
8	*Carex*	*lacustris*	2.29	2.42	2.18		51.4	44.1	38.0
9	*Carex*	*(ovales)*	2.10	2.21	2.57		91.4	88.9	31.2
10	*Polygonum*	*coccineum*	2.06	2.23	2.82		38.2	47.2	30.2
11	*Lycopus*	*spp.*	1.98	2.10	3.62		29.0	19.3	3.3
12	*Abies*	*balsamea*	1.94	2.04	1.49		68.3	61.9	65.1
13	*Lysimachia*	*spp.*	1.89	2.02	3.74		33.3	33.6	18.8
14	*Aster*	*spp.*	1.85	1.97	4.00		27.6	23.0	8.0
15	*Sium*	*suave*	1.36	1.45	2.57		46.8	43.0	26.0
16	*Fraxinus*	*spp.*	1.30	1.39	1.31		46.6	46.4	46.7
17	*Iris*	*versicolor*	1.21	1.28	1.03		42.6	35.8	17.0
18	*Equisetum*	*sylvaticum*	1.13	1.20	3.12		28.6	23.9	7.3
19	*Stachys*	*palustris*	1.10	1.18	1.27		25.7	29.2	22.7
20	*Sagittaria*	*cuneata*	1.05	1.11	1.65		72.9	71.3	52.4
		sums	**83.10**	**88.72**	**79.76**		**37.2**	**35.6**	**24.4**
									Means
	Most abundant taxa example						**Limits (95% CI)**		
				Means			**Lower**	**Upper**	
	Calamagrostis	*canadensis*	**Cover**	31.30			27.7	34.9	
	Calamagrostis	*canadensis*	**Rel. Cov.**	33.54			27.5	39.6	
	Calamagrostis	*canadensis*	**Imp. Val.**	20.43			16.8	24.1	

Table 106. Metric means and minimal detection of change percents for a single observer over repeated sampling of the aquatic habitat for all taxa. Taxa are ordered by their mean raw cover.

			Taxa Means				Minimum Detection of Change %		
	Genus	**species**	**Cover**	**Rel. Cov.**	**Imp. Val.**		**Cover**	**Rel. Cov.**	**Imp. Val.**
1	*Vallisneria*	*americana*	31.44	43.07	28.83		18.7	11.6	6.0
2	*Bidens*	*beckii*	11.12	15.27	13.51		13.7	13.1	10.7
3	*Ceratophyllum*	*demersum*	8.00	11.02	12.32		12.2	17.2	9.6
4	*Lemna*	*trisulca*	6.79	9.37	11.88		36.5	40.6	17.6
5	*Sagittaria*	*rosette*	6.13	8.43	4.97		20.2	22.9	19.3
6	*Potamogeton*	*foliosus*	2.76	3.79	6.42		18.4	11.0	16.9
7	*Myriophyllum*	*spp.*	2.58	3.54	7.62		29.6	29.4	20.0
8	*Potamogeton*	*zosteriformis*	1.85	2.53	1.73		41.4	36.5	38.9
9	*Elodea*	*canadensis*	1.63	2.23	5.47		36.8	31.2	7.2
10	*Chara*	*sp.*	0.35	0.48	1.92		102.4	106.5	41.3
11	*Najas*	*flexilis*	0.06	0.08	1.44		112.5	114.9	73.1
12	*Potamogeton*	*spirillus*	0.03	0.05	1.65		124.0	126.8	43.4
13	*Ranunculus*	*longirostris*	0.03	0.04	0.40		262.9	264.7	19.2
14	*Nymphaea*	*odorata*	0.03	0.04	0.69		183.7	183.7	51.2
15	*Potamogeton*	*vaseyi*	0.02	0.03	0.58		177.9	181.0	58.6
16	*Nitella*	*spp.*	0.01	0.02	0.30		318.2	318.2	106.9
17	*Utricularia*	*vulgaris*	0.01	0.02	0.10		318.2	318.2	318.2
18	*Potamogeton*	*richardsonii*	0.00	0.00	0.18		183.7	184.0	183.7
		Sums	**72.84**	**100.00**	**100.00**		**111.7**	**111.8**	**57.9**
									Means
	Most abundant taxa example						**Limits (95% CI)**		
				Means			**Lower**	**Upper**	
	Vallisneria	*americana*	**Cover**	31.44			25.6	37.3	
	Vallisneria	*americana*	**Rel. Cov.**	43.07			38.1	48.1	
	Vallisneria	*americana*	**Imp. Val.**	28.83			27.1	30.6	

Table 107. Metric means and minimal detection of change percents for single observers of the peatland habitat for all taxa with > 1.0% cover within either the single or the multiple observer assessments. Taxa are ordered by their mean raw cover in the multiple observer assessment.

			Taxa Means				**Minimum Detection of Change %**		
	Genus	**species**	**Cover**	**Rel. Cov.**	**Imp. Val.**		**Cover**	**Rel. Cov.**	**Imp. Val.**
1	*Carex*	*lacustris*	21.59	27.75	18.14		11.7	13.6	12.1
2	*Potentilla*	*palustris*	9.25	11.90	10.21		9.6	13.2	9.8
3	*Carex*	*utriculata*	12.28	15.65	11.92		39.3	31.5	20.7
4	*Typha*	*latifolia*	11.88	15.24	11.88		16.4	14.2	11.2
5	*moss*	*spp.*	2.28	2.91	4.86		29.0	21.1	15.9
6	*Calamagrostis*	*canadensis*	7.36	9.49	8.90		18.4	23.9	15.4
7	*Calla*	*palustris*	2.21	2.85	3.55		15.4	19.7	12.0
8	*Lysimachia*	*thyrsiflora*	1.47	1.88	4.35		5.1	9.0	13.9
9	*Utricularia*	*intermedia*	0.08	0.00	0.18		210.5	302.8	206.8
10	*Acorus*	*calamus*	0.34	0.43	1.10		48.6	41.5	65.2
11	*Polygonum*	*amphibium*	1.13	1.44	2.75		13.5	12.0	14.2
12	*Sphagnum*	*sp*	2.43	3.10	5.05		30.8	26.3	12.4
13	*Triadenum*	*fraseri*	1.13	1.43	2.84		43.1	35.0	16.8
		Sums	**73.40**	**94.08**	**85.73**		**37.8**	**43.4**	**32.8**
									Means
	Most abundant taxa example						**Limits (95% CI)**		
				Means			**Lower**	**Upper**	
	Carex	*lacustris*	**Cover**	21.59			19.1	24.1	
	Carex	*lacustris*	**Rel. Cov.**	27.75			24.0	31.5	
	Carex	*lacustris*	**Imp. Val.**	18.14			15.9	20.3	

Alternatively, the estimate of richness *did* follow observers' levels of experience, but not consistently in the same direction. For example, for both the peatland and the shoreline resources the experienced samplers recorded more taxa (8.1 vs. 7.4 taxa per $1m^2$ on average for the shoreline), whereas in the aquatic resource the less experienced observers recorded significantly more taxa (7.6 per $1m^2$, compared to 6.6 per $1m^2$ for the experienced observers). It should be noted that although there were *statistical* differences in cover and richness among observers, the differences may not be ecologically important, that is for the shoreline example above, 8.1 taxa per $1m^2$ may not be different in an *ecological* sense from taxa 7.4 per $1m^2$.

In addition to cover and richness, in the peatlands we also estimated *Typha* stem density as a means to monitor change. In this assessment of inter-observer bias, we found no significant differences among observers in the estimated mean number of live stems of *Typha*, which varied from 3.3 to 3.8 stems per m^2. This suggests that stem density counts of notable, dominant taxa may be a dependable and worthwhile metric in some habitats.

Individual taxa metrics (Multiple observers - frequency, cover, importance value)
As with the single observer analyses, we also calculated an *accuracy of detection* for multiple observers, and in general taxa inconsistently seen (i.e. missed) by a single observer were the same taxa inconsistently observed by multiple observers. However, there were exceptions—taxa not observed by experienced observers while thought to be present by less experienced observers. These likely were misidentified by the latter group. For example, neither experienced observer recorded *Ceratophyllum demersum*, although it was recorded by the other two observers. Unlike the shoreline and peatland habitats, the "call" as to who was correct here is more difficult to say, as visibility is much more of a problem. On a positive note, most of the possible miss-identified taxa were associated with the taxa-rich shoreline habitats and all these taxa were found in low abundance.

Across all three habitat types there were six taxa of the 63 assessed that showed significant differences in cover among the four different observers (Tables 81, 85, and 91). In all these cases the estimates of the two experienced observers were not significantly different. Similarly, using relative cover, there were six taxa that showed significant differences among the four different observers, but again estimates of the two experienced observers were not significantly different (Tables 83, 87, and 92). With both metrics it was the same taxa that showed significant differences, and three of these taxa had overall mean cover values of less than 5%.

As is the single observer assessment, detection of change limits for individual taxa are lower using importance values (IV). For example, in the shoreline habitat mean minimal detection of change percent for common taxa using IV is 63.21% as opposed to 89.8% for cover (Table 108), in the aquatic habitat mean minimal detection of change percent for all taxa using IV is 80.8% vs. 87.8% for cover (Table 109), and in the peatland habitat 46.0% for IV vs. 89.9% for cover (Table 110). Again, for all three habitat types variability is reduced by reporting IV.

Similarity Comparisons in all Habitat Types
In a final approach to looking at multiple observer bias, we calculated similarity index values measuring the percent similarity among observers in presence and absence of species on a quadrat per quadrat basis (Table 93). In general, observers agreed more in their floristic assessments of the aquatic and peatland habitats, with overall mean similarities of 85.6% and 81.6% respectively, with less similarity seen at the quadrat level in the shorelines (69.6%). This is likely due to a greater species pool in the shorelines, as more taxa are subject to omission. We had expected more similarity among experienced observers, but this was only significant in the case of the peatland quadrats with experienced similarities at 87.2% > the inexperienced at 79.8%.

Placement Bias
In addition to assessing bias and sampling variability relative to observers, we also assessed the variability inherent in different random placement of quadrats along transects, which we have called placement bias. Associated with this analysis, we also investigated the number of sub-samples (quadrats in this case) needed to produce reliable estimates. We did this study in the same habitat types that we tested in observer bias, including peatland, aquatic, and shoreline segments. In each case we then calculated the high and low mean estimates for a number of

Table 108. Metric means and minimal detection of change percents for multiple observers over repeated sampling of the shoreline habitat for the fifteen most abundant (by cover) taxa. Taxa are ordered by their mean raw cover.

			Taxa Means				**Minimum Detection of Change %**		
	Genus	**species**	**Cover**	**Rel. Cov.**	**Imp. Val.**		**Cover**	**Rel. Cov.**	**Imp. Val.**
1	*Myrica*	*gale*	27.04	26.78	18.57		27.8	9.8	7.7
2	*Calamagrostis*	*canadensis*	27.03	26.46	19.22		53.4	12.1	11.1
3	*Alnus*	*incana*	17.30	19.29	12.72		57.0	12.0	11.3
4	*moss*	*spp.*	4.49	5.05	6.42		94.0	67.7	58.0
5	*Pinus*	*strobus*	3.99	3.14	2.28		198.6	144.2	125.0
6	*Chamaedaphne*	*calyculata*	3.38	3.69	2.26		15.2	16.9	11.4
7	*Spiraea*	*alba*	1.94	2.00	2.25		125.1	107.4	107.0
8	*Potentilla*	*palustris*	1.70	1.75	3.45		58.4	77.6	37.5
9	*Lysimachia*	*spp.*	1.58	1.84	4.83		82.2	73.6	37.6
10	*Polygonum*	*amphibium*	1.50	1.70	2.37		24.7	54.8	24.9
11	*Salix*	*spp.*	1.14	1.19	1.64		121.3	162.3	137.2
12	*Carex*	*rostrata/vesicaria*	0.90	1.01	2.55		71.4	82.7	75.6
13	*Equisetum*	*spp.*	0.53	0.79	2.88		48.4	63.7	49.8
14	*Onoclea*	*sensibilis*	0.45	0.46	0.56		136.9	169.2	70.1
15	*Eleocharis*	*acicularis*	0.39	0.33	0.79		232.2	185.0	183.7
		sums	**93.35**	**95.48**	**82.79**		**89.8**	**82.6**	**63.2**
									Means
	Most abundant taxa example						**Limits (95% CI)**		
				Means			**Lower**	**Upper**	
	Myrica	*gale*	**Cover**	27.04			19.5	34.6	
	Myrica	*gale*	**Rel. Cov.**	26.78			24.2	29.4	
	Myrica	*gale*	**Imp. Val.**	18.57			17.1	20.0	

Table 109. Metric means and minimal detection of change percents for multiple observers of the aquatic habitat for all taxa. Taxa are ordered by their mean raw cover.

			Taxa Means				Minimum Detection of Change %		
	Genus	**species**	**Cover**	**Rel. Cov.**	**Imp. Val.**		**Cover**	**Rel. Cov.**	**Imp. Val.**
1	*Vallisneria*	*americana*	24.75	24.71	18.93		32.2	23.8	19.4
2	*Potamogeton*	*pusillus*	24.00	25.79	18.91		34.5	36.8	27.0
3	*Sagittaria*	*rosette*	12.73	12.59	10.08		64.4	48.5	44.8
4	*Lemna*	*trisulca*	11.46	10.49	11.70		142.9	125.8	55.6
5	*Myriophyllum*	*spp.*	10.62	11.22	12.52		37.1	59.4	27.0
6	*Elodea*	*canadensis*	5.98	6.57	9.40		5.6	21.6	12.5
7	*Bidens*	*beckii*	5.61	5.82	8.56		21.2	20.9	16.3
8	*Potamogeton*	*richardsonii*	1.41	1.53	2.88		48.5	39.3	19.4
9	*Najas*	*flexilis*	0.63	0.70	2.07		162.6	161.4	119.9
10	*Eleocharis*	*acicularis*	0.33	0.35	1.38		189.7	187.5	164.9
11	*Elatine*	*minima*	0.06	0.06	2.01		136.5	127.3	88.8
12	*Nymphaea*	*odorata*	0.13	0.06	0.20		45.0	184.9	184.2
13	*Chara*	*spp.*	0.08	0.06	0.66		145.8	188.4	130.5
14	*Ceratophyllum*	*demersum*	0.08	0.04	0.35		70.3	196.7	183.7
15	*Ranunculus*	*longirostris*	0.02	0.02	0.36		181.1	226.8	118.1
		Sums	**97.88**	**100.00**	**100.00**		**87.8**	**109.9**	**80.8**
									Means
	Most abundant taxa example						**Limits (95% CI)**		
				Means			**Lower**	**Upper**	
	Vallisneria	*americana*	**Cover**	24.75			16.8	32.7	
	Vallisneria	*americana*	**Rel. Cov.**	24.71			18.8	30.6	
	Vallisneria	*americana*	**Imp. Val.**	18.93			15.3	22.6	

Table 110. Metric means and minimal detection of change percents for multiple observers of the peatland habitat for all taxa with > 1.0% cover within either the single or the multiple observer assessments. Taxa are ordered by their mean raw cover.

			Taxa Means				Minimum Detection of Change %		
	Genus	**species**	**Cover**	**Rel. Cov.**	**Imp. Val.**		**Cover**	**Rel. Cov.**	**Imp. Val.**
1	*Carex*	*lacustris*	25.09	32.14	20.20		15.3	11.2	9.0
2	*Potentilla*	*palustris*	11.69	14.63	11.45		34.0	18.6	12.7
3	*Carex*	*utriculata*	9.00	10.97	9.05		56.1	63.9	39.4
4	*Typha*	*latifolia*	7.96	9.93	8.89		44.3	27.6	12.9
5	*moss*	*spp.*	6.98	8.14	7.74		74.6	78.0	51.2
6	*Calamagrostis*	*canadensis*	5.59	7.20	7.15		52.2	44.6	28.4
7	*Calla*	*palustris*	2.91	3.60	3.66		74.0	55.0	29.7
8	*Lysimachia*	*thyrsiflora*	2.32	3.05	5.56		64.9	50.0	23.9
9	*Utricularia*	*intermedia*	1.67	2.04	4.06		92.3	80.9	37.2
10	*Acorus*	*calamus*	1.36	1.68	3.35		66.6	49.6	14.6
11	*Polygonum*	*amphibium*	1.13	1.46	2.79		68.8	54.8	28.7
12	*Sphagnum*	*spp.*	1.04	1.17	2.79		258.3	227.7	126.7
13	*Triadenum*	*fraseri*	0.06	0.09	0.59		266.8	263.0	183.9
		Sums	**76.79**	**96.08**	**87.28**		**89.9**	**78.8**	**46.0**
									Means
	Most abundant taxa example						**Limits (95% CI)**		
				Means			**Lower**	**Upper**	
	Carex	*lacustris*	**Cover**	25.09			21.2	28.9	
	Carex	*lacustris*	**Rel. Cov.**	32.14			28.5	35.7	
	Carex	*lacustris*	**Imp. Val.**	20.20			18.4	22.0	

metrics using variable number of quadrats (in multiples of five, hence 5, 10, 15, and continuing up to 50 quadrats) and compared these estimates with that of the pseudo "true" mean (or the mean of all 50, the maximum number of quadrats sampled in each habitat).

Peatlands

For peatlands, in addition to looking at the abundance of individual taxa, we looked at changes in variability with sample size in five composite metrics, including total cover (single estimate), summed cover (all taxa), Typha stem densities (live and dead), and quadrat richness. In most cases standard deviation begins to level off at sample sizes of 20-25 quadrats (Table 97), suggesting that our choice of the number of quadrats in the intensive sampling (Intensive Sampling section) is adequate. Relative to individual taxa, variability about the means using increasing sample sizes was calculated for the twelve most abundant taxa by total cover. The most abundant taxon, *Carex lacustris*, had low and high estimates of 17.1 and 21.7%, using 20 quadrats or about 11-12% around the 50 quadrat mean of 19.3 (Table 98).

The variability associated with *Typha* cover is somewhat greater, and, again using 20 quadrats, the low and high cover estimates are 7.9 and 13.1%, or about 22-26% around the 50 quadrat mean of 10.3 (Table 98). This suggests for *Typha* (a taxon that VNP may have interest in monitoring) that differences in cover over two time periods need to exceed about 25% to suggest a real change.

Aquatics
In general the variability in aquatic habitat associated with sampling both composite metrics (Table 99) and individual taxa abundance (Table 100) is greater than the peatland habitat (above). For example, Wild celery (*Vallisneria americana*) was the most abundant aquatic taxa, and using 20 quadrats the extreme estimates of the mean cover for *Vallisneria* ranged between 9.8 and 17.6%, or about 26-32% around a mean of 13.3 using all 50 quadrats. The "true means" of all the other taxa were less than 5% per 1 m x 1 m quadrat, indicating a patchily vegetated site. Yet the utilization of 20 quadrats noted the presence of all taxa in all sampling trials except one (*Bidens beckii*), which was omitted in only 1 of the 10 trials.

Shorelines
Estimates of percent summed cover over all 50 quadrats was estimated at 91% and, using a 20 quadrat sample to estimate summed cover, resulted in low and high estimates of 84.3 and 96%, or only 6-8% around the "true" mean (Table 101). At 20 quadrats, the number used in our intensively sampled sites, the estimation of the mean cover for one of the two most abundant taxa, *Myrica gale*, varied between 23.8 and 37.5%, compared with the 30.6 mean using all 50 quadrats (Table 102). Hence by using 20 quadrats the extreme estimates of *Myrica* cover can be expected to be about 23% above and below the 'true' mean. For the next most abundance taxa, *Calamagrostis canadensis* using 20 quadrats, the extreme mean estimates varied between 13.0 and 20.7, or about 25% around the 50 quadrat mean of 17.9%.

Placement Bias Summary
For each of the three habitat types, 20 quadrats appeared to provide adequate estimates of composite metrics such as total cover and richness. Estimates of individual taxa cover were generally adequate using 20 quadrats, especially for the most abundant taxa, or those taxa with mean cover values greater than about 5%. In general, by using 20 quadrats these common taxa varied 20-25% about the "true" means using 50 quadrats, with the exception of some very patchily distributed species. This suggests that a measure of change from one time to the next of greater than 25% would represent a real change for most taxa.

There is evidence that some taxa, in the aquatic environment especially, could be better served with 25 quadrats, or the addition of 5 more per transect. Observers working in the aquatic transects were generally able to sample 40 quadrats in a day, and we believe that 50 quadrats would be reasonable for an increased daily goal (which represents an additional 5 for each of the two aquatic transect at the intensive sites). In peatlands, however, since the transects and quadrats are re-locatable (monumented) such that re-sampling may be at the level of individual quadrats, 20 quadrats would be very appropriate.

General Sampling Recommendations

Based on the results of the bias/variability assessment and the analyses of the 2002-2006 sampling, we make the following section by section recommendations.

Recommendations for Intensive Sampling section

Since much of the Park's interest is in monitoring the wetland vegetation's response to the new rule curves and water level management in general, we believe that *within-basin intensive sampling* and *analyses* to be of highest priority. Given this charge, it is important to sample vegetation in a "moderate" water level year, and additionally, care should be taken to make sure that all repeat sampling of the intensive sites within a given basin be done in a single season, optimally within a four week window (July 15 – August 15, when the aquatic and wetland taxa are in advanced growth stage). That is to say, while it is not likely to cover all three basins in one sampling season, all the sites of each basin (11 at Namakan, 10 at Rainy, and 10 at Lac la Croix) should be visited in one season. Again, we make this point because we believe the prime interest is how a given basin is changing over time, not necessarily comparisons among basins.

As an example, in Namakan there are 11 sites each with three elevations to sample. The priority should be the 2.0 depth, or the zone where we expected the most change, followed by the shoreline (where we expect some change due to sooner summer drawdowns), and then the 1.25 m depth (which might not be necessary as little change is expected). If all three elevations are done, however, (which we recommend, and which allows the best comparisons to the 2002 data) each elevation should be done by a single observer, that is if there are multiple observers, each should specialize on a specific elevation, reducing variability.

We also recommend that the number of quadrats in the aquatic transects be increased from 20 to 25, and if the shoreline number of quadrats is increased accordingly, it would mean a total of 75 quadrats to assess per site. This could translate to 50 quadrats as a goal for one observer, and 25 for the other, in order to complete a single site in one day and maintain the recommended specialization. Presumably the other observer would help lay out the quadrats for the third elevations, take overall site notes, and re-locate the start and end of the transects with GPS. It should be emphasized that aquatic transects (especially the 2.0m depth) be assessed in at least partial sunlight to maximize visibility. If one site is done per day, a two to three week sampling period should be sufficient, allowing one day off in each three days for inclement weather (or to sample peatland sites, see below). Since the 11 Namakan sites were sampled in 2002, re-sampling by 2012-14 would be a goal for decade to decade monitoring.

In general we believe the type of sampling we did in 2002, for each quadrat a total cover estimate followed by taxa by taxa cover estimates, to be sufficient. For the aquatic sampling a mask and snorkel are necessary, and for the shoreline transects care should be taken to exclude all cover above 2m in height (tree and shrub overhang) to be consistent with the earlier sampling. It is also recommended that the observers review the site by site species lists prior to re-sampling.

Analyses of the data should include cover, relative cover, and importance value (which includes frequency data) calculations. In addition, we recommend grouping data into the same life form group as we did in section one (e.g., for the aquatics: emergent, floating leaf, isoetid, low submergent, and tall submergent) for comparisons between sampling times.

Recommendations for Peatland Sampling (Peatland Assessment section)
Like the intensively sampled sites, the peatland sites were located by GPS, however, in addition, they were monumented with PVC pipe. This allows an exact repeat sampling of individual quadrats if care is taken to: 1) maintain the monuments at least once every five to six years (suggesting that these sites should be re-visited in 2009-2010), 2) carefully extend the meter tape through the midpoint making sure the lines are straight, 3) establish the quadrats on the left side of the sampling transect as one looks from start to finish (in order to sample the exact same spot), and 4) bring copies of the old data sheets in the field to help locate the quadrats in the same location (e.g. at the 4-5m mark) and have a handy known species pool. If this attention to detail is adopted, the next analysis could be from quadrat 'X' at time one to quadrat 'X' at time two and would be a robust metric to monitor stem density changes in *Typha*. We recommend that the *Typha* (live stem density) sampling take place each time the sites are maintained/monumented (approximately every 5-6 years), while full community assessment (of all taxa as we did) occur once every 10 years. The analyses of the every decade re-sampling could target those taxa that may drop out of the community as either *Typha* or shrub abundance increases.

There were 47 peatlands sampled in 2004-2005, and a two person sampling team was able to assess about three sites per day (60 quadrats, plus site to site travel). Assuming a similar effort, we estimate that a full sampling (all taxa) would take about three weeks, and here, unlike the aquatic intensive sampling, poor weather is less of a factor. However, since we do not expect change to occur here as quickly as is possible in the intensive sites (the lakes' water level influences are less), the peatland sites could be sampled over a two year period (attempting to separate the Rainy sites from the Namakan sites). Using this approach, peatland sampling could be partially accomplished in the same year as the intensive site sampling (on days when the weather is not optimal for aquatic sampling).

In summary, we believe the peatland data provide a good baseline for future monitoring and an opportunity to assess species loss with increasing *Typha* abundance. However, the comparisons of the Namakan and Rainy sites with Lac la Croix may not be apt, since there were only four sites chosen from that basin, and these were chosen in a pseudo-random fashion that may not represent the greater Lac la Croix region.

Recommendations for Intensive Sampling (Extensive Sampling section)
As suggested previously, the extensive sampling task was developed to offer a "quick and dirty" methodology for sampling only the floating and submergent vegetation, particularly on Namakan, and to establish a baseline for future monitoring. The rationale was to create a more rapid, more extensive metric focusing on the elevation (2.0 to 2.25 m below MHW) in Namakan where we expected the greatest vegetative response to the new rule curve. The vegetative predictions relative to the changes in rule curves would suggest that the Namakan sites would increase in macrophyte abundance since the new rule curve indicates that these areas (zone 1) will not be drawn down and exposed to winter/spring dessication and freezing.

We expected considerable variability in this type of sampling, but thought that it was important to sample at another spatial scale (other than the quadrats along elevational transects as in the intensive sampling). In addition, the goal was to develop one metric, frequency, to assess a lake wide average frequency that could be repeated again at a future time.

While it is obvious that there is merit in the effort to sample different spatial scales, we have come to the conclusion that re-sampling in this manner is not a high priority for the Park. We recommend it only if the repeat sampling of the intensive sites produce confusing results. For example, if half of the Namakan sites showed an increase in submergent vegetation and another half showed a decrease, this extensive approach could offer another metric (frequency) on a large data set that could help explain these curious results. It should be noted, however, that we did an assessment of the variability associated with this approach, and it suggested that only an increase in frequency of 50% or greater from time 1 to time 2 will indicate a real increase in vegetation frequency. Hence, even though there is a larger sample size (31 sites in Namakan vs. 11 for the intensive sampling in Namakan), this task is not a high priority.

Recommendations for Wild Rice Sampling (Wild Rice Surveys section)

Wild rice is an annually variable resource and thus is difficult to monitor. It is especially difficult to interpret changes from year to year in stem density and area and what these changes might mean for long term trends. However, we did successfully test a sampling technique and established a baseline for future monitoring.

We recommend that VNP make efforts to repeat the whole Kabetogama /Namakan /Sand Point sampling during a normal water level year at approximately 10-12 year intervals. To use these data as a baseline for future monitoring, VNP will need to recognize the different metrics used for each basin. In the Kabetogama /Namakan/Sand Point basin, the number of stands and their areas and densities can be used, while in Rainy the percent of the shoreline with at least scattered wild-rice present is the only metric. (In general, the distribution of wild rice in the Kabetogama /Namakan/Sand Point basin was in more discrete patches.) Since the Kabetogama /Namakan /Sand Point basin was assessed in a two week period in 2004, the process could be re-done with the same methods (omitting perhaps the 1 m x 1 m quadrat assessment) beginning about 2012. In the meantime, we recommend that VNP utilize the GIS maps of wild rice locations in the Kabetogama /Namakan /Sand Point basins (in the accompanying database) to create more detailed maps that can be used in the field by VNP personnel to check on observed wild rice locations. As field personnel spot a wild rice bed, they could refer to their maps to see if the location is new or not. In this manner, the cumulative number of known locations could then be used as an ongoing metric of abundance, *regardless of their size and density in a given year*. In addition, when the whole process is to be repeated in 10 years, all locations from the first total census, as well as any new locations, can be targeted first, making that year’s reconnaissance more efficient.

Recommendations for Shoreline Sampling (Shoreline Surveys section)

Although we think the shoreline surveys give us a good snapshot in time of the invaded status of the VNP shorelines, they do not lead us to logical management recommendations for those areas already substantially invaded. For example, it may not be important to determine whether the Namakan Reservoir “invaded” total increases from 51.2% (Table 60) to, for example, 65.0% in the future. In addition, *Typha* and or *Phragmites* eradication at that scale is not feasible, regardless of the native and non-native status of the invaders. However, it may be of interest to continue monitoring for the invasive status in and *establish an early detection/eradication plan for select portions of the shorelines*. In this case portions of shorelines that have not been highly invaded, perhaps less than 4-5%, should be targeted for future monitoring. This type of effort to maintain native communities, that is, concentrating where they are not yet established and forming an eradication plan at the very early infestation stages, could also begin on the smaller of the inland lakes of VNP or on sections of shoreline at the Sand Point area (or Lac la Croix).

The concept here would be to establish a “line in the sand” so to speak, and make serious efforts to maintain at least some small portions of VNP as invasive free well into the future. This will be a difficult sell to fiscal managers, in that workers will not be able to measure their efforts by “acres eradicated or sprayed,” yet if the metric “acres protected” is adopted instead, this approach would be a breakthrough in resource management. As a pilot project, we recommend that the Park randomly choose 5 or 6, 200-250 m long segments of shoreline from the pool of least invaded shoreline and monitor it as we did in this study. Depending on the location of the chosen segment, this assessment could be accomplished in one week at 5 year intervals, always locating the start and end points of the segment with GPS.

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Natural Resource Program Center
1201 Oakridge Drive, Suite 150
Fort Collins, CO 80525

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