Voyageurs National Park Wetland Monitoring

Final Report

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Introduction

In 2001-2002, Voyageurs National Park (VNP) began to document vegetative response to new rule curves for the Rainy and Namakan basins by re-sampling wetland areas assessed in 1987 and describing a new baseline condition for use in future monitoring (Meeker and Harris 2003). The summary of these vegetative re-sampling findings (1987 to 2002 changes) is included here in this report as an Addendum to the 2003 Final Report.

Background

Regulation of water levels to a strict regime (a set of rule curves) may significantly degrade the biotic resources of Voyageurs National Park (VNP), as suggested by a number of studies conducted during the period 1986-1990 (Kallemeyn et al. 1993; Wilcox and Meeker 1992). Under the 1970 rule curve, water-level fluctuations on the Namakan basin 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 (Wilcox and Meeker 1991), and this study found differences in structure and composition among the three lake systems especially among deep elevation aquatic macrophytes. Vegetation in Namakan 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 2 lakes (Meeker and Wilcox 1989, 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 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 basin (Figure 3). Second, following a ruling by the International Joint Commission, a new rule curve was established in 2001 as indicated in Figure 4, which compares the new and the old rule curves. 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.
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, Meeker and Harris (2003) identified four distinct zones (Figure 5) that characterized the difference between the 1970 and 2001 rule curves:

Zone 1: Areas formerly dewatered (i.e. exposed) in late winter, but should be now permanently covered. (Elevation approximately = 339.0 m to 337.9 m).

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 (Elevation approximately = 340.7 m to 339.0 m). Example: areas at 340.0 meters elevation were exposed under the old rule curve from mid-Dec. to end of May. Under new curve, it is exposed only until beginning of May. Thus, the duration of exposure is reduced by approximately one month.

Zone 3: Areas formerly flooded with water throughout most of the growing season, now gradually dewatered through the growing season (Elevation approximately = 340.9 m to 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 basin efforts. These include:

Zone 1. Aquatic vegetation (other than rosette-forming species) will increase in cover, diversity and frequency in Zone 1 on Namakan Lake. 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 on Namakan Lake.
Zone 3. Cover of shrubs and other species intolerant of prolonged flooding through the growing season will increase in Zone 3 on Namakan Lake. Summer drawdown increases oxygen availability in the rooting zone and enhances vegetative reproduction of clonal species and germination of seeds of some emergent species.

Summary of 2001-2002 study

During 2001-2002, Meeker and Harris established aquatic plant sampling in both the Rainy and Namakan basins at varying scales, what were termed intensive efforts (more detail, fewer sites) and extensive efforts (less detailed, more sites).

Intensive Efforts. One component of the intensive effort was the repeat sampling of two sites in each of the three basins (Namakan, Rainy and Lac La Croix). **This repeat sampling continued the initial work that was done in 1987, and these changes will be reported on in this Addendum.**

In addition to this repeat sampling, the total pool of wetlands intensively studied was increased in the Namakan basin to 11 sites (9 new sites), in the Lac La Croix basin to 5 sites (3 new sites) and in Rainy to complete 6 sites (4 new sites).

Extensive Efforts. Another component of the 2001-2002 study was to sample vegetation in Rainy and Namakan at select lower (deeper water) elevations in a much greater number of wetlands. This extensive sampling took place in August of 2002 and included 31 sites in the Namakan basin and 24 in the Rainy Basin. Extensive sampling of vegetation was conducted from a pool of potential wetland areas on both lakes, randomly chosen from the Voyageurs vegetation database in the same manner as the intensive sites. The extensive sampling was restricted to sampling of submerged and floating aquatic habitat at elevations 2.25 m below mean high water mark in both Rainy and Namakan basins. Again, the predictions for the future relative to the changes in rule curves would be that the Namakan sites would increase in macrophyte abundance since the rule curve suggests that these areas (Zone 1) will not be drawn down and exposed to winter/spring dessication and freezing, and that the Rainy aquatics would not be altered.

Repeat Sampling Methodology

Six sites, two in each basin, were sampled in 1987 and resampled in 2002 (Namakan and Lac La Croix) and 2003 (Rainy). At each site sampling transects were established to represent aquatic vegetation zones relative to mean high water level (MHW). Four or five elevational transects were sampled at each site: 0.00m, 0.50m, 1.25m, and 1.75m, and 2.00 to 2.5m. The deepest elevation (2.00 to 2.50m) was not sampled at every site, as sometimes the small basins were without this depth or there was a very sharp gradient to deeper water. Hence comparisons at his depth are not included in this report. Transects followed depth contours, approximately parallel to the shorelines.

Sampling water depths were determined relative to the mean high water by measuring the depth and adding or subtracting from the current day's water level. Mean high water levels for the sampling at both time periods (1987 and 2002) were as follows:

Namakan Lake: 340.9 m
Rainy Lake: 337.75 m
Lac la Croix: ~362.0 m

In 1987 water levels ranged from 30 to 50 cm below average across all basins, while in 2002, water levels ranged from 0 to 30 cm above average in Namakan Lake 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.

Twenty 1 m X 1 m quadrats were sampled along the four or five elevational transects at each site. Quadrats were distributed evenly from a random starting point by estimating the length of shoreline to be sampled and dividing the length into 20 equal segments. In deeper water, quadrat locations were marked with balloons attached to sinkers. The 0 m depth was sampled by walking the transect. Snorkeling gear used to sample the 0.5 to 1.75 m elevations.

At each quadrat, species identifications and percent cover estimations were made. Taxa present at less than 1% were recorded as 0.1%. Since plants may occupy space at different strata, cover estimates could exceed 100%. Nomenclature follows Gleason and Cronquist (1991).

Data Analyses

In order to follow the general vegetational changes across all three 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 0.00m (shoreline) transects at Lady Boot Bay (east and west) were combined for a total of 40 quadrats (20 for each site).

The combination of replicate sites was performed both on the 1987 and the 2002/3 data on all three basins. Five metrics were calculated on this combined data; for each taxon these include: **total raw cover** (over all 40 quadrats), **% frequency** of occurrence over the 40 quadrats, **relative cover** (each taxon's cover relative to all taxa's total cover, the sum of all relative cover for each basin's elevation = 100%), **relative frequency** (as relative cover, relative to all occurrences), and **relative importance** value (an average of relative cover and relative frequency, again the sum of all relative importance values for each basin's elevation = 100%).

In addition to species specific metrics, summaries of total cover, total frequency, mean quadrat richness (per 1 x 1 quadrats), and total richness (over all 40 quadrats) were computed for each of the three basin's elevations.

Results

All three basins showed increases in the total cover of shoreline (0.0 m) and shallow elevations (0.50m) over the 15-16 year period from 1987 to 2002-3 (Table 1). In particular, the change of vegetative cover along the 0.0 m transects in the Namakan basin was from 1085 to 3466, or a 219% increase. Along the other basins' 0.0 and 0.5 elevation transects cover increases varied from 41 to 187 %.

At the deeper elevations (1.25 m and 1.75 m) Lac La Croix experienced declines in cover compared to modest increases at Namakan (16 to 42%) and major increases in Rainy Lake (173 to 239%).

The frequency of occurrence declined along a number of the transects, especially in the Namakan Basin, where increased cover was concentrated on fewer species (Table 1).

Total richness and mean richness per 1 x 1 m quadrat showed no trend over all basins from 1987 to 2002, although mean quadrat richness increased along deeper elevations in Rainy Lake from 1987 to 2002, while the same metric declined along the deeper elevations in the Namakan basin (Table 1).

In order to look at the most general trends in species data, only taxa with importance values of 5.0% or greater *for either time period* were further investigated for the percent change in metric values from 1987 to 2002/3. In general, this procedure tracked from 4 to 11 taxa per basin/elevation combination, and accounted for between 65 and 88 percent of the total Importance Value (Tables 2-5). For example, total cover of sweet gale (*Myrica gale)* at the 0.0 m transect of the Namakan basin was 1671 in the 40 quadrats in 2002, up from just 20.3 in 1987, and this change is indicated in Table 2 by an 8131% increase in cover from 1987 to 2002 (2002 cover – 1987 cover)/1987 cover).

Namakan Lake. The 0.0 m transect in Namakan Lake showed significant percent increases in alder (*Alnus incana*) and sweet gale (*Myrica gale*) cover of 12,200 and 8,132% respectively (Table 2). These increases were accompanied by declines in sedge abundance (*Carex rostrata* and *C. lacustris*). Emergent taxa such as marsh horsetail (*Equisetum fluviatile*) and arrowhead (*Sagittaria rigida*), and rosette species (*Littorella uniflora*) increased along Namakan's 0.50 m transect, accompanied by declines in the classic mat-forming drawdown species *Ranunculus flammula, Elatine minima,* and *Polygonum lapathifolium.*

In the deeper transects of Namakan Lake the major changes occurred in the increases in wild celery (*Vallisneria americana*) and other aquatic macrophytes accompanied again by losses in the drawdown mat-formers that declined in the 0.50 m transect.

Rainy Lake. The 0.0 m transect of Rainy Lake showed major increases in sweet gale from 51.2 to 1117, or a 2082% increase (Table 3). This increase was accompanied by increases in bluejoint grass (*Calamagrostis canadensis*) and tear thumb (*Polygonum sagittatum*). At the 0.50 elevation there were major increases in the drawdown grasses (*Agrostis hyemalis* and *Panicum capillare*) as well as other drawdown taxa (*Juncus pelocarpus, Hypericum malus* and *Bidens cernua,* Table 3).

In the deeper Rainy transects, as in Namakan, the major changes occurred as increases in wild celery (*Vallisneria americana).*

Lac La Croix. In the Lac La Croix 0.0m transect, as in the shoreline transects of the other 2 basins, woody taxa such as the ash seedlings (*Fraxinus*) and sweet gale increased greatly in cover, while lake sedge (*Carex lacustris*) lost ground (Table 4). The 0.50 transect showed major increases in grasses and sedges, while declines in the mat-forming spikerush (*Eleocharis acicularis*), white water-lily (*Nymphaea odorata*), floating burreed (*Sparganium fluctuans*) and common naiad (*Najas flexilis*).

Over both deep transects (1.25 and 1.75) of Lac La Croix aquatic taxa generally declined (Table 4). Along the 1.25 m transects only the rosette forming arrowhead (*Sagittaria* spp.) showed an increase since 1987, while there were dramatic declines in cover for milfoil (*Myriophyllum* spp.), white water lily, and water marigold (*Bidens beckii*). At 1.75m transect, musky-weed (*Potamogeton amplifolius*) and Robbin's pondweed (*Potamogeton robbinsii*) both showed significant declines.

Discussion relative to hydrologic changes during the period 1987-2002

Namakan. Since water levels in Namakan have generally been maintained closer to the middle of rule curve beginning in about 1987, it has resulted in a moderation of the extreme drawdowns of the 1920s through the 1970s (Figure 3). This suggests that during the assessment period (1987 to 2002) aquatic vegetation in the deep zone (Zone 1, Figure 5) should have increased in cover because areas formerly exposed in late winter should now be permanently covered. This should favor the growth of aquatics and at the same time inhibit the growth of the mat-forming drawdown. These directions are supported by our preliminary change data with increases in aquatic cover and declines in mat-forming cover (see Table 1 and 2, above).

Rainy. Alternatively, since there appears to have been no obvious changes in the minimum and maximum water levels in the Rainy reservoir over the same 1987 – 2002 period (Figure 6), we would have predicted no significant changes in aquatic vegetation. As we saw in the results above, however, the Rainy Basin showed vegetation changes much like that of the Namakan Basin; aquatic cover increased in the deep transects while woody taxa increased in the shallow transects. We have no good explanation for this result, unless that our sampling was not robust enough to get the "real' signal for the Rainy Basin. Increasing the number of sites and transects should provide a more complete picture the next time the sites are re-assessed.

Lac la Croix. 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 (Figure 7). On the other hand, the low water marks appear not to have changed significantly over the 15 year period. This contraction of mean high water should favor an increase in woody plant taxa along the shoreline transects and a concomitant increase in the cover of graminoid taxa along the 0.5m transects. These predictions are born out in the assessment of change for the shallow transects discussed above (Table 4). 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 2 sites in this reference lake was not robust enough to get the overall "signal".

Recommendations for study of the vegetation changes in the future are described in 2004-2006 Work Plan that is scheduled to begin in June, 2004. In summary, we plan to increase the number of study sites from 2 in each basin reported on in this analysis to 10-12 for each of the three basins.

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Table 1. Summary of vegetation changes in each basin from 1987 to 2002/3.
Each value represents a mean or total over 40, 1 x 1 m quadrats.

Namakan	2002/3		Mean		1987		Mean		Percent Change 1987 to 2002/3	
Elevations	Total Cover	Total Frequency	Richness Quadrat	Total Richness	Total Cover	Total Frequency	Richness Quadrat	Total Richness	Cover	Frequency
0.00	3465.9	13.15	6.6	46	1085.3	13.65	6.8	55	219.3	-3.7
0.50	961.2	7.65	3.9	23	683.6	12.45	6.2	24	40.6	-38.6
1.25	1634.2	7.65	4.0	19	1406.3	13.60	6.8	21	16.2	-43.8
1.75	1620.0	5.60	2.8	12	1136.4	12.85	6.4	20	42.6	-56.4

Rainy	2002/3		Mean		1987.0		Mean		Percent Change 1987 to 2002/3	
Elevations	Total Cover	Total Frequency	Richness Quadrat	Total Richness	Total Cover	Total Frequency	Richness Quadrat	Total Richness	Cover	Frequency
0.00	3069.5	19.20	9.6	60	1493.0	17.60	8.8	61	105.6	9.1
0.50	6744.8	22.55	11.3	47	2352.3	20.75	10.4	45	186.7	8.7
1.25	1737.9	6.65	3.3	13	635.9	8.30	4.2	15	173.3	-19.9
1.75	2219.2	4.90	2.5	15	654.0	2.60	1.3	4	239.3	88.5
2.00	1402.8	3.55	1.8	14	222.0	2.05	1.0	5	531.9	73.2

Lac La Croix	2002/3		Mean		1987.0		Mean		Percent Change 1987 to 2002/3	
Elevations	Total Cover	Total Frequency	Richness Quadrat	Total Richness	Total Cover	Total Frequency	Richness Quadrat	Total Richness	Cover	Frequency
0.00	4045.3	22.10	11.0	54	1859.0	17.60	8.8	44	117.6	25.6
0.50	2467.0	14.00	7.0	30	1078.0	13.55	6.8	27	128.8	3.3
1.25	1316.6	11.80	5.8	34	2167.1	8.05	4.0	19	-39.2	46.6
1.75	932.8	11.10	5.6	22	2183.0	6.85	3.4	15	-57.3	62.0

Table 2. Measures of abundance for all Namakan Lake taxa with importance values greater than 5.0% at either sampling time. Taxa are listed in descending order of percent change in raw cover from 1987 to 2002.

		2002					1987					Percent Change				
		raw% cover	raw% freq.	rel.% cover	rel.% freq.	rel.% IV	raw% cover	raw% freq.	rel.% cover	rel.% freq.	rel.% IV	raw cover	raw freq.	rel. cover	rel. freq.	rel. IV
Elevation 0.0 m																
Alnus	incana	246	35	7.10	5.32	6.21	2	2.5	0.18	0.37	0.28	12200	1300	3752	1353	2156
Myrica	gale	1671	82.5	48.21	12.55	30.38	20.3	25	1.87	3.66	2.77	8132	230	2478	243	998
Equisetum	sylvaticum	111.2	57.5	3.21	8.75	5.98	24	22.5	2.21	3.30	2.75	363	156	45	165	117
Calamagrostis	canadensis	490	80	14.14	12.17	13.15	338	67.5	31.14	9.89	20.52	45	19	-55	23	-36
Carex	rostrata	34	7.5	0.98	1.14	1.06	174	55	16.03	8.06	12.05	-80	-86	-94	-86	-91
Lysimachia	terrestris	8.1	12.5	0.23	1.90	1.07	42.4	65	3.91	9.52	6.72	-81	-81	-94	-80	-84
Carex	lacustris	18	12.5	0.52	1.90	1.21	197	35	18.15	5.13	11.64	-91	-64	-97	-63	-90
Scirpus	cyperinus	6.2	12.5	0.18	1.90	1.04	79	25	7.28	3.66	5.47	-92	-50	-98	-48	-81
Elevation 0.50 m																
Equisetum	fluvulatile	213.1	45	22.17	11.76	16.97	0	0	0.00	0.00	0.00	NA	NA	NA	NA	NA
Sagittaria	rigida	145	27.5	15.09	7.19	11.14	0	0	0.00	0.00	0.00	NA	NA	NA	NA	NA
Littorella	uniflora	250.1	17.5	26.02	4.58	15.30	14.4	22.5	2.11	3.61	2.86	1637	-22	1135	27	435
Eleocharis	acicularis	39.2	20	4.08	5.23	4.65	18.3	60	2.68	9.64	6.16	114	-67	52	-46	-24
Glyceria	borealis	100.1	60	10.41	15.69	13.05	48.5	62.5	7.09	10.04	8.57	106	-4	47	56	52
Carex	vesicaria/rostrata	141	45	14.67	11.76	13.22	154	37.5	22.53	6.02	14.28	-8	20	-35	95	-7
Ranunculus	flammula	17.4	27.5	1.81	7.19	4.50	167.4	92.5	24.49	14.86	19.67	-90	-70	-93	-52	-77
Crassula	aquatica	0	0	0.00	0.00	0.00	20.6	85	3.01	13.65	8.33	-100	-100	-100	-100	-100
Elatine	minima	0	0	0.00	0.00	0.00	12.7	65	1.86	10.44	6.15	-100	-100	-100	-100	-100
Polygonum	lapathifolium	0	0	0.00	0.00	0.00	170.3	67.5	24.91	10.84	17.88	-100	-100	-100	-100	-100

Table 2(continued).

		2002					1987					Percent Change				
		raw%	raw%	rel.%	rel.%	rel.%	raw%	raw%	rel.%	rel.%	rel.%	raw	raw	rel.	rel.	rel.
Elevation 1.25 m		cover	freq.	cover	freq.	IV	cover	freq.	cover	freq.	IV	cover	freq.	cover	freq.	IV
Najas	flexilis	623	42.5	38.12	11.11	24.62	9.2	22.5	0.65	3.31	1.98	6672	89	5727	236	1142
Potamogeton	vaseyi	99	37.5	6.06	9.80	7.93	2	2.5	0.14	0.37	0.25	4850	1400	4160	2567	3011
Vallisneria	americana	643	72.5	39.35	18.95	29.15	68.1	35	4.84	5.15	4.99	844	107	713	268	484
Potamogeton	pusillis/spirillus	35.1	35	2.15	9.15	5.65	4	10	0.28	1.47	0.88	778	250	655	522	544
Nymphaea	odorata	77.2	52.5	4.72	13.73	9.22	47	15	3.34	2.21	2.77	64	250	41	522	233
Sagittaria	sp.	48.3	17.5	2.96	4.58	3.77	36.4	52.5	2.59	7.72	5.15	33	-67	14	-41	-27
Glyceria	borealis	5	5	0.31	1.31	0.81	97.1	52.5	6.90	7.72	7.31	-95	-90	-96	-83	-89
Crassula	aquatica	0	0	0.00	0.00	0.00	136.5	92.5	9.71	13.60	11.65	-100	-100	-100	-100	-100
Eleocharis	acicularis	0	0	0.00	0.00	0.00	416.8	92.5	29.64	13.60	21.62	-100	-100	-100	-100	-100
Isoetes	sp.	0	0	0.00	0.00	0.00	46.3	87.5	3.29	12.87	8.08	-100	-100	-100	-100	-100
Polygonum	lapathifolium	0	0	0.00	0.00	0.00	45.1	47.5	3.21	6.99	5.10	-100	-100	-100	-100	-100
Ranunculus	flammula	0	0	0.00	0.00	0.00	451	55	32.07	8.09	20.08	-100	-100	-100	-100	-100
Elevation 1.75 m																
Ceratophyllum	demersum	330.2	42.5	20.38	15.18	17.78	0	0	0.00	0.00	0.00	NA	NA	NA	NA	NA
Elodea	canadensis	7.9	35	0.49	12.50	6.49	0	0	0.00	0.00	0.00	NA	NA	NA	NA	NA
Vallisneria	americana	1107	70	68.35	25.00	46.68	141	37.5	12.41	5.84	9.12	685	87	451	328	412
Nymphaea	odorata	119.2	35	7.36	12.50	9.93	43	12.5	3.78	1.95	2.86	177	180	94	543	247
Potamogeton	richardsonii	26.2	12.5	1.62	4.46	3.04	144	52.5	12.67	8.17	10.42	-82	-76	-87	-45	-71
Chara	sp.	1.7	20	0.10	7.14	3.62	508.1	87.5	44.71	13.62	29.17	-100	-77	-100	-48	-88
Crassula	aquatica	0	0	0.00	0.00	0.00	26.5	77.5	2.33	12.06	7.20	-100	-100	-100	-100	-100
Eleocharis	acicularis	0	0	0.00	0.00	0.00	38.4	67.5	3.38	10.51	6.94	-100	-100	-100	-100	-100
Isoetes	sp.	0	0	0.00	0.00	0.00	32.4	72.5	2.85	11.28	7.07	-100	-100	-100	-100	-100

Table 3. Measures of abundance for Rainy Lake taxa with importance values greater than 5.0% at either sampling time. Taxa are listed in descending order of percent change in raw cover from 1987 to 2003.

	2002					1987					Percent Change				
Elevation 0.0 m	**raw% cover**	**raw% freq.**	**rel.% cover**	**rel.% freq.**	**rel.% IV**	**raw% cover**	**raw% freq.**	**rel.% cover**	**rel.% freq.**	**rel.% IV**	**raw% cover**	**raw% freq.**	**rel.% cover**	**rel.% freq.**	**rel. IV**
Myrica gale	1117.0	92.5	36.39	9.64	23.01	51.2	27.5	3.43	3.13	3.28	2082	236	961	208	602
Polygonum sagittatum	191.1	77.5	6.23	8.07	7.15	24.1	22.5	1.61	2.56	2.09	693	244	286	216	243
Calamagrostis canadensis	1020.1	92.5	33.23	9.64	21.43	383.0	62.5	25.65	7.10	16.38	166	48	30	36	31
Carex rostrata	110.2	57.5	3.59	5.99	4.79	134.0	50.0	8.98	5.68	7.33	-18	15	-60	5	-35
Hypericum majus	39.5	42.5	1.29	4.43	2.86	89.2	65.0	5.97	7.39	6.68	-56	-35	-78	-40	-57
Potentilla norvegica	18.1	52.5	0.59	5.47	3.03	53.2	67.5	3.56	7.67	5.62	-66	-22	-83	-29	-46
Scirpus cyperinus	35.0	17.5	1.14	1.82	1.48	202.0	22.5	13.53	2.56	8.04	-83	-22	-92	-29	-82
Polygonum lapathifolium	5.9	30.0	0.19	3.13	1.66	78.1	65.0	5.23	7.39	6.31	-92	-54	-96	-58	-74
Elevation 0.50 m															
Agrostis hyemalis	927.0	70.0	13.74	6.21	9.98	17.1	32.5	0.73	3.13	1.93	5321	115	1791	98	417
Panicum capillare	457.1	55.0	6.78	4.88	5.83	36.2	32.5	1.54	3.13	2.34	1163	69	340	56	149
Juncus pelocarpus	515.1	52.5	7.64	4.66	6.15	94.0	37.5	4.00	3.61	3.81	448	40	91	29	62
Hypericum majus	1818.0	100.0	26.95	8.87	17.91	372.1	92.5	15.82	8.92	12.37	389	8	70	-1	45
Bidens cernua	399.2	45.0	5.92	3.99	4.95	84.0	40.0	3.57	3.86	3.71	375	13	66	4	33
Polygonum lapathifolium	1104.0	90.0	16.37	7.98	12.18	966.0	100.0	41.07	9.64	25.35	14	-10	-60	-17	-52
Eleocharis acicularis	61.6	35.0	0.91	3.10	2.01	70.2	75.0	2.98	7.23	5.11	-12	-53	-69	-57	-61
Eleocharis ovata	108.8	40.0	1.61	3.55	2.58	210.0	50.0	8.93	4.82	6.87	-48	-20	-82	-26	-62

Table 3 (continued).

	2002					1987					Percent Change				
Elevation 1.25 m	**raw% cover**	**raw% freq.**	**rel.% cover**	**rel.% freq.**	**rel.% IV**	**raw% cover**	**raw% freq.**	**rel.% cover**	**rel.% freq.**	**rel.% IV**	**raw% cover**	**raw% freq.**	**rel.% cover**	**rel.% freq.**	**rel. IV**
Potamogeton gramineus	317.0	42.5	18.24	12.78	15.51	23.0	17.5	3.62	4.22	3.92	1278	143	404	203	296
Najas flexilis	69.4	37.5	3.99	11.28	7.64	15.1	27.5	2.37	6.63	4.50	360	36	68	70	70
Sparganium fluctuans	553.0	27.5	31.82	8.27	20.05	145.0	17.5	22.80	4.22	13.51	281	57	40	96	48
Vallisneria americana	570.0	70.0	32.80	21.05	26.93	213.0	77.5	33.50	18.67	26.09	168	-10	-2	13	3
Potamogeton robbinsii	40.0	27.5	2.30	8.27	5.29	35.0	20.0	5.50	4.82	5.16	14	38	-58	72	2
Isoetes sp.	35.2	30.0	2.03	9.02	5.52	78.0	97.5	12.27	23.49	17.88	-55	-69	-83	-62	-69
Eleocharis acicularis	8.6	25.0	0.49	7.52	4.01	23.2	37.5	3.65	9.04	6.34	-63	-33	-86	-17	-37
Sagittaria rigida		0.0	0.00	0.00	0.00	30.1	30.0	4.73	7.23	5.98	-100	-100	-100	-100	-100
Elevation 1.75 m															
Najas flexilis	134.4	47.5	6.06	19.39	12.72	0.0	0.0	0.00	0.00	0.00	NA	NA	NA	NA	NA
Potamogeton spirillus	12.5	25.0	0.56	10.20	5.38	0.0	0.0	0.00	0.00	0.00	NA	NA	NA	NA	NA
Vallisneria americana	1948.2	97.5	87.79	39.80	63.79	560.0	92.5	85.63	71.15	78.39	248	5	3	-44	-19
Potamogeton richardsonii	90.0	17.5	4.06	7.14	5.60	83.0	27.5	12.69	21.15	16.92	8	-36	-68	-66	-67
Elevation 2.00 m & >															
Potamogeton epihydrus	58.0	17.5	4.13	9.86	7.00	0.0	0.0	0.00	0.00	0.00	NA	NA	NA	NA	NA
Vallisneria americana	1275.1	70.0	90.90	39.44	65.17	131.0	57.5	59.01	56.10	57.55	873	22	54	-30	13
Najas flexilis	13.3	17.5	0.95	9.86	5.40	5.0	2.5	2.25	2.44	2.35	166	600	-58	304	130
Potamogeton richardsonii	36.0	15.0	2.57	8.45	5.51	67.0	32.5	30.18	31.71	30.94	-46	-54	-91	-73	-82
Potamogeton gramineus	0.1	2.5	0.01	1.41	0.71	9.0	7.5	4.05	7.32	5.69	-99	-67	-100	-81	-88

Table 4. Measures of abundance for Lac La Croix taxa with importance values greater than 5.0% at either sampling time. Taxa are listed in descending order of percent change in raw cover from 1987 to 2002.

		2002					1987					Percent Change				
Lac La Croix 0.0 m		raw% cover	raw% freq.	rel.% cover	rel.% freq.	rel.% IV	raw% cover	raw% freq.	rel.% cover	rel.% freq.	rel.% IV	raw% cover	raw% freq.	rel.% cover	rel.% freq.	rel. IV
Fraxinus	nigra	553	60	13.67	5.43	9.55	2	5	0.11	0.57	0.34	27550	1100	12606	856	2726
Myrica	gale	1491	100	36.86	9.05	22.95	21	30	1.13	3.41	2.27	7000	233	3163	165	911
Thelypteris	palustris	469	55	11.59	4.98	8.29	294	55	15.81	6.25	11.03	60	0	-27	-20	-25
Calamagrostis	canadensis	676	97.5	16.71	8.82	12.77	425	77.5	22.86	8.81	15.83	59	26	-27	0	-19
Lysimachia	terrestris	47.4	85	1.17	7.69	4.43	51	67.5	2.74	7.67	5.21	-7	26	-57	0	-15
Euthamia	graminifolia	2	2.5	0.05	0.23	0.14	85	50	4.57	5.68	5.13	-98	-95	-99	-96	-97
Carex	lacustris	0	0	0.00	0.00	0.00	515	80	27.70	9.09	18.40	-100	-100	-100	-100	-100
Lac La Croix 0.50 m																
Carex	vesicaria	1147	95	46.49	13.57	30.03	0	0	0.00	0.00	0.00	NA	NA	NA	NA	NA
Calamagrostis	canadensis	659.2	90	26.72	12.86	19.79	0	0	0.00	0.00	0.00	NA	NA	NA	NA	NA
Lysimachia	terrestris	25.8	67.5	1.05	9.64	5.34	0	0	0.00	0.00	0.00	NA	NA	NA	NA	NA
Juncus	filiformis	187.3	87.5	7.59	12.50	10.05	11	27.5	1.02	4.06	2.54	1603	218	644	208	296
Eleocharis	palustris	27.6	40	1.12	5.71	3.42	80	50	7.42	7.38	7.40	-66	-20	-85	-23	-54
Sium	suave	8.8	35	0.36	5.00	2.68	33	75	3.06	11.07	7.07	-73	-53	-88	-55	-62
Glyceria	borealis	27.1	20	1.10	2.86	1.98	182	55	16.88	8.12	12.50	-85	-64	-93	-65	-84
Eleocharis	acicularis	43.5	22.5	1.76	3.21	2.49	319	85	29.59	12.55	21.07	-86	-74	-94	-74	-88
Najas	flexilis	3	5	0.12	0.71	0.42	26	55	2.41	8.12	5.26	-88	-91	-95	-91	-92
Nymphaea	odorata	0	0	0.00	0.00	0.00	81	25	7.51	3.69	5.60	-100	-100	-100	-100	-100
Sparganium	fluctuans	0	0	0.00	0.00	0.00	81	25	7.51	3.69	5.60	-100	-100	-100	-100	-100

Table 3 (continued).

		2002					1987					Percent Change				
Lac La Croix 1.25 m		raw% cover	raw% freq.	rel.% cover	rel.% freq.	rel.% IV	raw% cover	raw% freq.	rel.% cover	rel.% freq.	rel.% IV	raw% cover	raw% freq.	rel.% cover	rel.% freq.	rel. IV
Sagittaria	(rosette)	346.3	55	26.30	9.32	17.81	0	0	0.00	0.00	0.00	NA	NA	NA	NA	NA
Sparganium	fluctuans	40.7	52.5	3.09	8.90	5.99	0	0	0.00	0.00	0.00	NA	NA	NA	NA	NA
Najas	flexilis	544.3	62.5	41.34	10.59	25.97	925	55	42.68	13.66	28.17	-41	14	-3	-22	-8
Chara	sp.	21.9	42.5	1.66	7.20	4.43	89	47.5	4.11	11.80	7.95	-75	-11	-59	-39	-44
Myriophyllum	verticillatum	46.6	40	3.54	6.78	5.16	247	20	11.40	4.97	8.18	-81	100	-69	36	-37
Bidens	beckii	32.9	42.5	2.50	7.20	4.85	186	35	8.58	8.70	8.64	-82	21	-71	-17	-44
Nymphaea	odorata	30.2	42.5	2.29	7.20	4.75	452	57.5	20.86	14.29	17.57	-93	-26	-89	-50	-73
Myriophyllum	sp.	0.1	2.5	0.01	0.42	0.22	89	27.5	4.11	6.83	5.47	-100	-91	-100	-94	-96
Lac La Croix 1.75 m																
Utricularia	vulgaris	36.2	47.5	3.88	8.56	6.22	0	0	0.00	0.00	0.00	NA	NA	NA	NA	NA
Bidens	beckii	40.9	55	4.38	9.91	7.15	3	5	0.14	1.46	0.80	1263	1000	3091	579	795
Najas	flexilis	550.6	62.5	59.03	11.26	35.14	618	42.5	28.31	12.41	20.36	-11	47	109	-9	73
Potamogeton	spirillus	10.1	57.5	1.08	10.36	5.72	12	20	0.55	5.84	3.19	-16	188	97	77	79
Chara	sp.	85.5	62.5	9.17	11.26	10.21	199	42.5	9.12	12.41	10.76	-57	47	1	-9	-5
Nymphaea	odorata	35.8	60	3.84	10.81	7.32	89	15	4.08	4.38	4.23	-60	300	-6	147	73
Myriophyllum	sp.	38.5	17.5	4.13	3.15	3.64	152	40	6.96	11.68	9.32	-75	-56	-41	-73	-61
Vallisneria	americana	23.5	45	2.52	8.11	5.31	155	52.5	7.10	15.33	11.21	-85	-14	-65	-47	-53
Potamogeton	foliosus	0.3	7.5	0.03	1.35	0.69	78	22.5	3.57	6.57	5.07	-100	-67	-99	-79	-86
Potamogeton	robbinsii	1	2.5	0.11	0.45	0.28	418	25	19.15	7.30	13.22	-100	-90	-99	-94	-98
Nitella	sp.	0	0	0.00	0.00	0.00	150	10	6.87	2.92	5.00	-100	-100	-100	-100	-100
Potamogeton	amplifolius	0	0	0.00	0.00	0.00	207	22.5	9.48	6.57	8.03	-100	-100	-100	-100	-100