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Aquatic Plant Communities in Waneta Lake and Lamoka Lake, New York

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Abstract - A point-intercept survey was implemented in August 2000 to determine the distribution and richness of aquatic plant species present in Waneta Lake and Lamoka Lake, NY. *Myriophyllum spicatum* (Eurasian watermilfoil) was the most commonly observed species in Waneta Lake (25% of entire lake, 78% of littoral zone) and Lamoka Lake (43% of entire lake, 77% of littoral zone). Eurasian watermilfoil biomass (24.3 g DW/m^2) was also significantly greater ($p \leq 0.001$) in Waneta Lake than native plant biomass. Our data suggests that Eurasian watermilfoil is invading the native plant communities of Waneta Lake and Lamoka Lake, thereby displacing native plants and limiting their growth to the shallow waters of the littoral zone.

Introduction

Aquatic plants are important to lake ecosystems (Madsen et al. 1996, Wetzel 2001). These plants are essential in promoting the diversity of an aquatic system (Carpenter and Lodge 1986). Aquatic plants in the littoral zone may be responsible for a significant proportion of primary production for the entire lake (Ozimek et al. 1990, Wetzel 2001); they produce food for aquatic organisms and serve as the base of the food chain. Also, these plants provide habitat for invertebrates, fish, and other aquatic or semi-aquatic organisms (Cyr and Downing 1988, Madsen et al. 1996). Littoral-zone habitats are prime areas for the spawning of most fish species, including many species important to sport fisheries (Madsen et al. 1996, Savino and Stein 1989). Aquatic macrophytes anchor soft sediments, stabilize underwater slopes, remove suspended particles, and remove nutrients from overlying waters (Barko et al. 1986, Doyle 2000, Madsen et al. 2001). Reductions in littoral-zone species richness may lead to decreases in fish production (Savino and Stein 1989) as well as increased sediment resuspension, turbidity, and algal production that will further exacerbate plant loss (Case and Madsen 2004, Doyle 2000, Madsen et al. 1996, Wersal et al. 2006).

The introduction of non-native plants may alter the complex interactions occurring in this habitat (Madsen 1998). Dense stands of non-native

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plants are often responsible for reduction in oxygen exchange, depletion of dissolved oxygen, increases in water temperatures, and internal nutrient loading (Madsen 1998). *Myriophyllum spicatum* L. (Eurasian watermilfoil) is a non-native invasive species that, when present, has been associated with declines in native-plant species richness and diversity (Madsen et al. 1991b). Eurasian watermilfoil is a submersed, herbaceous, perennial aquatic plant that typically grows in water depths of 1 to 3 m (Aiken et al. 1979). Vegetative propagation is either by direct stem fragmentation (e.g., cutting by a boat motor) or by autofragmentation, through the development of an abscission layer in stem segments (Madsen et al. 1988). The production of these stem fragments either by external forces or by autofragmentation allows for widespread plant dispersal in littoral habitats and rapid infestation and establishment of monotypic stands of Eurasian watermilfoil. Monotypic stands of Eurasian watermilfoil directly reduce native-plant species richness and diversity, and also indirectly reduce habitat complexity resulting in reduced macroinvertebrate abundance (Keast 1984, Krull 1970), and reduction in fish growth (Lillie and Budd 1992). Eurasian watermilfoil also poses nuisance problems to humans in the form of increasing flood frequency and intensity, impeding navigation, and limiting recreation opportunities (Madsen et al. 1991a, b).

Waneta and Lamoka Lakes are used extensively for recreation and fishing. Both water-bodies have plant communities that have become dominated by Eurasian watermilfoil, and assistance was requested by the lake associations on the design and implementation of measures to control this problem. Prior to designing and implementing lake-wide management programs for Eurasian watermilfoil suppression on these two lakes, preliminary site evaluations were recommended to document the current distributions of Eurasian watermilfoil and native plant species in the two lakes. For this purpose, we performed a quantitative whole-lake study of plant communities to evaluate plant distribution and abundance as well as to quantify the potential influences of Eurasian watermilfoil on native-plant species richness, density, and biomass abundance.

Field Site Description

Waneta Lake and Lamoka Lake are located in the Finger Lakes Region of New York. Both lakes are surrounded by residential homes and support extensive recreational activities, most notably fishing and boating. Lamoka Lake is located in Schuyler County (42°24'59"N, 77°05'10"W). The lake is 334.2 hectares in size with a mean depth of 5.2 m and a maximum depth of 14.1 m. Lamoka Lake has a shallow basin, with an extensive shelf at a depth range of 2.9 to 7.9 m. Lamoka Lake is one of the most biologically productive lakes in central New York due to its diversity of plants and animals. Mean dissolved oxygen in Lamoka Lake is approximately 3.5 ± 1.0

mg L^{-1}, mean pH is 8.3 ± 0.2, mean Secchi depth is 136.0 ± 12.9 cm, and chlorophyll-*a* content ranges from 24.0–57.0 µg L^{-1}. Lamoka Lake is connected on the north end to Waneta Lake via a 0.8-km long channel. Waneta Lake is 329 hectares in size and is located in Schuyler and Steuben counties (42°27'56"N, 77°06'17"W). The mean depth is 5.3 m, with a maximum depth of 9.2 m. Mean dissolved oxygen in Waneta Lake is approximately 4.9 ± 1.1 mg L^{-1}, mean pH is 8.0 ± 0.2, mean Secchi depth is 108.0 ± 14.6 cm, and chlorophyll-*a* content ranges from 24.0–69.0 µg L^{-1}.

Methods

Vegetation survey

To assess plant species distribution in Waneta and Lamoka Lakes, a whole-lake point-intercept survey was conducted in August of 2000. For each lake, a 50-m grid of sample points was developed using MapInfo (MapInfo Corp., Troy, NY) (Figs. 1 and 2). Once on the lake, a

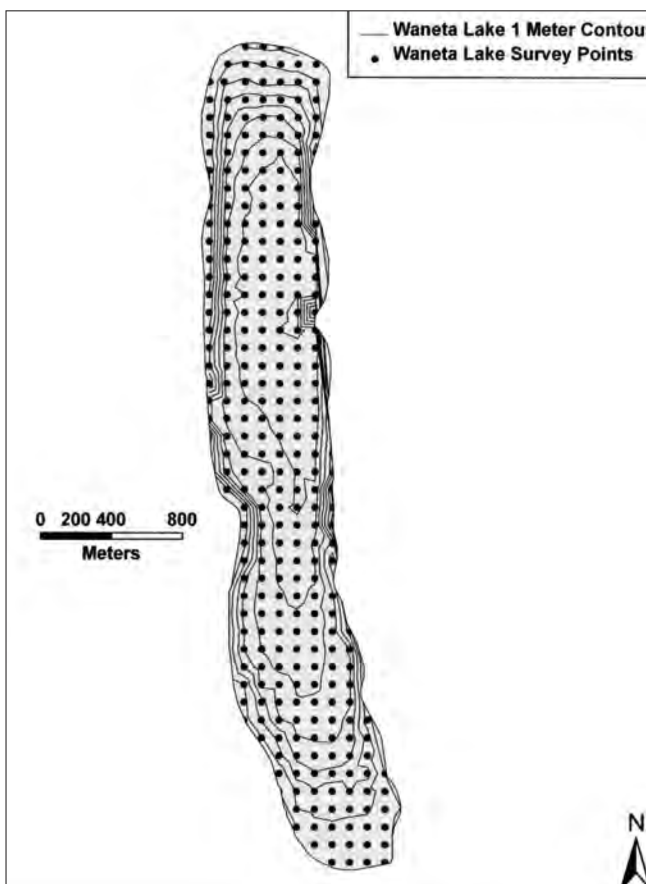

Figure 1. Map of Waneta Lake including 1-m depth contours and survey sample points.

GeoExplorer II GPS (Trimble Corp., Santa Rosa, CA) with real time correction was used to locate the sampling points (Madsen 1999). A total of 303 points were visited on Waneta Lake, and 314 points were visited on Lamoka Lake. At each point, species present in a 3-m by 3-m area were identified and recorded. Floating plant species were identified and recorded by visual observations. Submersed plant species were sampled by deploying a plant rake at each point to sample species growing in the water column (Case and Madsen 2004, Madsen 1999, Wersal et al. 2006). The plant rake was deployed from the boat to the lake bottom and retrieved. Plants harvested by the rake were identified and recorded as being present for that sample point. Water depth was also determined at each sample point during the vegetation surveys. Voucher specimens of all submersed aquatic plant species in each lake were taken and archived at the US Army Engineer Research and Development Center, Lewisville Aquatic Ecosystem Research Facility herbarium (Hellquist 1993). Differences in distribution between native plant species and non-native

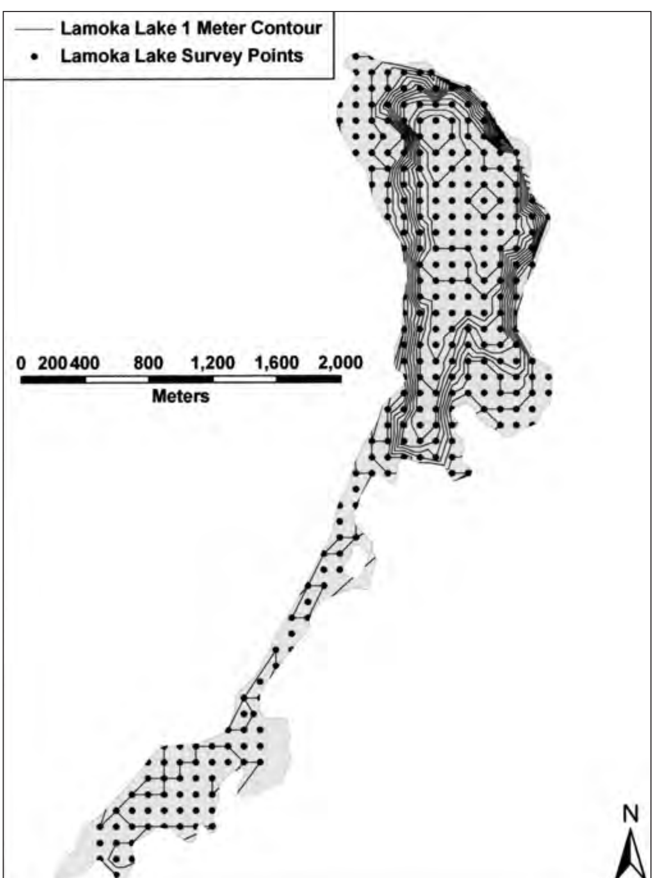

Figure 2. Map of Lamoka Lake including 1-m depth contours and survey sample points.

plant species (mainly comprised of *M. spicatum*) were determined using Statistical Analytical Software's (SAS) McNemar's test for dichotomous response variables that assesses differences in the correlated proportions within a given data set between variables that are not independent (Stokes et al. 2000). For the purposes of this study, we used the McNemar's test to determine if there was a difference in the distribution of native and non-native species by analyzing the differences in proportion of the distribution frequencies represented by the two variables at every point. For the purposes of these analyses, only the presence of rooted native plants were compared to the presence of non-native species. An $\alpha = 0.05$ was used to determine statistical significance in these analyses.

Depth distribution of plants. The depth distribution of plant species was estimated by categorizing water depth and the survey points corresponding to those water depths into 30-cm intervals from depth 0.0 to the maximum water depth observed during the surveys of Waneta Lake and Lamoka Lake. Percent frequency of occurrence within a depth interval for native species and Eurasian watermilfoil was estimated by dividing the number of vegetated points in a given depth interval by the total number of points in that interval. This relationship allows for a visual representation of how plants are distributed within a lake in relation to water depth. The depth distribution was used to estimate the littoral zone (i.e., all survey points at or below the maximum observed depth of plant growth was considered littoral zone) as well as the aerial coverage of native species and Eurasian watermilfoil in Waneta Lake and Lamoka Lake. Littoral-zone percent frequency of occurrence for native and non-native species were estimated based on the number of points where plant species were observed growing, in relation to the total number of points within the littoral-zone boundary. Whole-lake species' percent frequency of occurrence was estimated for native and non-native species based on the number of points where plant species were observed growing, in relation to the total number of points sampled within a given lake.

Plant biomass collection

Aquatic plant abundance in each lake was measured in August 2000 by harvesting plant biomass. The biomass samples were taken at 50 of the grid points visited during the vegetation survey. The 50 biomass sample locations were randomly selected from those points visited during the vegetation survey. Samples were taken by a SCUBA diver using a 0.1-m^2 quadrat frame and harvesting the above-ground plant biomass of rooted plants at the sediment surface (Madsen 1993). Samples were placed in cold storage until they could be processed. Plant processing consisted of washing and sorting plants by species and drying biomass at 105 °C until a constant mass was achieved. Plant samples were then weighed to assess biomass. A one-way ANOVA was used to analyze differences in biomass within each lake; a pairwise comparison between plant species' means within each lake was conducted using a Bonferoni post hoc analysis. A linear regression analysis was used to determine if a relationship exists between biomass of Eurasian watermilfoil and biomass of native plant species. Analyses were conducted using Statistics 8.0 software, with an $\alpha = 0.05$ threshold for statistical significance for all analyses.

Results

Vegetation survey

In Lamoka Lake, we observed a total of 20 plant species, with 16 being submersed species, 3 floating species, and 1 emergent species

Table 1. Aquatic plant species observed in Waneta Lake and Lamoka Lake during August 2000. * denotes non-native species.

		Lamoka Lake		Waneta Lake	
Scientific name	Common name	Entire lake freq (%)	Littoral zone freq (%)	Entire lake freq (%)	Littoral zone freq (%)
Ceratophyllum demersum L.	Coontail	108 (36.0)	108 (64.0)	42 (13.0)	42 (41.0)
Chara sp.	Chara	2 (0.6)	2 (1.0)	4 (1.0)	4 (4.0)
Elodea canadensis Michx.	Canadian elodea	89 (29.0)	89 (53.0)	17 (5.0)	17 (17.0)
Lemna trisulca L.	Duckweed	3 (0.9)	3 (2.0)	0	0
Myriophyllum spicatum L.*	Eurasian watermilfoil	130 (43.0)	130 (77.0)	80 (25.0)	80 (78.0)
Najas flexilis Willd.	Bushy naiad	4 (1.0)	4 (2.0)	9 (3.0)	9 (9.0)
N. guadalupensis Spreng.	Southern naiad	41 (14.0)	41 (24.0)	29 (9.0)	29 (28.0)
Nymphaea odorata Ait.	White water lily	40 (13.0)	40 (24.0)	4 (1.0)	4 (4.0)
Nuphar advena (Ait.)Ait. f.	Yellow pond lily	24 (8.0)	24 (14.0)	2 (0.6)	2 (2.0)
Potamogeton amplifolius Tuckerm.	Large-leaved pondweed	13 (4.0)	13 (8.0)	4 (1.0)	4 (4.0)
Potamogeton crispus L.*	Curlyleaf pondweed	1 (0.3)	1 (0.6)	0	0
P. diversifolius Raf.	Narrow pondweed	0	0	1 (0.3)	1 (1.0)
P. praelongus Wulf.	Whitestem pondweed	8 (3.0)	8 (5.0)	2 (0.6)	2 (2.0)
P. pusillus L.	Baby pondweed	0	0	2 (0.6)	2 (2.0)
P. robinsii Oakes	Robbins' pondweed	36 (12.0)	36 (21.0)	8 (3.0)	8 (8.0)
P. zosteriformis Fern.	Flatstem pondweed	18 (6.0)	18 (11.0)	2 (0.6)	2 (2.0)
Ranunculus sp.	Water buttercup	4 (1.0)	4 (2.0)	0	0
Typha angustifolia L.	Narrowleaf cattail	3 (1.0)	3 (2.0)	0	0
Ultricularia vulgaris L.	Common bladderwort	16 (5.0)	16 (9.0)	0	0
Vallisneria americana Michx.	Wild celery	27 (9.0)	27 (16.0)	12 (4.0)	12 (12.0)
Zanichellia palustris L.	Horned pondweed	2 (0.6)	2 (1.0)	0	0
Zosterella dubia (Jacq.) Small.	Water stargrass	33 (11.0)	33 (20.0)	2 (0.6)	2 (2.0)
Total species occurrence (mean ± 1 SE per point)		1.9 ± 0.1	3.6 ± 0.2	0.7 ± 0.1	2.2 ± 0.2
Native plant occurrence (mean ± 1 SE per point)		1.6 ± 0.1	2.8 ± 0.2	0.4 ± 0.1	1.4 ± 0.2
Non-native plant occurrence (mean ± 1 SE per point)		0.4 ± 0.0	0.8 ± 0.0	0.3 ± 0.1	0.8 ± 0.1
Depth (m) (mean ± 1 SE per point)		5.2 ± 0.1	1.6 ± 0.0	5.3 ± 0.2	1.8 ± 0.1
Total number of sites		302	169	316	102

(Table 1). Of these, Eurasian watermilfoil and *Potamogeton crispus* L. (curlyleaf pondweed) were the only two non-native species. Dominant species in the lake by frequency of occurrence were Eurasian watermilfoil (77% of the littoral zone), *Ceratophyllum demersum* (coontail, 64%), and *Elodea canadensis* (Canadian elodea, 53%). Comparing all vegetated sites, the distribution of native plants versus Eurasian watermilfoil was not statistically different ($\chi^2 = 2.66$, d.f. = 1.0, p = 0.102). Littoral-zone plant diversity was relatively high with 3.56 species per point, 0.78 non-native species per point, and 2.79 native species per point. Plants were present in 96% of the littoral zone samples, with native plants occurring at 84% of the points in the littoral zone. Plants were widely distributed in Lamoka Lake, particularly in the southern arm. Eurasian watermilfoil (43% frequency of occurrence) was the most widely distributed species and was observed growing along most shorelines. Coontail (36%) was the dominant native plant species followed by Canadian elodea (27%).

Waneta Lake had a total of 16 plant species, with 14 submersed species, and 2 floating species. Of these, only one non-native species, Eurasian watermilfoil, was observed (Table 1). The dominant species observed in the lake was Eurasian watermilfoil (78% of samples in the littoral zone), followed by coontail (41%). Comparing all vegetated sites, the distribution of native plants versus Eurasian watermilfoil was statistically different ($\chi^2 = 6.736$, d.f. = 1.0, p = 0.013). Littoral-zone plant diversity in Waneta Lake was somewhat lower than in Lamoka, with 2.16 plant species per point in the littoral zone. Similar to Lamoka, 0.78 non-native species per point was observed. Native species richness was 1.37 species per point. Waneta Lake plant cover was 89% in the littoral zone, with 63% of points in the littoral zone having native plants. Whole-lake plant distribution was sparse in Waneta Lake; plants were most common in the southern portions of the lake. Plant distribution was very sparse along the eastern shore. This pattern was consistently observed for coontail (13%), Eurasian watermilfoil (25%), and *Najas guadalupensis* Spreng. (southern naiad, 9%). Canadian elodea (5%) was found predominantly in the shallow southern end of the lake, while *Vallisneria americana* Michx. (water celery, 4%) was scattered along all shores.

Depth distribution of plants. The actual observed maximum depth of plant colonization for Lamoka Lake was less than 3.6 m, indicating that plants occupied approximately 55% of the lake bottom. From lakeshore to 2.0 m depth, almost 100% of the points were vegetated (Fig. 3). In Waneta Lake, plants were observed to a maximum depth of 3.4 m, with plants observed in 100% of the sample points at depths less than or up to 2.1 m, more than 80% from 2.1 m to 3.0 m, and 40% of the sites 3.3 m to 3.4 m (Fig. 3). No plants were found at the three sites in the 3.1-m to 3.3-m depth interval. A maximum depth of plant colonization out to 3.4 m indicates that about 34% of the lake area is littoral zone, with 89% of this zone being vegetated. Eurasian watermilfoil was observed at 70% of sample points out to a depth of 3.0 m, with frequency of occurrence dropping to 40% at a depth of 3.4 meters.

Plant abundance by biomass

Plant biomass in Lamoka Lake was different among species (F = 2.8, d.f. = 350.0, p = 0.009). Lamoka Lake was dominated by Canadian elodea (50.8 g DW m^{-2}), followed by coontail (24.3 g DW m^{-2}) and Eurasian watermilfoil (21.9 g DW m^{-2}) (Fig. 4). Plant biomass in Waneta Lake was also different among species (F = 7.74, d.f. = 249.0, $p \leq 0.001$). Waneta Lake was dominated by Eurasian watermilfoil (24.3 g DW m^{-2}). Total macrophyte biomass in Waneta Lake was 47.3 g DW m^{-2}. There was no relationship between biomass of native plants (total macrophyte biomass minus Eurasian watermilfoil biomass) and biomass of Eurasian

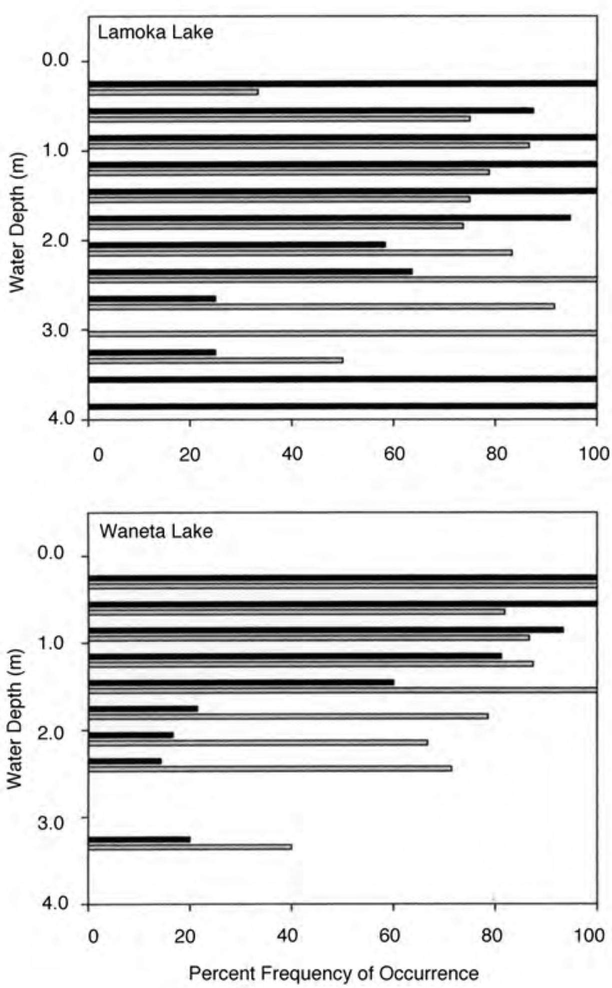

Figure 3. Depth distribution of the percent frequency of occurrence of aquatic plants in Lamoka Lake and Waneta Lake, August 2000. Black bars represent data for native-plant percent frequency of occurrence; grey bars represent Eurasian watermilfoil (*Myriophyllum spicatum*) percent frequency of occurrence.

watermilfoil for Lamoka Lake (F = 2.62, d.f. = 49, p = 0.112) or Waneta Lake (F = 0.31, d.f. = 49, p = 0.582) (Fig. 5).

Discussion

Eurasian watermilfoil was the dominant species in Waneta Lake and was co-dominant in Lamoka Lake as determined by frequency of occurrence and biomass samples. Overall plant species richness was much lower in Waneta Lake than in Lamoka Lake, a result of the increased presence of Eurasian watermilfoil in Waneta Lake. Eurasian watermilfoil was able to colonize and spread in deep-water habitats where it was observed growing in water depths to 3.4 m. In Lamoka Lake, native plants were dominant to a water depth of 2.0 m, with suppression of these native plants in deeper waters where they competed with Eurasian watermilfoil. Native species in Waneta Lake were observed in depths out to 1.2 m, and were also suppressed in deeper areas. Eurasian watermilfoil was commonly observed in deep-water habitat and appeared to replace native plants in depths of 1.5 m to 3.6 m, indicating that Eurasian watermilfoil was limiting native plant growth in deeper water. The absence of native plants in deep-water habitat accounts for the difference

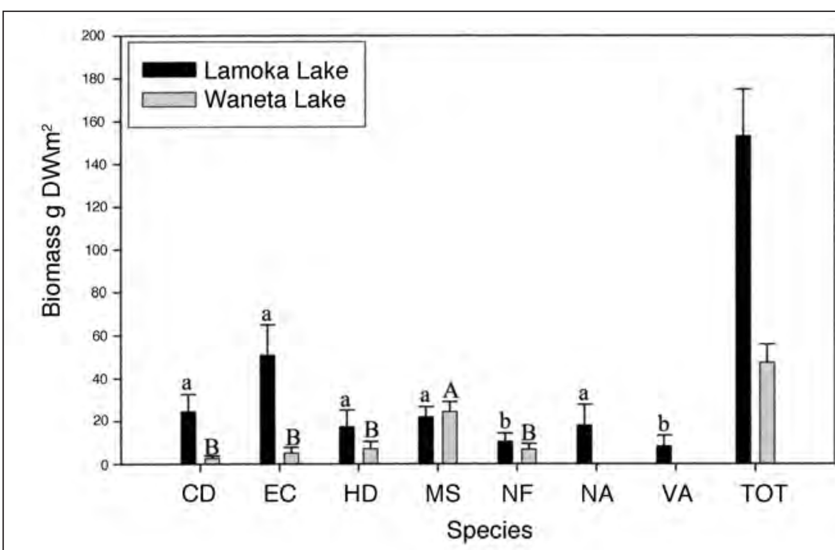

Figure 4. Plant biomass of the most abundant species in Lamoka Lake and Waneta Lake during the time of biomass harvest, August 2000. Abbreviations: CD = coontail, EC = elodea, HD = water stargrass, MS = Eurasian watermilfoil, NF = bushy naiad, NA = yellow pondlily, VA = wild celery, and TOT = total macrophyte. Analyses were conducted for each lake and not between lakes; different lower-case letters above bars refer to differences (± 1 SE) in plant biomass within Lamoka Lake, and different capital letters above bars refer to differences (± 1 SE) in plant biomass within Waneta Lake.

in distribution between Eurasian watermilfoil and native plants in Waneta Lake. The difference in distribution between native plant species and Eurasian watermilfoil in Waneta Lake suggests that Eurasian watermilfoil has already displaced native vegetation throughout the majority of the lake. In Lamoka Lake however, no differences in distribution were detected between native plant species and Eurasian watermilfoil, indicating that Eurasian watermilfoil is able to invade and inhabit the same locations as native plant species. One can speculate that Eurasian watermilfoil may have invaded Lamoka Lake after Waneta Lake and has not been present long enough to displace the native species.

The suppression and displacement of native plants by Eurasian watermilfoil has been observed in other New York lakes (Madsen et al. 1991a, b). Over a three-year period (1987–1989) in Lake George, NY, Eurasian watermilfoil

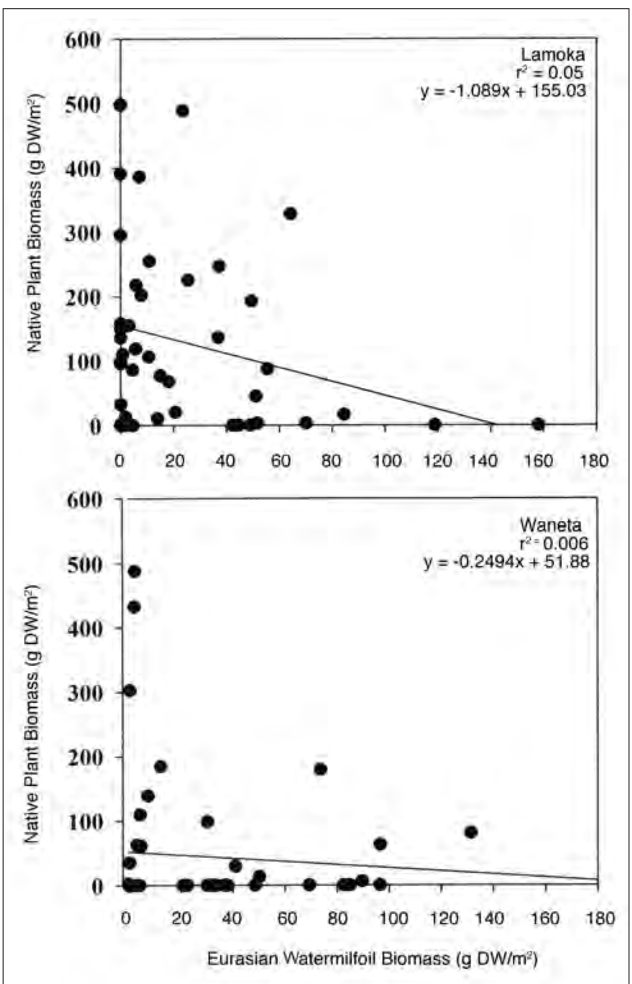

Figure 5. Comparison of Eurasian watermilfoil (*Myriophyllum spicatum*) biomass and native-plant biomass in Lamoka Lake and Waneta Lake during the time of biomass harvest, August 2000.

spread from 30% coverage to over 95% coverage at a monitoring site (Madsen et al. 1991b). At this same location, it was empirically shown that the native-plant density was significantly reduced from 5.5 species per quadrat to 2 species (Madsen et al. 1991b). Native plant species occurrence per point for Waneta Lake and Lamoka Lake was 0.4 and 1.6 respectively in the presence of Eurasian watermilfoil, values much lower than in other studies.

The coverage of Eurasian watermilfoil in Waneta Lake and Lamoka Lake was approximately 80% in the littoral zone. Madsen et al. (1991b) stated that Eurasian watermilfoil coverage greater than 50% is considered a dense bed. However, the overwhelming presence of Eurasian watermilfoil and its subsequent biomass in the two lakes was not related to native-plant biomass, though both lakes do show a general negative relationship between Eurasian watermilfoil and native-plant biomass. It has been implied that there is an inverse relationship between the abundance (biomass) of Eurasian watermilfoil and native plant species (Madsen 1998) where lakes with more than 50% Eurasian watermilfoil were found to have less than 60% native-plant cover (Madsen 1998). The relationship has been quantitatively documented by Madsen et al. (1991b) and reported as occurring in other systems (Aiken et al. 1979, Grace and Wetzel 1978, Madsen 1998, Smith and Barko 1990). The small number of samples used to compare Eurasian watermilfoil biomass to native-plant biomass in this study limited the power of the analysis; had we collected more samples for this portion of the study, a negative relationship would have likely been found.

Although Eurasian watermilfoil was dominant in both lakes, there was still a diverse native-plant community in each lake. Waneta Lake had 16 species of aquatic plants present; of these, only one was non-native (Eurasian watermilfoil), and 13 of these species were native submersed plants that directly competed with Eurasian watermilfoil. Similarly, Lamoka Lake had 20 species of aquatic plants present, of these only two were non-native—Eurasian watermilfoil and curlyleaf pondweed—and 14 were native submersed plants. Coontail, Canadian elodea, and southern naiad were the dominant submersed native plants in both Waneta Lake and Lamoka Lake.

Potamogeton spp. (native pondweeds) appear to be the most vulnerable to invasion by Eurasian watermilfoil due their low presence compared to other species of submersed plants during the survey. The pondweeds may have been better adapted to grow in low light environments (deep-water habitats), which were the first areas to be invaded by the more aggressive Eurasian watermilfoil. Spence and Chrystal (1970a, b) demonstrated a greater photosynthetic capacity in deep water of some pondweeds, and suggested that shade tolerance was directly linked to the natural depth distribution of these species. Madsen and Adams (1989) found that *Stuckenia pectinata* Börner (sago pondweed) has photosynthetic characteristics that allow it to grow in a broad range of environments. However, the pondweeds are primarily early season dominants, and have a lower temperature optimum than species such as coontail and Eurasian watermilfoil (Madsen and Adams 1989), which would put the pondweeds at a disadvantage when competing with Eurasian watermilfoil for light later in the growing season (the time of this survey). Also, under low-light conditions, Eurasian watermilfoil reallocates its biomass to the formation of a canopy which further reduces light availability to native plants, resulting in reductions in native plant distribution and biomass (Barko and Smart 1981, Madsen et al. 1991a).

The presence of Eurasian watermilfoil in Waneta Lake and Lamoka Lake has caused a shift in the distribution of native plant species. The growth of these native plants has been limited to shallow depths within the littoral zone while Eurasian watermilfoil dominates the deeper water. The dominance of Eurasian watermilfoil should be of concern as its aggressive growth and ability to survive under adverse environmental conditions could allow it to overtake the remaining native plant communities in Waneta Lake and Lamoka Lake. Adequate diversity and representation of native plant species already occur in Waneta and Lamoka Lakes to revegetate or replace Eurasian watermilfoil after the implementation of management techniques. Furthermore, light transparency in both lakes is low, and additional efforts should be made to reduce algal and particulate turbidity in these lakes. The reductions in turbidity will further assist in native-plant restoration and establishment and reduce the competitive advantage by Eurasian watermilfoil.

Acknowledgments

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