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Distribution and Abundance of Eurasian Watermilfoil (*Myriophyllum spicatum* L.) and Curly-leaf Pondweed (*Potamogeton crispus* L.) in Shawano Lake, Wisconsin

by Chetta S. Owens, William F. James, John G. Skogerboe, and R. Michael Smart

INTRODUCTION: Shawano Lake, Wisconsin has a history of invasive aquatic plant problems, specifically curly-leaf pondweed (*Potamogeton crispus* L.) and Eurasian watermilfoil (*Myriophyllum spicatum* L.). In addition to problems associated with invasive plant species, Shawano Lake has been experiencing declining water quality associated with phosphorus (P) loading potentially due to summer senescence of curly-leaf pondweed (James and Owens 2006). Located in east-central Wisconsin, this 6,063-acre lake has been infested with Eurasian watermilfoil, the dominant invasive aquatic plant, since 1991 (www.dnr.state.wi), and more recently curly-leaf pondweed. Both exotic plants are problematic in the northern tier states, and are proven to negatively impact water quality, recreational usage, fisheries, native plant populations, and waterfowl usage. In an effort to document P loading associated with curly-leaf pondweed senescence (James and Owens 2006), an aquatic plant survey was conducted in June 2005 to determine the frequency of occurrence for Eurasian watermilfoil and curly-leaf pondweed populations in the lake. In June 2006, plant biomass was collected to document abundance of Eurasian watermilfoil and curly leaf pondweed as well as native plants in Shawano Lake. Additionally, Eurasian watermilfoil and curly-leaf pondweed biomass samples were ground and analyzed for nitrogen, phosphorus, and potassium within plant tissue.

METHODS: During the week of June 13-16, 2005, a lake-wide survey of Shawano Lake, WI was undertaken to determine frequency of occurrence of all aquatic plant species observed in the lake, including Eurasian watermilfoil and curly-leaf pondweed (Figures 1 and 2). This survey was conducted using the point-intercept method (Madsen 1999). Using MapInfo mapping software (Troy, NY), coordinates were determined for each intersecting point on a 200- by 200-m grid (Figure 3). A Garmin GPS map 76CS GPS unit (Olathe, KS) was used to navigate to each point. All plant species were identified at 694 points and water depths were recorded. Plant species were identified by visual inspection and by deploying a sampling rake to the bottom. Additionally, voucher specimens were collected for all plant species and stored at the Lewisville Aquatic Ecosystem Research Facility (LAERF) in Lewisville, TX for future reference.

During the week of June 1-6, 2006, plant aboveground biomass and curly leaf pondweed turions were collected using a box-core sampler (Figure 4). The box-core sampler had a sampling area of $0.1m^2$. The boat containing the sampler was driven to predetermined points where curly-leaf pondweed (the primary plant of interest), had been found during the 2005 point-intercept survey. The box-core sampler was raised using a battery-powered winch, deployed into the lake where the sampler snapped closed, cutting the plants. The retrieved sample was dropped into a container, washed, and all plant biomass and turions were collected and bagged. Observational data on sediment type were recorded. Fifty randomly selected sites were sampled for determination of

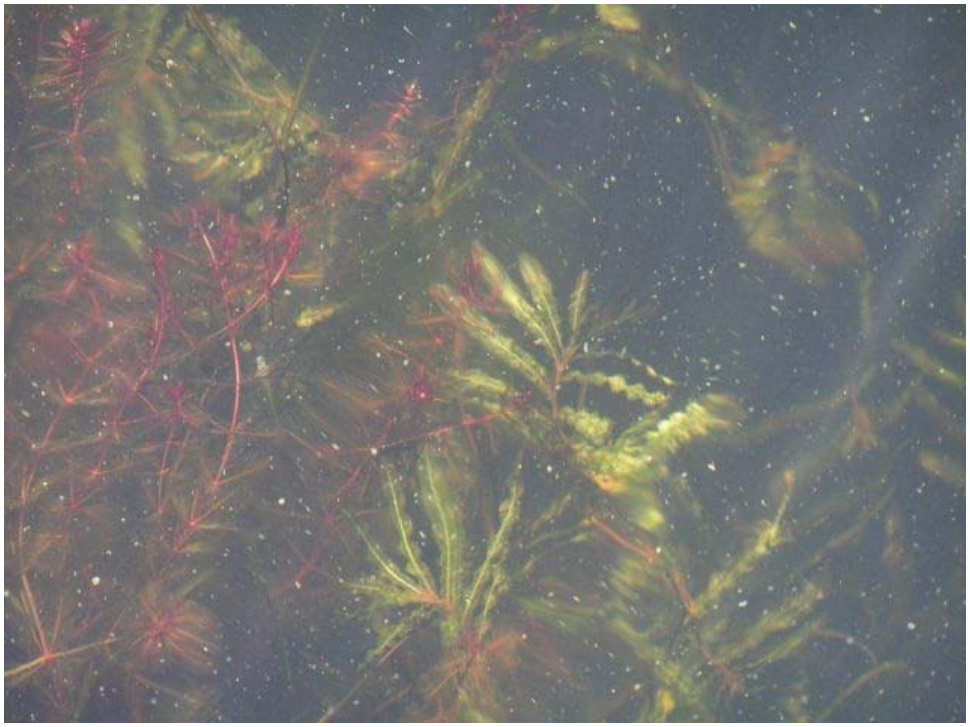

Figure 1. Mixed community of Eurasian watermilfoil and curly-leaf pondweed in Shawano Lake, WI.

Figure 2. Dense mat of Eurasian watermilfoil and curly-leaf pondweed in Shawano Lake, WI (June 2006).

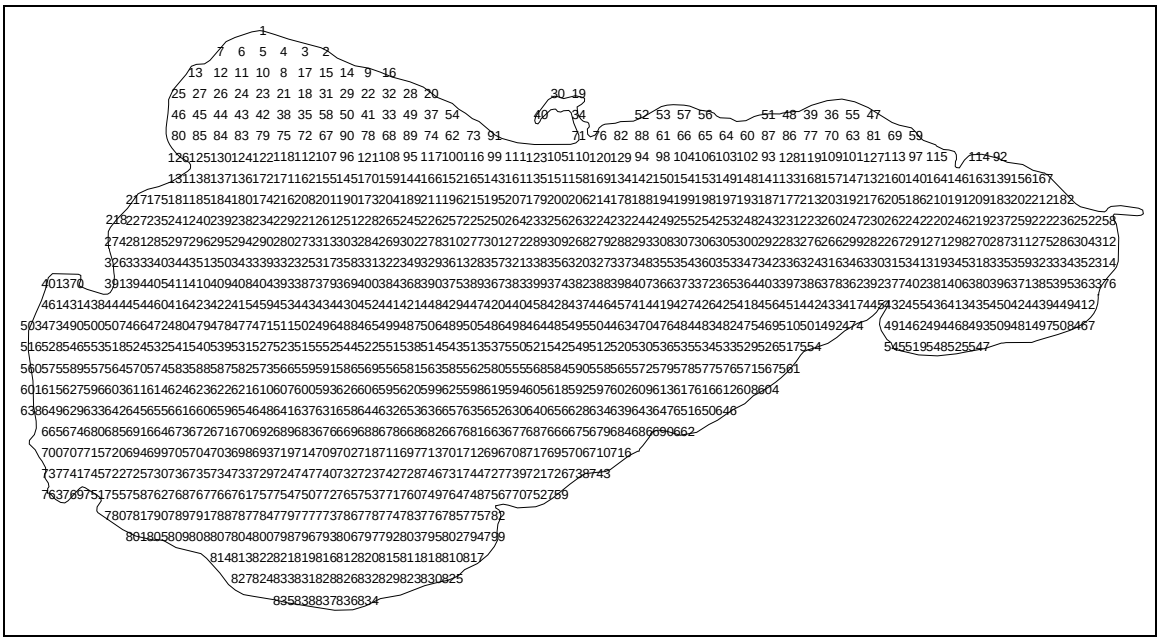

Figure 3. Point-intercept points for the 2005 survey. UTM coordinate, Zone16, NAD 27.

Figure 4. Box-core sampler after being deployed to capture plant sample.

biomass (Figure 5). Plant material was shipped overnight to the LAERF, sorted to species, dried, and weighed. Eurasian watermilfoil and curly-leaf pondweed samples were finely ground using a Cyclone Sampling Mill (UDY Corp., Fort Collins, CO). Ground plant samples were block-digested (Figure 6) according to Allen et al. (1974), then analyzed for nitrogen, phosphorus, and potassium (American Public Health Association (APHA) 1995).

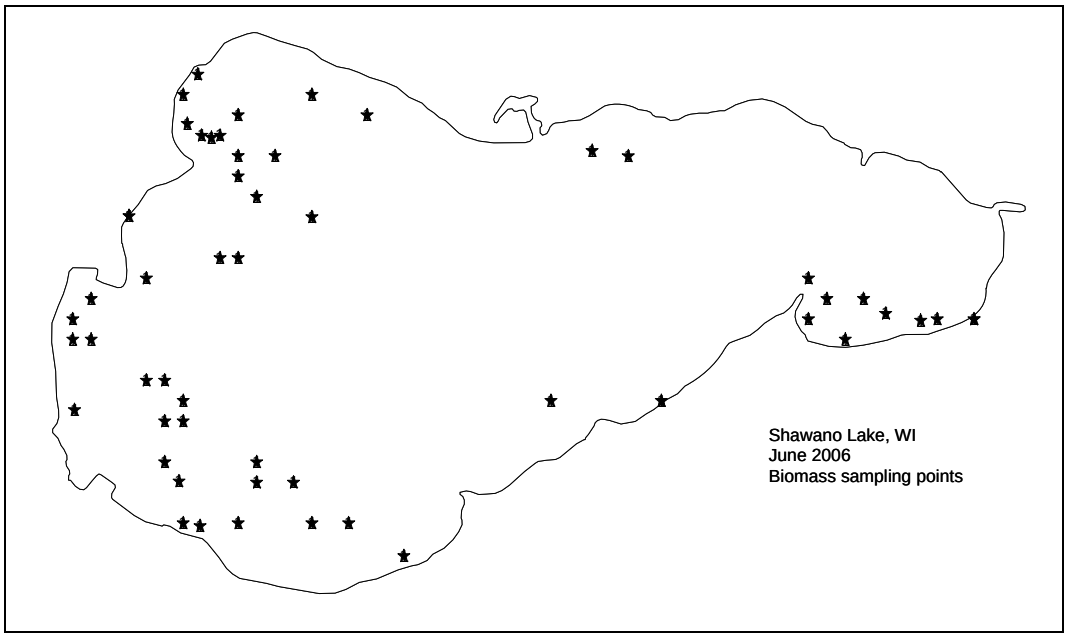

Figure 5. Sites for biomass collection sampled in June 2006.

Figure 6. Setup for block digests of plant tissue for analysis for N, P, and K.

RESULTS AND DISCUSSION

June 2005 Macrophyte Survey:

Species list. The maximum depth sampled in Shawano Lake was approximately 9 m, although most vegetated points were considerably less than 1.4 m. No plants were found at greater than 4.6 m in the lake. Table 1 lists 31 species of aquatic and wetland plants observed and collected in the lake. Of these species, three were introduced exotic plants, including two submersed plant species: Eurasian watermilfoil and curly-leaf pondweed. Of the 28 native plant species, 19 were submersed, 6 were emergent, and 3 were floating-leaf.

Table 1
Aquatic and Wetland Plant Species Observed in Shawano Lake, Wisconsin[1]

Scientific Name	Common Name	Exotic/ Native	Growth Form	Frequency %
Bidens beckii Torr.	Water marigold	N	Submersed	0
Ceratophyllum demersum L.	Coontail	N	Submersed	19.7
Chara spp.	Muskgrass	N	Submersed	0.4
Elodea canadensis Michx.	Common waterweed	N	Submersed	21.4
Eleocharis quadrangulata (Michx.) Roemer & Schultes	Squarestem spikerush	N	Emergent	0
Juncus spp.	Rush	N	Emergent	0
Lythrum salicaria L.	Purple loosestrife	E	Emergent	0.1
Lemna trisulca L.	Forked duckweed	N	Floating	0
Myriophyllum alterniflorum DC	Alternate watermilfoil	N	Submersed	0
M. sibiricum Komarov	Northern watermilfoil	N	Submersed	7.9
M. spicatum L.	Eurasian watermifoil	E	Submersed	38
M. tennellum Bigelow	Dwarf watermilfoil	N	Submersed	0
Najas spp.	Naiad	N	Submersed	13.4
Nuphar advena (Aiton) Aiton f.	Yellow pond lily	N	Floating	1.6
Nymphaea odorata Aiton	White water lily	N	Floating	0.3
Pontederia cordata L.	Pickerelweed	N	Emergent	0
Potamogeton amplifolius Tuck.	Broadleaf pondweed	N	Submersed	5.6
P. crispus L.	Curly-leaf pondweed	E	Submersed	24
P. foliosus Raf.	Leafy pondweed	N	Submersed	2.3
P. gramineus L.	Variable pondweed	N	Submersed	8.2
P. illinonensis Morong	Illinois pondweed	N	Submersed	0.3
P. praelongus Wulfen	Whitestem pondweed	N	Submersed	0
P. richardsonii (Ar. Bennett) Rydb.	Clasping leaf pondweed	N	Submersed	0
P. robbinsii Oakes	Robbin's pondweed	N	Submersed	3.5
P. zosterformis Fern.	Flatstem pondweed	N	Submersed	9.4
Sagittaria spp.	Arrowhead	N	Emergent	0.1
Scirpus spp.	Bulrush	N	Emergent	0
Sparganium spp.	Burreed	N	Emergent	0
Utricularia spp.	Bladderwort	N	Submersed	0.7
Vallisneria americana L.	Wild celery	N	Submersed	12.2
Zannichellia palustris L.	Horned pondweed	N	Submersed	0.7

[1] (E) denotes exotic and (N) denotes native.

Frequency of occurrence. Frequency of occurrence for plants, including Eurasian watermilfoil and curly-leaf pondweed, is shown in Table 1. Of the 694 points that were sampled, Eurasian watermilfoil was found at 264 points or approximately 38 percent of sampled points (Figure 7, Table 1). Curly-leaf pondweed was found at 164 points or approximately 24 percent of sampled points (Figure 8, Table 1). In addition, 28 native aquatic and wetland plants were observed in Shawano Lake, with 17 collected in samples (Table 1, Figure 9). By combining survey points that had at least one native plant occurrence, a total of 392 points or approximately 56 percent of sampled points included at least one native plant, indicating greater frequency than the combined exotic plant species (Figure 9). Of the 16 native submersed plant species collected from the lake, 4 occurred in greater than 10 percent of all sampled points. These native plant species included common waterweed (21.4 percent), coontail (19.7 percent), naiad (13.4 percent) and wild celery (12.2 percent), suggesting that a diverse community of native aquatic and wetland plants exists in the lake.

Figure 10 shows a distributional comparison between the two introduced exotic plant species and native plant species with the highest frequency of occurrence in the lake. Eurasian watermilfoil and curly-leaf pondweed were well represented in the western region of the lake and could be found forming dense mats (Figure 2). This area of the lake also contained numerous native plants including waterweed, many of the pondweeds, naiads, and coontail. Definitive impact comparisons were difficult to conclude with just post-invasion data; however, existing documentation on other invaded aquatic systems found that native plant communities could be negatively impacted by invasive species (Madsen 1998, Wisconsin Department of Natural Resources (WI DNR) 2006).

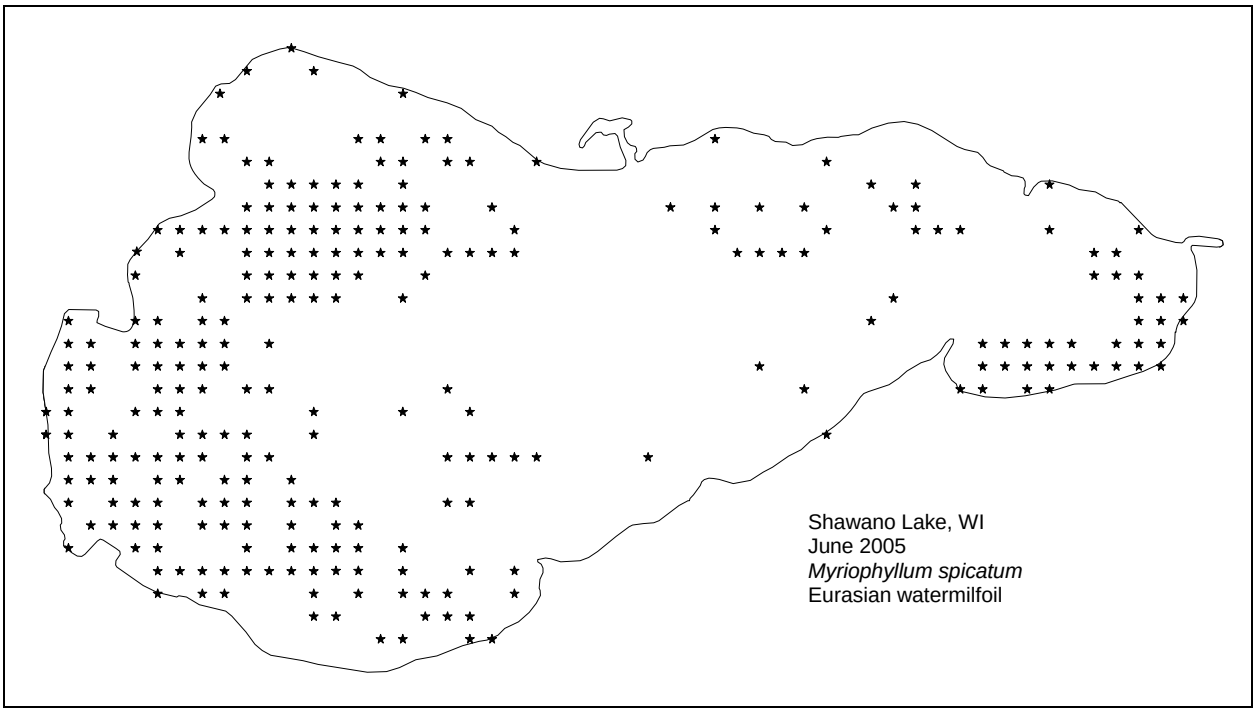

Figure 7. Surveyed points where Eurasian watermilfoil was found in Shawano Lake, WI.

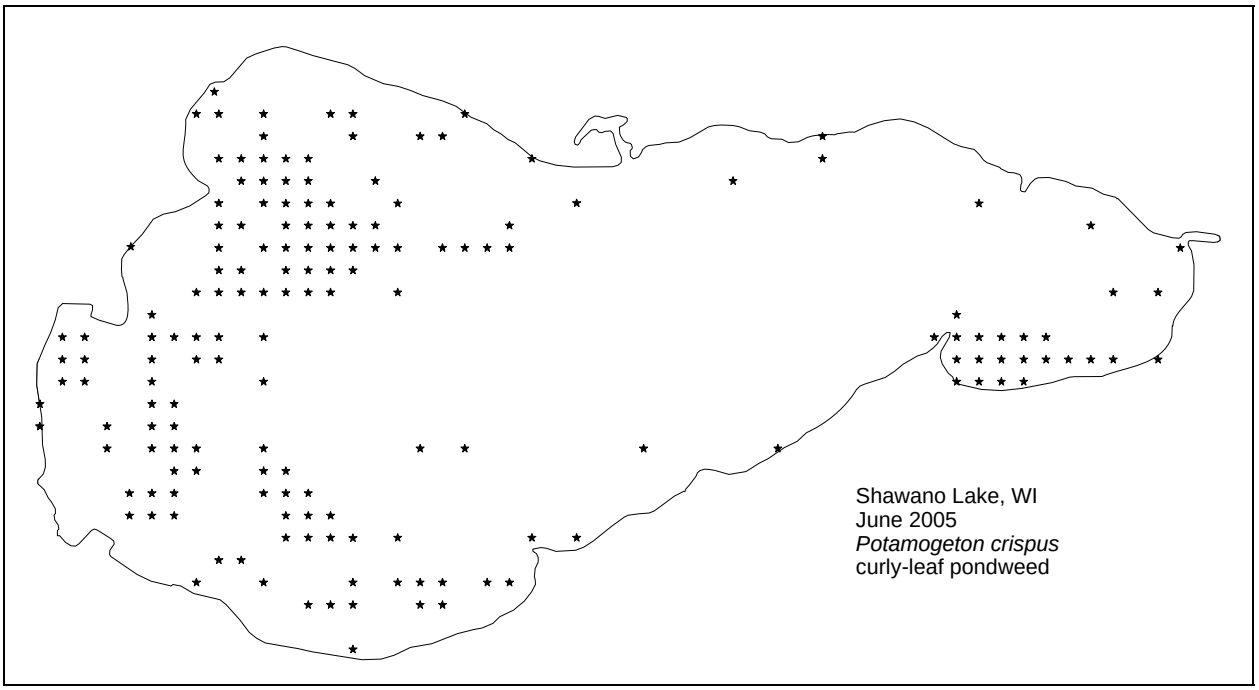

Figure 8. Surveyed points where curly-leaf pondweed was found in Shawano Lake, WI.

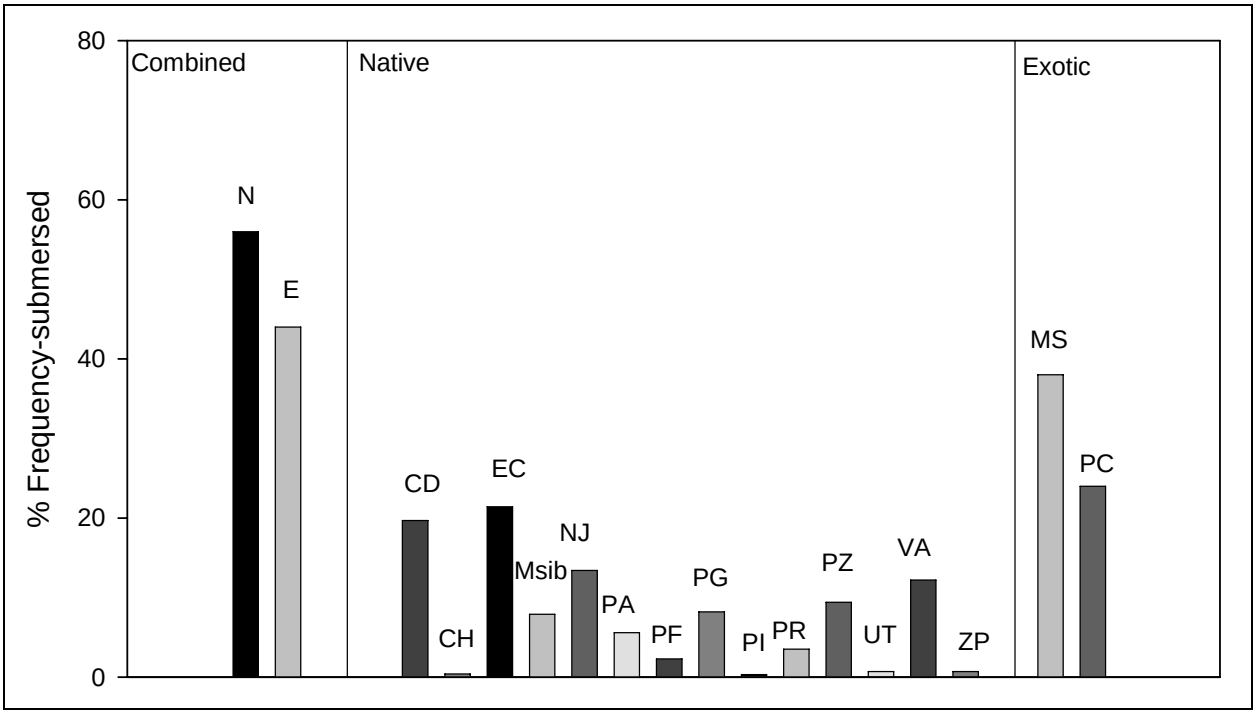

Figure 9. Percent frequency comparison between the native submersed aquatic plants and the two introduced exotic species. Abbreviations are N (native), E (exotic), CD (coontail), CH (Chara), EC (waterweed), Msib (northern milfoil), NJ (naiad), PA (broadleaf pondweed), PF (leafy pondweed), PG (variable pondweed), PI (Illinois pondweed), PR (Robbin's pondweed), PZ (flatstem pondweed), UT (bladderwort), VA (wild celery), (horned pondweed), MS (Eurasian watermilfoil) and PC (curly-leaf pondweed).

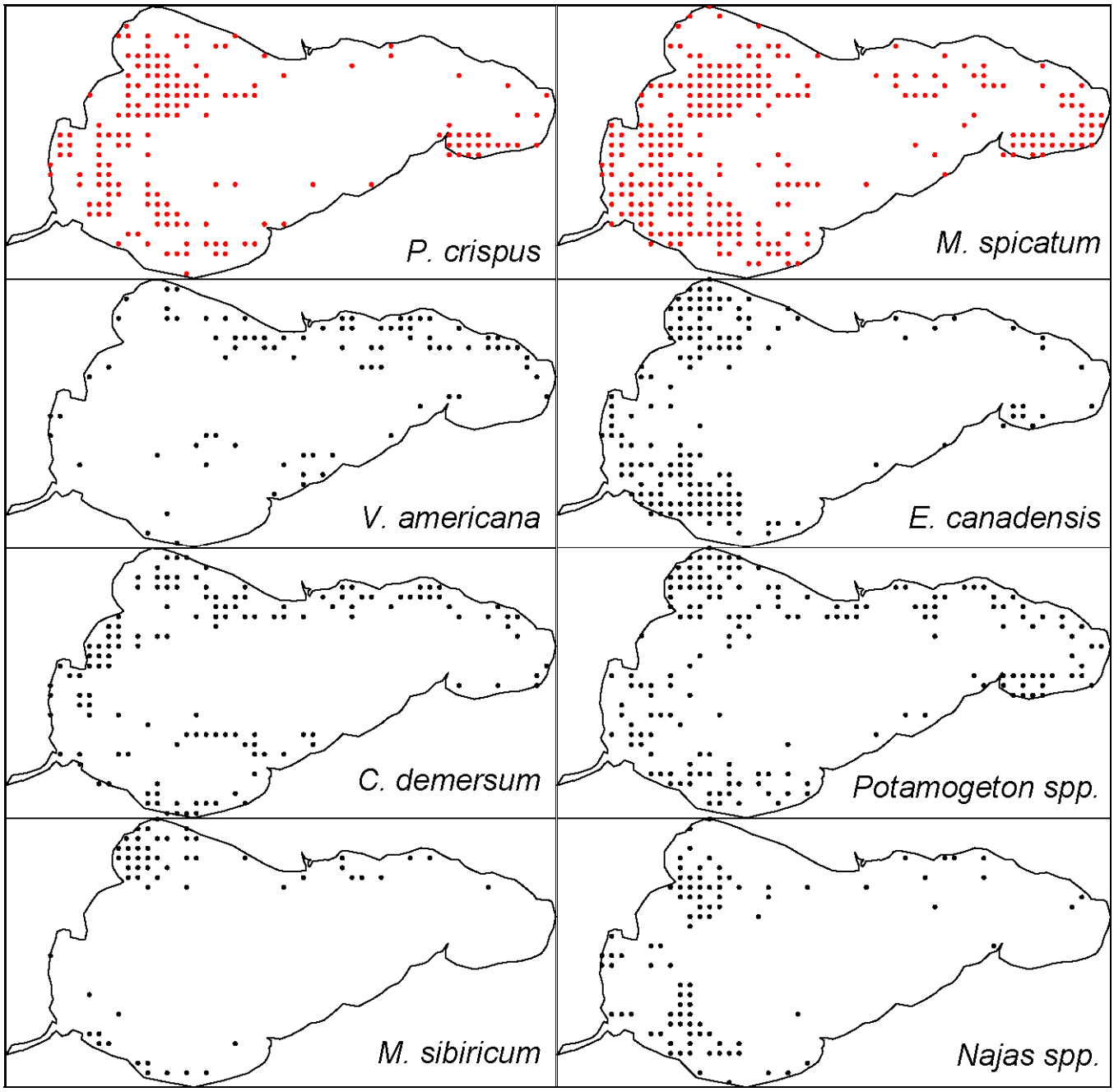

Figure 10. Distributional comparison between curly-leaf pondweed and Eurasian watermilfoil with the more abundant native plants found in Shawano Lake, WI

However, it should be noted that native aquatic plants occurred at greater percent frequency in Shawano Lake at depths of 1.8 m and less than either Eurasian watermilfoil or curly-leaf pondweed (Table 2). Nichols (1999) indicated that many native aquatic plants in Wisconsin lakes occur in waters of less than 2 m. Therefore, in Shawano Lake many of the resources (light, nutrients, and space) were evidently preempted at these depths, thus slowing or preventing Eurasian watermilfoil and curly-leaf pondweed from forming monocultures. At greater depths where less native aquatic plants naturally occurred, Eurasian watermilfoil (especially) and curly-leaf pondweed have become better established (Table 2). It is interesting to note that in the areas with sandy sediments (northeastern portion of the lake), wild celery populations were well documented. Sediments in the western areas of the lake with very fine, organic sediments supported less of that species.[1]

Table 2
Percent Frequency for Depth Distribution of Eurasian Watermilfoil, Curly-leaf Pondweed, and Natives

Depth, m	Eurasian Watermilfoil % Frequency	Curly-leaf Pondweed % Frequency	Total Native Plant % Frequency
0.3-0.9	26.3	17.9	72.4
1.2-1.8	47.4	23.7	87.4
2.1-2.7	71.8	48.9	55.2
3.0+	22.4	16.8	13.6

June 2006 Macrophyte Biomass Survey:

Species biomass. Plant biomass data are summarized in Table 3 for the biomass-collecting trip in June 2006. Eurasian watermilfoil had an average aboveground biomass of 96.99 g DW m^{-2} with a minimum dry weight of 0 and a maximum of 402 g DW m^{-2}. Curly-leaf pondweed averaged 43.19 g DW m^{-2} aboveground plant biomass with a minimum dry weight of 0 and a maximum of 166.5 g DW m^{-2}. Total biomass for both exotic species was 97.84 g DW m^{-2} while biomass for total native plants was 98.16 g DW m^{-2}. Eleven native submersed plant species were collected during the sampling period (Table 3). Although biomass-sampling sites were randomly chosen from 2005 survey points where curly-leaf pondweed (the plant of interest) had been recorded, curly-leaf pondweed was not always collected when sampling for biomass in 2006. Curly-leaf pondweed was found growing in dense mats in some areas of the lake, but in most areas was intermixed with other plants, including Eurasian watermilfoil and natives. Of the 50 samples taken, only 14 sites contained curly-leaf pondweed. Eurasian watermilfoil, however, was collected at 30 sites.

Curly-leaf pondweed was producing turions (vegetative reproductive structures) during the June biomass collection period. Turion density for Shawano Lake was found to average 31.8 m^{-2} with a minimum density of 0 and a maximum density of 340 propagules m^{-2}. Turions germinate during the winter months, and explode in growth with the warmer temperatures of spring (Wehrmeister and Stuckey 1992).

[1] Personal observation, June 2006, Chetta Owens, SpecPro, Inc., Lewisville, TX.

Table 3
Species of Plants Collected as Biomass During the June 2006 Sampling Period (Biomass was collected from 50 sites)

Scientific Name	Average Biomass, g DW m^{-2} (±1 S.E.)	n
Ceratophyllum demersum L.	11.36 (3.22)	32
Chara spp.	9.21(5.27)	9
Elodea canadensis Michx.	28.05 (8.58)	29
Lemna trisulca L.	19.85 (4.53)	43
Myriophyllum alterniflorum DC	7.53 (5.96)	4
M. sibiricum Komarov	7.7 (1.53)	4
M. spicatum L.	96.99 (21.68)	30
Najas spp.	20.15 (5.21)	43
Potamogeton amplifolius Tuck.	10.05 (6.55)	10
P. crispus L.	43.19 (13.15)	14
P. praelongus Wulfen	31.7 (10.336)	7
P. robbinsii Oakes	23.64 (5.38)	23
P. zosterformis Fern.	14.98 (3.67)	29
Vallisneria americana L.	11.12 (4.19)	22
Exotic-total	**97.84 (19.1)**	**35**
Native-total	**98.16 (10.48)**	**49**

Tissue nutrient content. Mean concentrations of nitrogen, phosphorus, and potassium for curly-leaf pondweed and Eurasian watermilfoil are shown in Table 4. Overall, mean concentrations were within the range of values reported by Barko et al. (1988) and Smith et al. (2002). Results suggested that these nutrients did not limit curly-leaf pondweed or Eurasian watermilfoil growth in Shawano Lake.

Table 4
Mean (standard error in parentheses) Tissue Nutrient Content for Curly-leaf Pondweed and Eurasian Watermilfoil Collected from Shawano Lake, Wisconsin, 2006

Plant	Nitrogen (mg/g)	Phosphorus (mg/g)	Potassium (mg/g)
Curly-leaf pondweed	23.01 (± 0.27)	2.4 (± 0.09)	18.41 (± 0.39)
Eurasian watermilfoil	21.76 (±0.39)	2.1 (±0.06)	12.43 (± 0.28)

In conclusion, the frequency of occurrence for the introduced exotic species Eurasian watermilfoil and curly-leaf pondweed was 38 and 24 percent, respectively. Eurasian watermilfoil and curly-leaf pondweed had greater frequency and biomass when examined individually; however, combined native plant frequency and biomass suggested that a diverse community of native plants also existed in Shawano Lake. Twenty-eight native species were found in the lake, including common waterweed (21.4 percent), coontail (19.7 percent), naiad (13.4 percent) and wild celery (12.2 percent), and at least one native species was found in 56 percent of the sampling points. Distributional patterns indicated that Eurasian watermilfoil and curly-leaf pondweed dominated in the western region of the lake, where they sometimes formed dense mats. However, this area of the lake also supported numerous native plants including waterweed, many of the pondweeds, naiads, and coontail.

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