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Article Author: Wakeman, R. W. and D.

two species do not directly compete with each other, results do demonstrate that in the critical early period of growth Large Leaf Pondweed would not be hampered by competitive influences from Eurasian Watermilfoil.

The recolonization analysis shows that Eurasian Watermilfoil may not be the most successful invading species in cleared plots. This may provide evidence that hand clearing of Eurasian Watermilfoil may allow native species to become established without planting. However, if Eurasian Watermilfoil is present the ability of natives to become established is very limited.

Without interspecific competition at the early stages of growth, the potential for establishing Large Leaf Pondweed is increased. Additional work needs to be conducted to determine at what stage Eurasian Watermilfoil begins to out-compete natives. If Eurasian Watermilfoil can be managed so that its competitive advantages can be minimized, then establishing and maintaining a native population should be feasible.

Lake and Reservoir Management, 9(1):129-133. (1994) Extended Abstract of a paper presented at the 13th International Symposium of the North American Lake Management Society, Seattle, WA, Nov. 29-Dec. 4, 1993

Optimum Growth Conditions For *Potamoqeton amplifolius*, *Myriophyllum spicatum* and *Potamoqeton richardsonii*

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The Wisconsin Department of Natural Resources, the University of Wisconsin - Milwaukee, the Okauchee Lake Management District and the Lac La Belle Management District entered into a cooperative agreement to investigate the feasibility of increasing diversity of aquatic vegetation in the lakes. Both lakes are located in southeastern Wisconsin and are characterized as being hardwater, mesotrophic lakes with an aquatic plant community dominated by Eurasian Watermilfoil (*Myriophyllum spicatum*).

The objectives of this research were to determine;

1. the optimum depth for Large Leaf Pondweed (*Potamogeton amplifolius*) and Eurasian Water Milfoil,
2. the effect of sediment nutrient concentrations on the growth of Large Leaf Pondweed, Eurasian Watermilfoil, and Richardson's Pondweed (*Potamogeton richardsonii*).

Separate experiments were conducted for each objective.

Study Area

Both Lac La Belle and Okauchee Lake are located in Waukesha County, Wisconsin and are approximately 45 minutes west of Milwaukee. *Lac La Belle* is a 1164 acre, hardwater, mesotrophic, drainage lake. Spring total phosphorus concentrations are typically below 20 µg/l and a summer average secchi disk reading of 2.5 m. The littoral zone sediments are primarily coarse sand.

The submergent aquatic plant community is dominated by Eurasian Watermilfoil although it does not interfere with recreational uses. The diversity of submergent aquatic plant species is very low. Historically Lac La Belle supported a diverse and abundant aquatic plant community including emergent, floating and submergent plants. The location of these extensive plant beds were adjacent to portions of the shoreline that had significant nonpoint source pollution discharges.

Okauchee Lake is a 1187 acre, mesotrophic lake with organic littoral zone substrates. Spring total phosphorus concentration averages below 20 µg/l and the summer secchi disk reading vary between 1.0 and 3.0 meters.

Eurasian Watermilfoil is the dominant species; however, the diversity of submerged aquatic plants is much greater than in Lac La Belle. The lake management district has intensively managed the aquatic plant community, using both aquatic herbicides and mechanical harvesters.

Methods

Depth Optimum Study

Two transects were established perpendicular to the 1.0 m to 4.5 m depth contours at the Lac La Belle - Island Site (Fig. 1). Using compass bearings, surface buoys marked plots at water depth increments of 0.5 m from 1.0 m to 4.5 m. All vegetation was hand-cleared along both transects using SCUBA to provide a cleared width of 2.0 m. Along one side of the center line of each transect 10 Large Leaf Pondweed fragments were planted at each 0.5 m depth interval; 10 Eurasian Watermilfoil fragments were planted at each 0.5 m depth on the other side of the center line. Eurasian Watermilfoil was obtained from the general vicinity of the study area, but outside of the plots. Large Leaf Pondweed was obtained from nearby Pine Lake, Waukesha County.

Fragments of each species were collected by divers and stored in large fiberglass tanks. The fragments of Large Leaf Pondweed were prepared for planting by trimming healthy shot apexes back, leaving four large expanded leaves. Biodegradable cheesecloth bags containing a small stone were affixed to the base of each fragment using a small piece of yellow nylon string. The fragments of Eurasian Watermilfoil were prepared by trimming healthy shoot apexes to 15 cm lengths. Cheesecloth bags were affixed to fragments as described for Large Leaf Pondweed.

A subsample of 20 Eurasian Watermilfoil and 20 Large Leaf Pondweed fragments were returned to the lab, dried and weighed to determine a representative dry weight.

At the end of September light readings were taken from the surface to 4.5 m and all plants were hand harvested. Plants were returned to the lab, counted, dried at 115°F, and weighed.

Sediment Nutrient Dilution Experiment

Laboratory experiments were conducted to determine the optimum sediment nutrient concentration. Pre-weighed fragments of Large Leaf Pondweed, Richardson Pondweed (*Potamogeton richardsonii*) and Eurasian Watermilfoil were grown (with eight replicates) in dilution series of Lac La Belle, Okauchee Lake, and Lake Mendota (Dane County, Wisconsin) sediments. Richardson Pondweed and Lake Mendota sediment were included in the experiment because of interest from other researchers. The dilution series for each lake sediment consisted of 100, 80, 60, 40, 20, 10, 5, and 0% mixtures of degassed sediment and sand. The lake sediment was covered in each pot by a 2-3 cm layer of fine silica to restrict movement of nutrients into the water column. Individual pots were randomly placed into fiberglass tanks under growth lights.

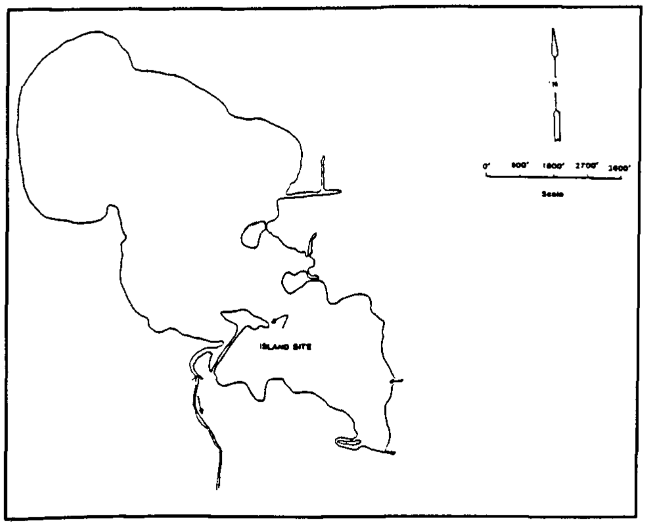

Figure 1.—Lac La Belle, Waukesha County, Wisconsin.

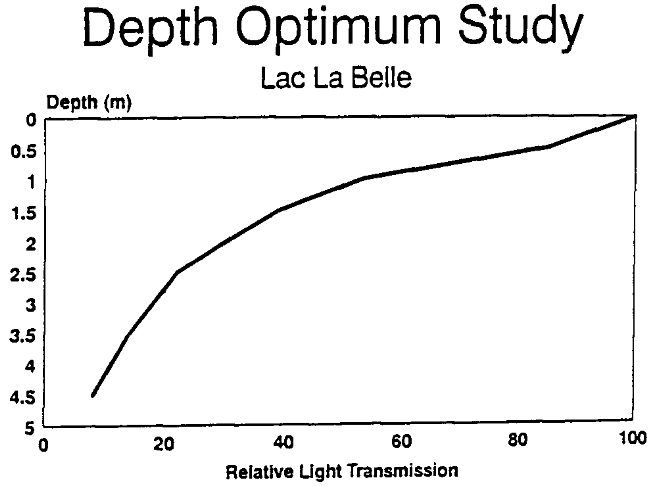

Figure 2.—Light penetration in Lac La Belle.

Subsamples of sediments were collected for nutrient analysis before and after the experiments. During the course of the experiment, water temperature, light, dissolved oxygen, and pH were monitored and subsamples were taken for nutrient analysis. Silica sand and the sand used to dilute the sediment was also analyzed for nutrients. Sediment texture was also analyzed for each mixture.

All plants were harvested after two months of growth. Relative illumination, tank position, and total biomass (wet weight basis) was measured and recorded for each plant harvested.

Results

Depth Optimum Study

Relative light transmittance decreased logarithmically from the surface to 4.5 m (Fig. 2). The percent survival and biomass responses of Large Leaf Pondweed and Eurasian Watermilfoil are shown in Figs. 3 and 4. Survival of Large Leaf Pondweed was lowest at 4.5 m and uniformly high from 1.0 m to 4.0 m. Large Leaf Pondweed biomass peaked at 2.0 m. Eurasian Watermilfoil survival peaked at 2.0 m to

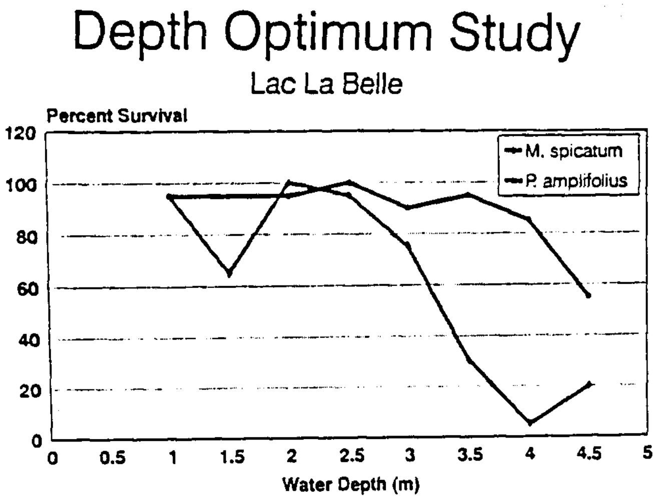

Figure 3.—Percent survival of *M. spicatum* and *P. amplifolius* at different depths in Lac La Belle.

2.5 m and also at 1.0 m. Eurasian Watermilfoil biomass showed a bi-modal maxima at 1.0 m and at 2.0 m to 2.5 m.

Sediment Dilution Study

Sediment Analysis.

Table 1 summarizes the concentration of total nitrogen, nitrate, ammonia nitrogen, available phosphorus, found in the sediment from the three lakes. The highest total nitrogen was found in Okauchee Lake sediments (0.72%) where as, total nitrogen was similar in both Lake Mendota (0.36%) and Lac La Belle (0.31%). Nitrate was highest in Lac La Belle (34.5 ppm) sediment. Available ammonia nitrogen (NH_4) was more than two-fold higher in sediments from Lake Mendota (94.1 ppm) than in Lac La Belle (34.5 ppm) or Okauchee Lake (41.6 ppm). Available phosphorus was below detection in all three sediments prior to the experiments.

After the experiments, sediments were re-analyzed for these same nutrients. Total nitrogen and ammonia nitrogen decreased in all experimental cultures. Available phosphorus remained unchanged in Lac La Belle and Okauchee Lake sediments but increased in the Lake Mendota sediments following the experiments.

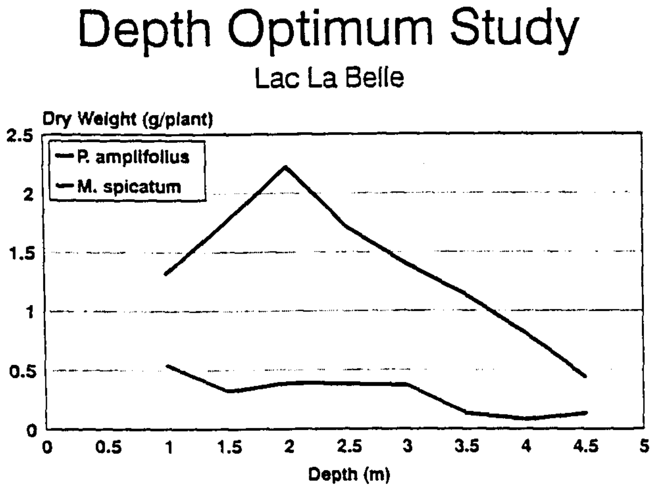

Figure 4.—Biomass response of *M. spicatum* and *P. amplifolius* at different depths in Lac La Belle.

Table 1.—Nutrient concentration in sediment, initial and final.

Initial Concentration

	N	Total N (%)	NH_4 - N (ppm)	NO_3 - N (ppm)	Avail. P (ppm)
Lake Mendota	3	0.36	94.1	8.9	<0.5
Okauchee Lake	3	0.72	41.6	7.2	<0.5
Lac La Belle	3	0.31	34.5	34.5	<0.5
Sand	1	0.03	3.6	0.8	6.6
Silica	1	0.01	6.8	1.6	1.1

Final Concentration

	N	Total N (%)	NH_4 - N (ppm)	NO_3 - N (ppm)	Avail. P (ppm)
Lake Mendota	21	0.32	13.8	10.1	1.3
Okauchee Lake	21	0.57	17.3	12.3	<0.5
Lac La Belle	21	0.27	9.8	6.7	<0.5

Three replicates of each undiluted lake sediment were also analyzed for concentrations of 12 elements. Total phosphorus was two-fold higher in Lake Mendota and Okauchee Lake sediment (0.4%) than Lac La Belle (0.2%), but the levels were relatively low. Few differences were noted among the three lake sediments for other elements.

Texture analysis of sediment subsamples indicated that the dilution series effectively increased ratios of sand, and decreased ratios of silt/clay at expected proportions.

Plant Response.

Some responses to sediment dilution differed among the three species. Biomass (relative wet weight), was greater for both pondweed species than for Eurasian Watermilfoil at most dilutions of all three lake sediments (Figs. 5 - 7). Biomass increase was highest overall for Richardson Pondweed, intermediate for Eurasian Watermilfoil, and lowest

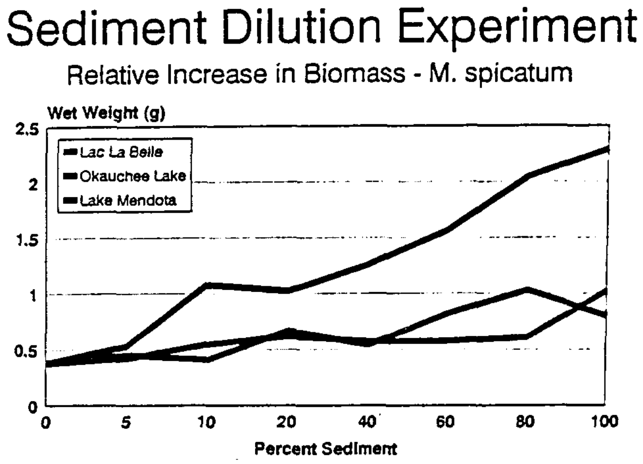

Figure 5.—Relative increase in biomass of *M. spicatum* at different sediment dilutions.

for Large Leaf Pondweed.

All three species exhibited some growth responses to lake sediment dilution with a proportional decline to sediment dilution. With the exception of some Lake Mendota sediment dilutions (percent sediment >40%), the observed growth responses were relatively small. Biomass increased with percent sediment, but only a roughly two-fold productivity increase was observed for Eurasian Watermilfoil and Large Leaf Pondweed across the maximum dilution range in both Okauchee Lake and Lac La Belle sediments (Figs. 5 and 6) and a 3-fold increase for Richardson Pondweed in these sediments (Fig. 7). Higher sediment dilutions (percent sediment >40%) of Lake Mendota sediment resulted in a significant increase in biomass for all three species. The maximum response observed ranged from a roughly 5-fold increase of Large Leaf Pondweed and Eurasian Watermilfoil to an approximately 8-fold increase of Richardson Pondweed.

Discussion

Depth Optimum Study

There does not appear to be an obvious difference in growth performance between Large Leaf Pondweed and Eurasian Watermilfoil with depth. Eurasian Watermilfoil displays uniformly high growth from 2.0 m to 3.0 m. This region includes the optimal depth (2.0 m) for Large Leaf Pondweed. Survival of Large Leaf Pondweed, however is much higher than Eurasian Watermilfoil at 3.5 m to 4.0 m depths. Plantings of Large Leaf Pondweed at these depths do not grow optimally, but high survival relative to Eurasian Watermilfoil may provide it with an advantage.

Sediment Dilution Study

Results indicate a possible occurrence of a threshold gradient specified by some component of the Lake Mendota sediment. Once this limit was surpassed (percent sediment > 40%), the growth of all three species greatly increased. This response may indicate the presence of a "physiological switch" in these species that is triggered by a certain nutrient gradient level. Although there are differences in the magnitude of the response across the three species, it is apparent that all three are responding to a similar "cue."

The factor correlating best with the observed differences was the initial concentration of ammonia (NH_4) nitrogen in the undiluted sediments. Notably, a 50% dilution of Mendota sediments provides roughly the same ammonia nitrogen concentration as undiluted sediments from either Lac La Belle or Okauchee Lake. It is near this dilution factor that the greatest growth responses were observed (Figs. 5 - 7). These results indicate that sediment NH_4 levels may limit growth of aquatic plants in these Wisconsin Lakes. Each of the three species excelled at ammonia nitrogen removal in different lake sediment (Fig. 8). The response of both pondweed species was punctuated in sediment concentrations greater than 40% of Lake

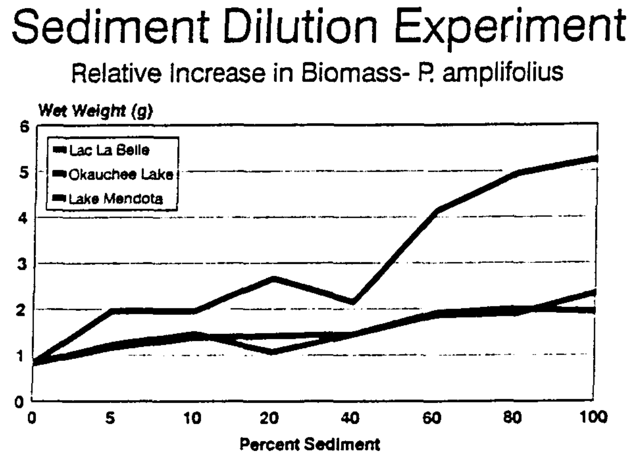

Figure 6.—Relative increase in biomass of *P. amplifolius* at different sediment dilutions.

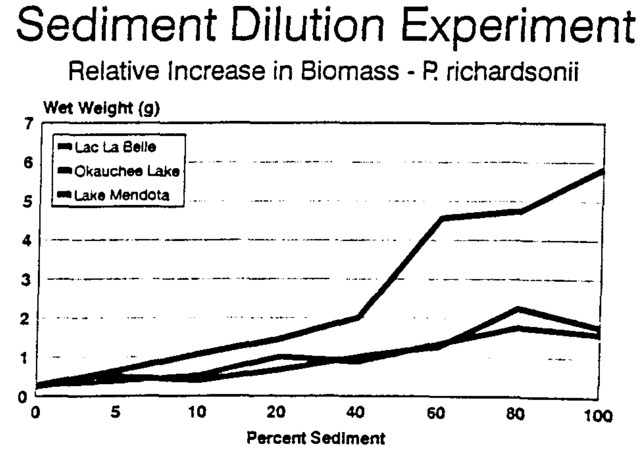

Figure 7.—Relative increase in biomass of *P. richardsonii* at different sediment dilutions.

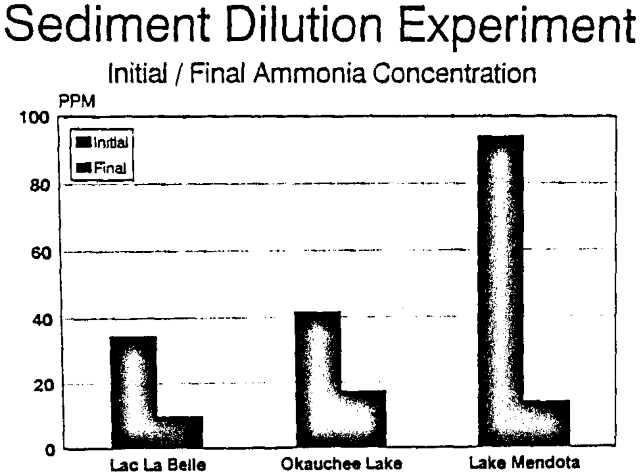

Figure 8.—Ammonia removal in different lake sediments.

Mendota sediments, whereas that of Eurasian Watermilfoil was essentially linear throughout the dilution series. These observations suggest the possibility that ammonia nitrogen uptake mechanisms may operate differently among these three submersed aquatic plants.

The lack of a 1:1 correlation of dilution responses from lake to lake cautions against making sweeping generalizations regarding the responses of macrophytes in different Wisconsin lakes. A 100% (undiluted) sediment from Lac La Belle, for example possesses the ammonia nitrogen equivalent of only a 50% diluted sediment from Lake Mendota. The majority of growth responses observed in our study occurred above this level.

Conclusions

The in-situ optimum depth experiments demonstrate that while neither species grew any better at a particular depth the percent survival of Large Leaf Pondweed compared to Eurasian Watermilfoil was greater below 3.0 m. This may provide Large Leaf Pondweed with an advantage over Eurasian Watermilfoil and improve the chance for successful plantings. The sediment dilution experiments indicate the possible presence of a sediment ammonia nitrogen threshold which accelerates growth if exceeded.

The results of this research may be used to develop an aquatic plant management strategy that may include planting native species in Eurasian Watermilfoil beds and intensively managing the community in favor of the native vegetation. Understanding the optimum growing conditions will aid managers in identifying areas where native species may be established and maintained.

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Potential Impacts of Purple Loosestrife and its Control on Wetlands in Washington State: An Evaluation of Research Needs

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Purple loosestrife is a wetland perennial that is native to Europe and Asia. The historical distribution and spread of purple loosestrife is closely correlated with human exploration from northern Europe and the plant is now found in northern Africa, Australia and across temperate North America (Stuckey, 1980).

Purple loosestrife was probably introduced to northeastern North America by emigrants in the early 1800's. By the 1830's, the plant was well established in New England estuaries. Its spread to the inner continent was no doubt assisted by the construction of canals and cargo transport to inland ports. During the first half of the twentieth century, purple loosestrife spread into the glaciated wetlands of North America, and has now spread across the northern United States and the southern provinces of Canada (Thompson et al., 1987). It was first documented in Washington State on Lake Washington in 1929 and is now present in 30 of the State's 39 counties (Brookreson, 1991) (Fig. 1).

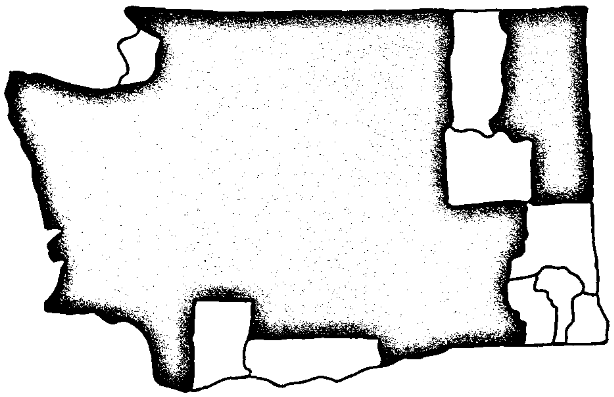

Figure 1.—The distribution of purple loosestrife in Washington State by county. The gray counties are those in which purple loosestrife has been detected.