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Impact of Aquatic Plant Management Methodologies on Eurasian Watermilfoil Populations in Southeast Wisconsin

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ABSTRACT

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Declines and increases in Eurasian watermilfoil populations (*Myriophyllum spicatum* L.) throughout North American Lakes have highlighted the need for long-term studies. Similarly, understanding the long-term implications of different aquatic plant management techniques (e.g., mechanical harvesting, chemical treatment, no management) is a crucial component of aquatic plant management. We examined the aquatic plant communities and management techniques for nine Southeast Wisconsin lakes for a period of 6 to 9 years prior to 1996 to assess the long-term population changes of Eurasian watermilfoil subjected to different management regimes. In eight of the nine lakes, the Eurasian watermilfoil populations either declined in frequency or remained constant; while in seven of the nine lakes the native aquatic plant community either increased in average number of plant species per sample location or remained constant. The long-term aquatic plant community information for these nine case study lakes suggest that "typical" aquatic plant management activities does not negatively effect the lake-wide aquatic plant community; although changes, or the lack of changes, of an aquatic plant community cannot be directly attributed to management activities.

Key Words: plant management, Eurasian watermilfoil, chemical, mechanical, native plants.

Many of the documented changes in macrophyte communities in North America are associated with an invasion or decline of exotic species (Bates and Smith 1994, Nichols 1994, Rogers 1994). Population shifts in Eurasian watermilfoil (*Myriophyllum spicatum* L.) and other exotic populations have been examined more closely because of their propensity to develop nuisance conditions (Newroth 1985, Bode et al. 1992) and impact native plants (Madsen et al. 1991), macroinvertebrate distribution (Sloey et al. 1997), and affect fish feeding (Keast 1984, Storlie et al. 1995). Since Eurasian watermilfoil's introduction into Wisconsin's waters in the 1960s (Engel 1993), a number of documented invasions and declines have occurred throughout southern Wisconsin (Carpenter 1980, Trebitz et al. 1993, Nichols and Lathrop 1994, Lillie 1996).

Aquatic plant community shifts have been linked to a wide range of biotic and physio-chemical factors (Barko and Smart 1986, Shearer 1994). Similarly, long-term changes in macrophyte communities have also been attributed to cultural factors (Nichols and Lathrop 1994) and poor water quality associated with eutrophication (Jones et al. 1983). Inherently, aquatic plant management activities, in combination or independently from the factors previously mentioned, also induce changes in aquatic plant communities and individual species (Engel 1990, Anon. 1990, Cooke et al. 1993, Pullman 1992).

The combined effects of aquatic plant management and natural causes of macrophyte populations changes have not been well documented over the long-term (> 5 years). In fact, given that lake-wide aquatic plant management actions will result in the removal or control of aquatic plants, there have been surprisingly few studies that examine whether management changes the plant community species composition compared with no management. Hence, the question is how do "typical" aquatic plant management programs affect a lake's aquatic plant community?

This is especially true for macrophyte populations where exotic Eurasian watermilfoil is competing with native plants. We compared aquatic plant community changes in nine southeast Wisconsin lakes that had no aquatic plant management to lakes managed by mechanical harvesting, chemical treatments or a combination of both methods.

Methods

Nine Lakes in Southeast Wisconsin (Fig. 1) were monitored as part of the Wisconsin Department of Natural Resources long-term, ambient lakes monitoring program (Anon. 1987) that started in 1986 and encompasses 50 Lakes across the state. The physical characteristics of the southeast lakes vary widely; although most of the lakes are mesotrophic or slightly eutrophic (Table 1). The lakes studied range in size from 62 ha to 1008 ha with average depths ranging from 1.8 m to 10.9 m. Six of the lakes have a long history of organized aquatic plant management programs. Browns, Pewaukee and Big Cedar Lakes districts have been controlling nuisance aquatic plants lake-wide since the early 1960s and exclusively with mechanical harvesters since 1980. The local communities at Whitewater and Nagawicka Lakes have also been controlling aquatic plants since the 1980s using a combination of mechanical harvesting and near-shore chemical treatments; although limited treatments occur at Nagawicka Lake (less than 3 ha). No management efforts have been employed at Pike or Crystal Lakes and; although chemical treatments occurred at Lac La Belle in the early 1980s, no aquatic plant management has occurred there for the last 15 years.

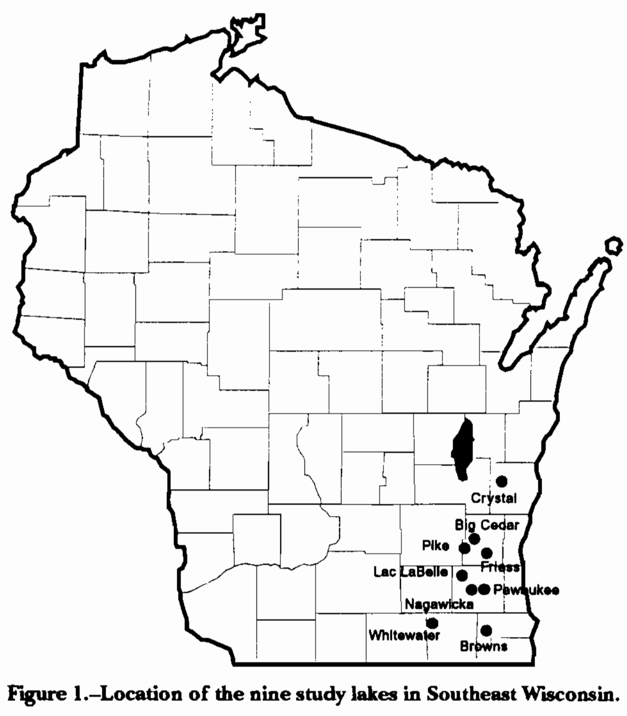

Figure 1.–Location of the nine study lakes in Southeast Wisconsin.

Beginning in 1986, the aquatic plant community of nine lakes in Southeast Wisconsin were monitored on a 3 year rotational schedule (i.e., 3 of the nine lakes were sampled each year). For each lake, the aquatic plants monitoring was performed in August or September using a modified Jessen and Lound (1962) sampling method. Twenty to 25 transects were equally spaced around the lake's shoreline. Species occurrence were collected at five depths along each transect per lake starting with a depth of 0.5 meters to a depth equal to the greatest rooting depth (4 m ≥). At each sampling point, a 2 meter diameter circular plot was established and divided into quarters (i.e., quadrants). Species occurrence was recorded by quadrant at each of the sampling points. The total number of transect quadrants sampled ranged from 320 (4 quadrants sampled at 5 discrete depths along 16 transects) to 500 (4 quadrants sampled at 5 discrete depths along 25 transects). In shallow and clear water, occurrence was noted visually or by the use of rake tows; whereas rake tows were used to determine occurrence where plants were not clearly visible.

Given Eurasian watermilfoil's long history of dominance in southeast Wisconsin (Engel 1993) and due to the number of different individuals involved in taxonomy during the 9 year period and the difficulty of distinguishing between some *Myriophyllum* species (Nichols 1984a), we combined the three species identified as *M. sibiricum* (formerly *M. exalbescens*), *M. verticilitum* and *M. spicatum* as Eurasian watermilfoil, except when one of the authors provided field or herbarium sample verification. Although this "lumping" of species may cause some data interpretation problems, given the dominance of *M. spicatum* in the 1980s throughout most of Southeast Wisconsin, it is very likely that, unless documented otherwise, the *Myriophyllum* species was *M. spicatum*.

Table 1.–Physical characteristics and trophic status of the nine study lakes. The trophic state index (Lillie et al. 1993) was calculated from the average of the annual total phosphorus, Secchi disk and chlorophyll *a* measurements for the study period 1986-1996.

Lake	Surface Area (ha)	Average Depth (m)	% Littoral Zone	Trophic State Index	Trophic Class
Big Cedar	377	10.4	42	46	Mesotrophic
Browns	160	2.4	95	48	Mesotrophic
Pewaukee	1008	4.6	65	49	Mesotrophic
Friess	47	8.2	19	57	Eutrophic
Nagawicka	371	10.9	41	46	Mesotrophic
Whitewater	259	1.8	91	55	Eutrophic
Crystal	62	6.1	42	43	Mesotrophic
Lac La Belle	471	3.4	24	48	Mesotrophic
Pike	211	2.7	70	52	Eutrophic

Eurasian watermilfoil, curlyleaf pondweed (*Potamogeton crispus* L.) and spiny naiad (*Najas marina* L.) were the three nonnative aquatic plant species, as classified by Swink and Wilhelm (1994), in these lakes. Generally, Eurasian watermilfoil was the target nuisance species for control; although Curlyleaf pondweed is known to cause nuisance conditions (Bolduan et al. 1994) and may have required some limited management in these lakes. However, this plant usually senesces with warm water temperatures (Nichols and Shaw 1986) and is usually not a major component of the plant community by the middle of August. Spiny naiad is an uncommon plant in Wisconsin's lakes (Nichols and Vennie 1991) and, with the exception of Pike Lake where no management occurs, is not a major component of the study lakes.

Significant differences ($p \leq 0.05$) between years for Eurasian watermilfoil frequency and average number of native aquatic plant species were calculated using a nonparametric, two by two frequency table (Statistica 1995). Significant differences ($p \leq 0.05$) among sampling years for the average number of native aquatic plant species were tested using ANOVA for all transect sampling points (Statistica 1995).

Results

Water Quality Trends

Between the nine study lakes, the Trophic State Indices (Lillie et al. 1993) ranged narrowly from 43 to 57 and are typical of many of the mesotrophic of Southeast Wisconsin lakes with well established populations of Eurasian water milfoil (Engel 1993) and mesotrophic to eutrophic conditions (Anon. 1978). Although there was some year to year variations in water quality of the nine lakes, there was not a significant pattern of declining or improving water quality. In fact, during the period 1986 through 1995, none of the lakes showed significant trends ($p \leq 0.10$) in any of the three commonly used water quality metrics (total phosphorus, chlorophyll *a* or Secchi depth) as determined by the seasonal Kendall Tau test (Webster 1998). Only Nagawicka Lake had a small (0.10 m/yr median slope), but significant improvement ($p = 0.087$) in water clarity as measured by a Secchi disk that could have affected aquatic plant growth.

General Aquatic Plant Community Characteristics

Some of the aquatic plant community metrics vary little throughout the study period for all of the lakes. The average percent vegetation exceeded 80% and varied less than 10% for all lakes except Lac La Belle which had an average percent vegetation of less than 40% (Fig. 2). Similarly, the Simpson Diversity Index (SDI) (Simpson 1949) of the aquatic plant community ranged narrowly between 0.82 and 0.91 throughout the study period for most of the lakes with the exceptions of Whitewater Lake and Lac La Belle. The SDI for Whitewater Lake increased substantially between 1991 and 1994, from 0.55 to 0.80. While the SDI for Lac La Belle ranged widely between 0.48 and 0.68 with no discernible trend.

The greatest number of aquatic plant species

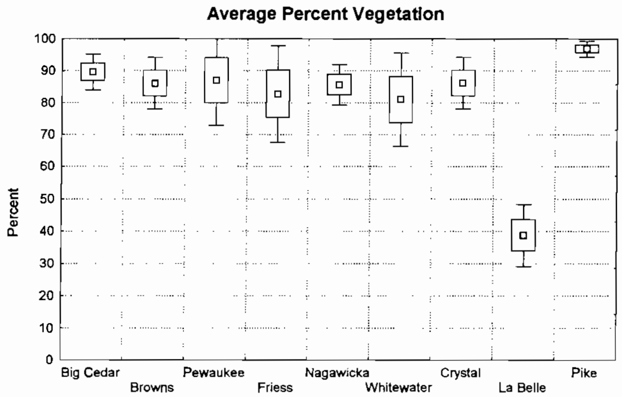

Figure 2.–Average percent vegetation coverage for all lakes for sampling years between 1986 - 1996. The box represent mean ±1 Std error and the bars represent mean ± 1 Std deviation.

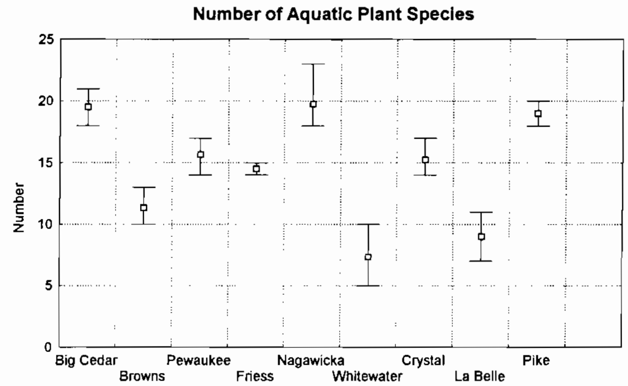

Figure 3.–Average total number of aquatic plant species for each lake during sampling years between 1986-1996. Vertical bars show species number range.

recorded in any 1 year was 22 at Nagawicka Lake, while the least number of species recorded was five at Whitewater lake. Both of these lakes also had the greatest variability in the total number of species (Fig. 3). With the exception of Whitewater, Lac La Belle and Browns Lakes, the total number of aquatic plant species recorded from a lake was always greater than fourteen.

Eurasian watermilfoil Community Changes

For nearly all of the nine lakes presented here, the dominance of Eurasian watermilfoil declined or remained the same regardless of the aquatic plant management technique used (Table 2). The Eurasian watermilfoil frequency ranged from 73% to 83% for all lakes with the exception of Lac La Belle which had a frequency of less than 39%. Both, Lac La Belle and Browns Lakes show no significant changes in the Eurasian watermilfoil frequency (Fig. 4). Crystal, Big Cedar, Pewaukee, Nagawicka and Whitewater Lakes, had significant decreases of Eurasian watermilfoil, with no significant increases in Eurasian watermilfoil frequency during the study period. At Pewaukee Lake, where only mechanical harvesting is employed, the Eurasian watermilfoil frequency declined the greatest from 90% to 33% between 1988 and 1991. The smallest significant decline of Eurasian watermilfoil (17.7%) occurred at Big Cedar Lake between the years of 1992 and 1995.

Chemical treatments are the only method used at

Table 2.–Summary of significant changes ($p \leq 0.05$) between sampling years of all lakes for average number of native aquatic plant species and *M. spicatum* frequency of occurrence for all sampling locations.

Lake	Management Strategy	# Native Species	*M. Spicatum* Frequency
Big Cedar Lake	Mechanical Harvesting	No Change	Declined 92-95
Browns Lake	Mechanical Harvesting	Declined 88-91	No Change
Pewaukee Lake	Mechanical Harvesting	No Change	Declined 88-91
Friess Lake	Chemical Treatment	No Change	Increased 86-89 Declined 89-92
Nagawicka Lake	Combination	No Change	Declined 93-96
Whitewater Lake	Combination	Increase 91-94	Declined 91-94
Crystal Lake	No Management	No Change	Declined 89-93
Lac La Belle Lake	No Management	Declined 87-90	No Change
Pike Lake	No Management	Increased 90-92	Increased 90-92 Declined 92-95

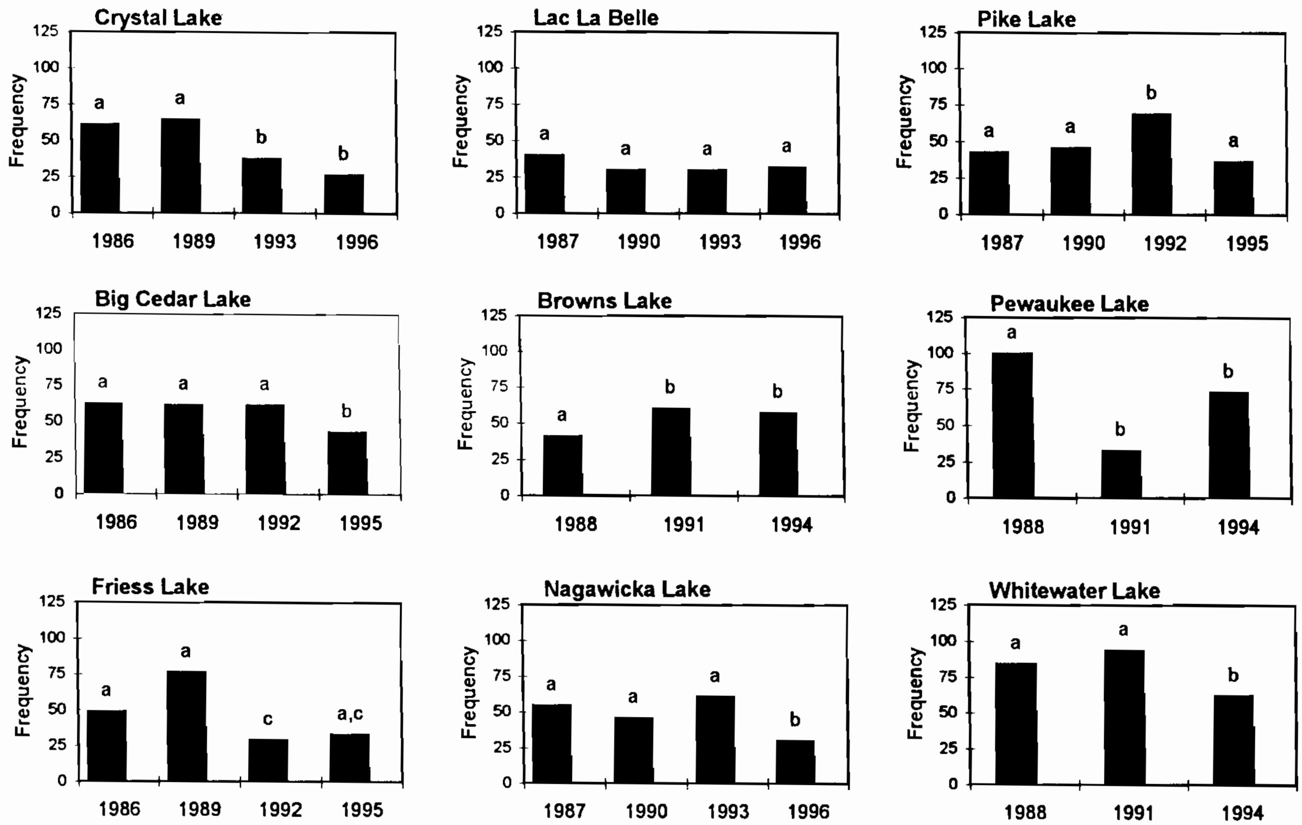

Figure 4.–Frequency of occurrence for Eurasian watermilfoil for all nine lakes for sampling period between 1986 - 1996. Different letters denote significant difference ($p \leq 0.05$) between Eurasian watermilfoil frequencies for each sampling year within a lake using a nonparametric, two by two frequency test (Statistica 1995).

Friess Lake, where Eurasian watermilfoil frequency increased by of 26% between 1986 and 1989, then decreased in Eurasian watermilfoil between 1989 and 1992 by 43%. Pike Lake also had a significant increase in the Eurasian watermilfoil frequency in 1992, followed by a significant decrease by 1995; however, the 1995 frequency was not different from the 1990 frequency. Lac la Belle was different from other lakes with little native plant cover and Eurasian watermilfoil frequencies substantially less than any of the other nine lakes (< 40%).

Native Aquatic Plant Community Changes

Whereas Eurasian watermilfoil generally declined, the native aquatic plant community remained stable or improved in seven of the nine lakes. The most common native aquatic plants (greater than 30% relative frequency in any one lake) found in these southeast Wisconsin lakes included *Ceratophyllum demersum, Chara* sp, *Elodea canadensis, Najas* sp, *Potamogeton* sp, *Ruppia maritima* and *Vallisneria americana.* During the study period (1986-1996), the average number of native aquatic plants found at each sampling point ranged between 0.25 and 3.00 for all lakes (Fig. 5). Lac La Belle had the lowest average number of native aquatic plants well below 1.0 species per sample location. The average number of native aquatic plants for the other lakes generally ranged between 2.0 and 3.0 with the exception of Whitewater Lake that ranged between 0.75 and 1.5. The average number of native aquatic plants increased significantly at both Pike Lake and Whitewater Lake. For the majority of lakes, including Crystal, Big Cedar, Browns, Friess and Nagawicka, the average number of native aquatic species did not change during the study period. At Lac La Belle and Pewaukee Lake, the average number of native aquatic plants decreased between two sampling years.

Management Intensity

Five of the nine study lakes utilize mechanical harvesting, in part or exclusively, to control nuisance aquatic plants. In fact, all of the mechanical harvested lakes have local units of governments (lake districts or

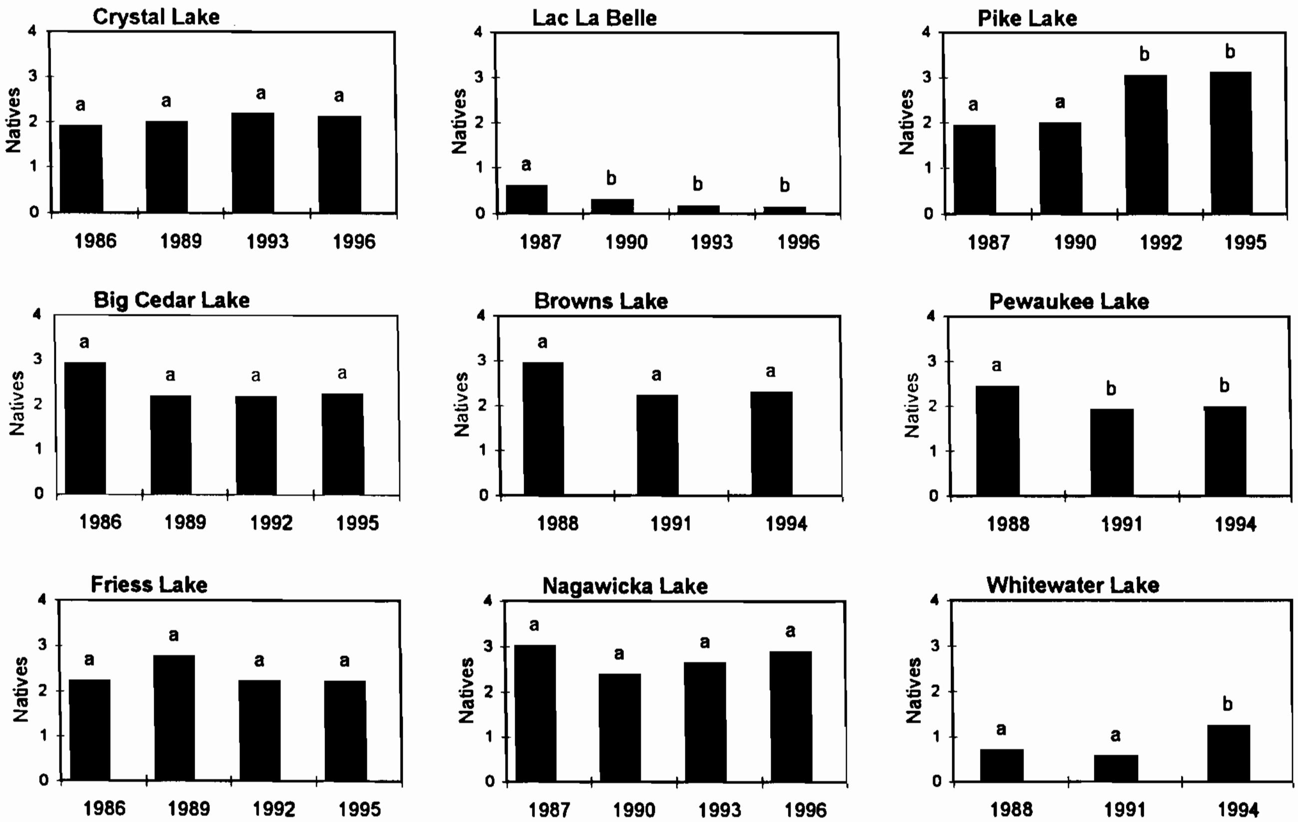

Figure 5.–Average number of native aquatic plants species recorded for each sampling location for all nine lakes for the sampling period between 1986-1996. Different letters denote significant difference ($p \leq 0.05$) between the average number of native aquatic plants species within a Lake using ANOVA (Statistica 1995).

municipalities) that own and operate at least two mechanical harvesters and accessory equipment. The number of harvester loads at Big Cedar, Pewaukee and Whitewater Lakes all declined during the study period 1986-1996 (Fig. 6). Big Cedar Lake had a gradual decline in the harvester loads from 188 to 50 loads in a 7 year period. The number of harvester loads at Whitewater Lake fluctuated widely but still showed a gradual decline from 604 loads to 307 in a 3 year period followed by an increase of 148 loads the fourth year. Pewaukee Lake had the most dramatic decline in harvester loads between 1991 and 1992 with a decrease of 543 loads followed by 5 years when the annual harvester loads ranged between 50 and 150. Browns Lake consistently harvested approximately 120 to 290 loads per year with a small increasing trend.

The area of chemical treatment remained relatively consistent on Friess Lake, never exceeding 2.8 ha of treatment (Fig. 7). Early in the study period prior to 1989, chemical treatments at Nagawicka Lake exceeded 8 hectares. Subsequent to 1989, annual chemical treatments declined to less than 3 hectares. The area of chemical treatment at Whitewater Lake has varied greatly from less than 2 hectares in 1988 to greater than 16 hectares in 1990. Since 1990, Whitewater Lake has been integrating near-shore chemical application along developed shorelines with mechanical harvesting (Anon. 1997a).

Discussion

There has been extensive documentation of the effects of aquatic plant control techniques within the management zone where they are employed (Madsen 1997). Although plant community restoration is often a major goal for regulatory agencies and the research community (Bode et al. 1992); the overriding purpose of aquatic plant management for most lake organizations is the removal of the plants for recreational activities and/or improved aesthetics. Thus, it is not surprising that information is available on site specific effects of plant management, but not lake-wide aquatic plant community information; even though the lake-wide plant community may shift as a result of the cumulative effect of site-specific management.

The shift (i.e., expansion and decline) of aquatic

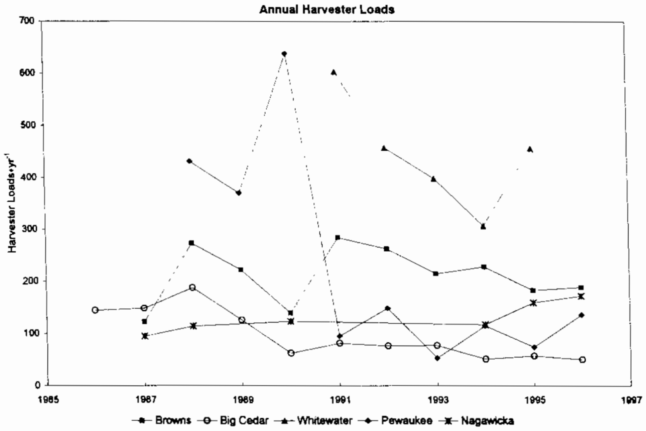

Figure 6.–Annual total number of harvester loads of aquatic plants harvested from the five lakes. Mechanical harvesting is used exclusively at Big Cedar, Browns and Pewaukee Lakes; whereas Whitewater and Nagawicka use mechanical harvesting and chemical treatments to manage aquatic plants.

macrophytes have been attributed to many factors or combinations of factors. Barko et al. (1994) lists seven factors among others that can contribute to the decline of aquatic macrophytes. Attributing the declines to a specific factor, for instance a particular aquatic plant management activity, is difficult. However, we were able to account for some of the affects of these seven factors by examining the aquatic plant community data from nine lakes over a long period of time (9 nine years).

All of the nine study lakes were located within the same ecoregion (Omernic and Gallant 1988) and within an hour of Milwaukee, Wisconsin (estimated population 600,000). Because the lakes have similar public access and recreational uses, we can assume that climatic changes and recreational use were similar during the study period. Of the seven factors listed by

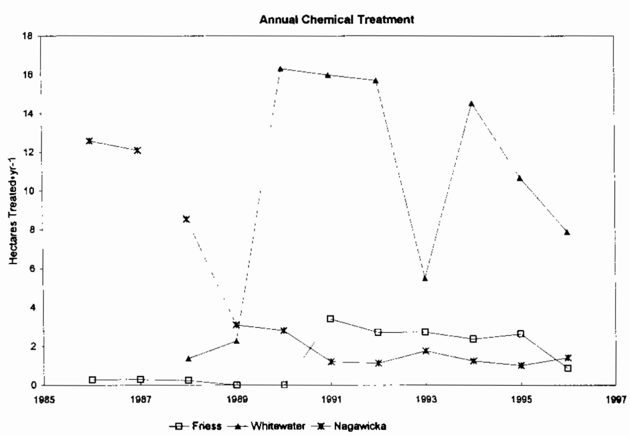

Figure 7.–Annual chemical treatment hectares reported for the study period 1986-1996 for the three lakes utilizing USEPA registered aquatic herbicides. Friess Lake uses chemical exclusively whereas both Whitewater and Nagawicka Lakes integrate the use of chemicals with mechanical harvesting.

Barko et al. (1994), we have no data to evaluate the effect of plant competition, nutrient depletion, pathogens, parasites and accumulations of toxins on the plant community. However, information is available to assess the effect on the aquatic plant community of water clarity, herbivory and aquatic plant management activities at these lakes.

The lack of any detectable trends in seasonal water quality data during the study period suggests that water clarity was not a factor in the macrophyte community changes. However, the seasonal Kendall tau test examines trends across years and may not account for relatively small temporal shifts in water quality during critical growth periods in the spring or early summer. For instance, the effect of summer drought years (e.g., 1988) and spring flood years (e.g., 1993) are not well respresented by the seasonal Kendall tau test for water quality. Such effects may account for the shifts in aquatic plant community (Rogers 1994), yet may not be distinguishable by examining water quality trends over the entire study period.

Site specific declines in aquatic macrophyte biomass and height have been attributed to motor boat use on lakes (Asplund and Cook 1997) and during this study, lake use has increased dramatically in southern Wisconsin (John Plenke, pers. comm. WDNR Milwaukee, WI). Yet motor boats and recreation use in general should favor disturbance-tolerant plants like Eurasian watermilfoil (Nichols 1984b, Nichols and Lathrop 1994) and possibly an increase in the distribution of this plant. On the contrary, only two of the nine lakes showed significant increases in milfoil frequency (Table 2), and both of the increases were followed by significant declines.

A sharp decline in Eurasian watermilfoil frequency over a 2 or 3 year period parallels similar reductions observed in other midwest lakes correlated with herbivory by the native weevil, *Euhrychiopsis lecontei* (Kirschner 1995, Lillie and Helsel 1997, Anon. 1997b). Weevils have been found in all but three of the study lakes (Jester 1998) and are likely present in all of them. The weevil's herbivory (Creed and Sheldon 1993, Newman et al. 1996) and selectivity (Creed and Sheldon 1993, Sheldon and Creed 1995) to Eurasian watermilfoil have been well documented. A substantial lake-wide decline in Eurasian watermilfoil exemplified by the reduction in management activity at Whitewater Lake in 1993 (Figs. 6 and 7) that was unexplained at the time (Anon. 1997a) and later attributed, in part, to weevil herbivory (Lillie and Helsel 1997, Jester 1998). Although Sheldon and O'Bryan (1996) suggested that mechanical harvesting significantly reduces weevil abundance, there may be unharvested areas in a lake where weevils can survive and expand their population even in the presence of mechanical harvesting. Still, high weevil densities and mechanical harvesting seem to be mutually exclusive. Thus, for lakes that are extensively harvested, like Pewaukee and Big Cedar, there may be other substantial factors contributing to the Eurasian watermilfoil decline.

The lack of a Eurasian watermilfoil decline at Browns Lake might be caused by the combination of extensive harvesting (increasing management), intense motor boat use and extensive developed shorelines that are correlated with lower weevils densities (Jester 1998). Native aquatic plants species numbers increased in two of the lakes where Eurasian watermilfoil declined (Whitewater and Pike Lake) and decreased where management intensity gradually increased (Browns Lake). Eurasian watermilfoil has replaced native plant species (Nichols and Lathrop 1994, Barko et al. 1994) although some species compete fairly well (Wakeman and Les 1994). Madsen (1991) has shown native plants decline under Eurasian watermilfoil canopies in a relatively unmanaged lake (George Lake, NY). However, in lakes with highly manipulated aquatic plant communities, it is unclear whether Eurasian watermilfoil more readily takes advantage of disturbances and impacts to native aquatic plants. The stability or decline of Eurasian watermilfoil frequency in five out of six managed lakes (Table 2), indicates that lake-wide disturbances on native plants by chemical treatments or mechanical harvesting did not provide the milfoil with an advantage sufficient to out compete the natives.

Summary

This paper provides one of the first assessments of lake-wide aquatic plant management efforts on aquatic plant communities over multiple years. Our experience indicates that aquatic plant management activities at levels usually employed for nuisance relief in southeastern Wisconsin does not substantially degrade the native plants or promote the dominance of Eurasian watermilfoil.

In seven out of nine lakes, the number of native aquatic plants species increased or remained the same, independent of the aquatic plant management. In eight out of nine lakes, Eurasian watermilfoil frequency remained the same or declined regardless of the specific aquatic plant management method. Given all of the factors that impact aquatic plants and induce aquatic plant community shifts, the causes for the changes (or lack of changes) are debatable.

This conclusion must be tempered with the fact that many of these Southeast Wisconsin lakes have been dominated by Eurasian watermilfoil since at least the 1970s and the available data is 20 years after the original infestation. Although native plants communities were not significantly affected by lake-wide aquatic plant management, these lakes also show that typical mechanical harvesting and chemical treatment activities may be unlikely to reduce Eurasian watermilfoil more rapidly than if no management occurs.

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