North & South Twin Lakes

Vilas County, Wisconsin

Comprehensive Management Plan – Phase II

August 2006

Sponsored by:

North & South Twin Lake Riparian Association
Town of Phelps
&
Wisconsin Department of Natural Resources Lake Management Grant Program

LPL-952-04 & LPL-953-04

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Lake Management Planning

North & South Twin Lakes

Vilas County, Wisconsin

Comprehensive Management Plan Phase II

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Wisconsin Dept. of Natural Resources (LPL-952-04 & LPL-953-04)

Acknowledgements

This management planning effort was truly a team-based project and could not have been completed without the input of the following individuals:

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Members of the Planning Committee

Wisconsin Dept. of Natural Resources

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INTRODUCTION

North and South Twin Lakes (2788 and 642 acres, respectively) are mesotrophic drainages lakes with their water levels maintained by a dam located at the South Twin Lake outlet. Property owners on the lakes organized the North and South Twin Lakes Riparian Association (NSTLRA) in 1995. In 1996, the NSTLRA partnered with Vilas County, the University of Wisconsin-Extension, and the Wisconsin Department of Natural Resources (WDNR) to begin the creation of a *Comprehensive Lake Management Plan* for the lakes. Phase I of the comprehensive plan was completed in 2000 (NSTLRA 2000) and included components addressing fisheries, watershed composition, water quality, geology, aquatic vegetation communities, and wildlife use of the lakes, along with the results of a detailed property owner survey. Although the Phase I plan contains a great deal of information, additional work was required to continue the planning effort. Specifically, there were two areas requiring further attention:

1. Updated aquatic plant surveys were required to:
    a. plan the management of Eurasian water-milfoil (*Myriophyllum spicatum*) colonies discovered in 2001.
    b. investigate the possible occurrence of curly-leaf pondweed (*Potamogeton crispus).*
    c. plan for the protection of existing native aquatic plant communities that provide valuable habitat for the lakes' fisheries and wildlife.
2. A more in-depth study of the watershed was required to access its role in the phosphorus budget of the lakes.

The original timeline slated the plan for completion during 2005. However, its completion was delayed until 2006 after the realization that the Eurasian water milfoil infestation was worse than anticipated and that a more in-depth plan for its control was required. Although they were not included in the original project scope, specific tasks were completed in order to assure that the completed plan contained the most up-to-date information. For instance, the water quality section of the Phase I plan was updated to include data from 2005 and a more thorough explanation of the lake water quality condition and trophic state of North and South Twin Lakes. Furthermore, additional aquatic plant surveys were completed in 2005 and 2006 to provide current assessments of the Eurasian water milfoil infestation.

This document is intended to guide the NSTLRA in its management of the Twin Lakes Chain from an ecosystem point-of-view. It is broken into three primary sections; Results and Discussion, Summary and Conclusions, and Implementation Plan. The Results and Discussion Section outlines and expands upon the study results from the water quality analysis, watershed assessments, numerous plant surveys, and other aspects of the project. This section, like the others, is written for the layperson's understanding, so many points are elaborated upon within the text and in text boxes. Overall, this section is not only intended to deliver the results of the project, but also to raise the reader's understanding of lakes and their management in a more general sense.

The Summary and Conclusion Section is written to be somewhat of a stand-alone document summarizing the project and its implications on the management of the Twin Lakes Chain. It basically ties everything together by reviewing and expanding upon the important findings of the studies and by setting the focus for the implementation plan.

The Implementation Plan consists of management goals and the actions that are intended lead to the meeting of those goals. Each action is associated with a facilitator or facilitators who are charged with the responsibility of carrying out the action. A timeframe is also included with each action to remind the group of when each action should occur. In the end, the Implementation Plan is the course of action the NSTLRA will use to continue their management of North and South Twin Lakes; however, it is important to note that this is not the final step in the management planning effort. In fact, it is only one of many steps because a lake management plan is a *living document* that must be revisited and adjusted as changes occur in and around the Twin Lakes Chain.

STAKEHOLDER PARTICIPATION

Stakeholder participation is an important part of any management planning exercise. During this project, stakeholders were not only informed about the project and its results, but also introduced to important concepts in lake ecology. Stakeholders were also informed about how their use of the lake's shorelands and open water areas impact the lake. Stakeholder input regarding the development of this plan was obtained via communications and meetings with the NSTLRA through their Planning Committee and Board of Directors. A description of each stakeholder participation event can be found below, while supporting materials can be found in Appendix A.

Project Kick-off Meeting

On Saturday, May 22, 2004 a Project Kick-off Meeting was held in Phelps to introduce the project to North and South Twin Lakes riparians and other interested stakeholders. Unfortunately, the meeting was not well attended.

Newsletters

The NSTLRA uses their quarterly newsletter as the primary mode of communication with their membership. They also use it to keep nonmembers updated by sending many of the newsletter editions to all shoreland property owners on the Twin Lakes Chain. This increases the printing and shipping expenses considerably, however the association believes that it is needed because the NSTLRA represents the lakes in so many management decisions. In fact, of the nearly 20 newsletters that were mailed out from the spring of 2002 to the winter of 2006, seven of those editions were sent to all known Twin Chain riparian properties. The Spring 2002 edition was published with a complete summary of the Eurasian water milfoil situation on the Twin Chain; including the initial results of the first chemical treatments and the association's "game plan" to continue monitoring from the surface and sub-surface and to continue using herbicides. The 2003 Spring/Summer edition contained an update of the situation, including a brief accounting of the previous year's treatments. The Summer 2004 newsletter reported that the NSTLRA Board of Directors discussed the formation of a lake district during their last meeting. That edition also contained an update on the Eurasian water milfoil situation and made a major call for donations to fund planned treatments. The Spring 2005 edition contained numerous articles discussing the formation of a lake district and its role in the battle against Eurasian water milfoil. The Fall 2005 and Winter 2006 newsletters contained updates concerning the district formation and the associations plan to treat Eurasian water milfoil through the use of WDNR Aquatic Invasive Species Grant funds. Obviously, the NSTLRA has worked diligently to keep all riparians, including those outside of its membership, informed on important lake management issues.

Planning Meeting I

On August 5, 2005 Tim Hoyman, Onterra, LLC met with an expanded Planning Committee of the NSTLRA. During the meeting, Tim presented the findings of the aquatic plant studies completed in 2004 stressing the importance and outstanding nature of the native plant populations of both lakes. He also presented detailed information concerning the Eurasian water milfoil infestation and alternative paths that may lead to control. Finally, WDNR Aquatic Invasive Species (AIS) Grants were discussed and a rough plan with costs was presented.

Planning Meeting II

The second planning meeting was held with the NSTLRA and Tim Hoyman on September 15, 2005. During this meeting the group was presented with the results of the Eurasian water milfoil survey completed by Onterra staff on August 30, 2005. A new rough control plan was also outlined with new costs. The outlined control plan was later accepted by the NSTLRA Board of Directors for use in an AIS Grant application.

Other Communication and Meetings

During the course of the project, the Planning Committee met on its own numerous times to discuss the project findings and map the NSTLRA future course. Furthermore, constant communications occurred between the NSTLRA Planning Committee, Board of Directors, and Tim Hoyman.

The NSTLRA also held public meetings during August and September 2006 to inform lake stakeholders about the need to form a lake district to fund the continued management of North and South Twin Lakes. These meetings included discussions about the specifics of forming a lake district, the procedure in doing so, and the role the district would have in the management of the lakes and the Eurasian water milfoil infestation. Lake specialists from Vilas County and the state were in attendance to answer questions and provide objective guidance to the attendees.

Planning Meeting with WDNR and other Agency Staff

On October 20, 2005, Tim Hoyman met with WDNR staff and representatives from Vilas County and UW-Extension. The goal of this meeting was to update the WDNR staff on the current and past projects regarding the Twin Lakes Chain and present a preliminary Eurasian water milfoil control plan. The discussion provided a great deal of information useful to all of the meeting participants.

Project Wrap-up Meeting

A public meeting was held on October 21, 2006 in which Tim Hoyman detailed the findings of the project's studies and discussed the management plan for the Twin Lakes Chain. Thirty-two people attended the meeting that was advertised in area newspapers, the NSTLRA newsletter, on the radio, and even on the marquee of a Phelps bank. The meeting minutes can be found in Appendix A.

Plan Acceptance by North & South Twin Lakes Riparian Association

The North and South Twin Lakes Riparian Association Board of Directors accepted the report and management plan (within the bounds of their budget) contained here by unanimous vote on November 9, 2006.

RESULTS & DISCUSSION

Lake Water Quality

Judging the quality of lake water can be difficult because lakes display problems in many different ways. However, focusing on specific aspects or parameters that are important to lake ecology, comparing those values to similar lakes within the same region, and historical data from the study lake provides an excellent method to evaluate the quality of a lake's water. To complete this task, three water quality parameters are focused upon within this document:

Phosphorus is a nutrient that controls the growth of plants in the vast majority of Wisconsin lakes. It is important to remember that in lakes, the term "plants" includes both *algae* and *macrophytes*. Monitoring and evaluating concentrations of phosphorus within the lake helps to create a better understanding of the current and potential growth rates of the plants within the lake.

Chlorophyll-*a* is the green pigment in plants used during *photosynthesis*. Chlorophyll-*a* concentrations are directly related to the abundance of free-floating algae in the lake. Chlorophyll-*a* values increase during algal blooms.

Secchi disk transparency is a measurement of water clarity. Of all limnological parameters, it is the most used and the easiest for non-professionals to understand. Furthermore, measuring Secchi disk transparency over long periods of time is one of the best methods of monitoring the health of a lake. The measurement is conducted by lowering a weighted, 20-cm diameter disk with alternating black and white quadrates (a Secchi disk) into the water and recording the depth just before it disappears from sight.

The parameters described above are interrelated. Phosphorus controls algal abundance, which is measured by chlorophyll-*a* levels. Water clarity, as measured by Secchi disk transparency, is directly affected by the particulates that are suspended in the water. In the majority of natural Wisconsin lakes, the primary particulate matter is algae; therefore, algal abundance directly affects water clarity. In addition, studies have shown that water clarity is used by most lake users to judge water quality – clear water equals clean water.

Each of these parameters is also directly related to the *trophic state* of the lake. As nutrients, primarily phosphorus, accumulate within a lake, its productivity increases and the lake progresses through three trophic states: *oligotrophic*, *mesotrophic*, and finally *eutrophic*. Every lake will naturally progress through these states; however, under natural conditions (i.e. not influenced by the activities of humans) this progress can take tens of thousands of years. Unfortunately, human influence has accelerated this natural aging process in most Wisconsin lakes. Monitoring the trophic state of a lake gives stakeholders a method by which to gauge the productivity of their lake over time. Yet, classifying a lake into one of three trophic states does not give clear indication of where a lake really exists in its trophic progression. To solve this problem, the parameters described above can be used in an index that will specify a lake's trophic state more clearly and provide a means for which to track it over time.

Trophic states describe the lake's ability to produce plant matter (production) and include three continuous classifications: *Oligotrophic* lakes are the least productive lakes and are characterized by being deep, having cold water, and few plants. *Eutrophic* lakes are the most productive and normally have shallow depths, warm water, and high plant biomass. *Mesotrophic* lakes fall between these two categories.

The complete results of these three parameters and the other chemical data that were collected at North and South Twin Lakes can be found in Appendix B. The results and discussion of the analysis and comparisons described above can be found in the paragraphs and figures that follow.

Comparisons with Other Datasets

Lillie and Mason (1983) is an excellent source for comparing lakes within specific regions of Wisconsin. They divided the state's lakes into five regions each having lakes of similar nature or apparent characteristics. Vilas County lakes are included within the study's Northeast Region (Figure 1) and are among 242 lakes randomly sampled from the region that were analyzed for water clarity (Secchi disk), chlorophyll-*a*, and total phosphorus. These data along with data corresponding to statewide natural lake means and historic data from North and South Twin Lakes are displayed in Figures 2-4. Please note that the data in these graphs represent values collected only during the summer months (June-August) (Map 1). Furthermore, the phosphorus and chlorophyll-a data represent only surface samples. Surface samples are used because they represent the depths at which algae grow and depths at which phosphorus levels are not greatly influenced by phosphorus being released from bottom sediments.

Figure 1. Location of North & South Twin Lakes within the regions utilized by Lillie and Mason (1983).

Fortunately, there is a great deal of water quality data for both North and South Twin Lakes over the past decade. Most of the total phosphorus values for North Twin Lake (Figure 2) would be considered good with the values from 1996 and 2003 being considered very good. The mean phosphorus concentration for 1997 is significantly higher than the others and was calculated using a value of 34 µg/L from June of that year, which may have been overestimated during laboratory analysis or a result of a collection error. Values in South Twin (Figure 2) are generally a bit lower than those found in North Twin and all considered good. Although the differences are slight, they may be the result of settling of phosphorus and particulates as they flow through North Twin to South Twin. In other words, South Twin likely benefits from the "sedimentation basin effect" provided by North Twin.

The chlorophyll-*a* values for both lakes (Figure 3) would be considered very good with only a few values from each lake being considered within the good range. These findings would be expected based upon the low total phosphorus values found within both lakes.

Nitrogen to phosphorus ratios indicate if algal growth within a lake is limited by nitrogen or phosphorus. If the ratio is greater than 15:1, the lake is considered phosphorus limited; if it is 10:1 or less, it is considered nitrogen limited. Ratios in between these values indicate that the lake likely fluctuates between nitrogen and phosphorus limitation. The ratios are related to the normal nitrogen to phosphorus ratio found in most algae.

Utilizing data from South Twin Lake collected on October 27, 1998, the only recent sample data found with nitrogen values, a nitrogen to phosphorus ratio of 33:1 was calculated. This indicates that South Twin Lake, like the vast majority of lakes in Wisconsin, is phosphorus limited. Sufficient nitrogen data does not exist for North Twin Lake to calculate its nitrogen to phosphorus ratio; however, it is likely that North Twin is also phosphorus limited.

With the exception of 2001, all of the Secchi disk clarity values for North and South Twin Lake fall into the very good range. Again, this is expected based upon the lakes' low phosphorus and chlorophyll-*a* concentrations.

Although the water quality would still be considered good, compared to the other years in the dataset, 2001 and 2004 had the poorest water quality. This trend is found in both lakes and in all three parameters. The spring and summer of both years likely experienced higher amounts of precipitation than the other years, which increased surface runoff to the lakes. This increased the phosphorus loads to the lake, and following the normal relationship, chlorophyll *a* values increased. As algal abundance increased, water clarity decreased as shown in the Secchi disk values.

Overall, the water quality of both lakes would be considered very good, especially when compared to other lakes in the region and state. The values for both lakes fluctuate over the years, but there are no indications of trends towards better or worse water quality based upon the total phosphorus, Secchi disk, or chlorophyll-*a* data.

North and South Twin Lakes Trophic State

Figure 5 displays the Wisconsin Trophic State Index (WTSI) (Lillie, et al. 1993) values calculated from average surface levels of chlorophyll-*a*, total phosphorus, and Secchi disk transparencies measured during the summer months at North and South Twin Lakes. The WTSI is based upon the widely used Carlson Trophic State Index (TSI) (Carlson 1977), but is specific to Wisconsin lakes. In essence, a trophic state index is a mathematical procedure that assigns an index number that corresponds to a lake's trophic state based upon three common lake parameters; chlorophyll-*a*, Secchi disk transparency, and total phosphorus. The WTSI is used extensively by the WDNR and is reported along with lake data collected by Self-Help Volunteers.

Overall and based primarily on WTSI-Chlorophyll-*a* levels (as suggested by Carlson (1979)), both lakes would be considered mesotrophic, with North Twin leaning a bit more towards the eutrophic state and South Twin leaning more towards the oligotrophic state. As with the water quality mean values, there are no trends indicated within WTSI data as they have remained steady, but fluctuating over the past two decades.

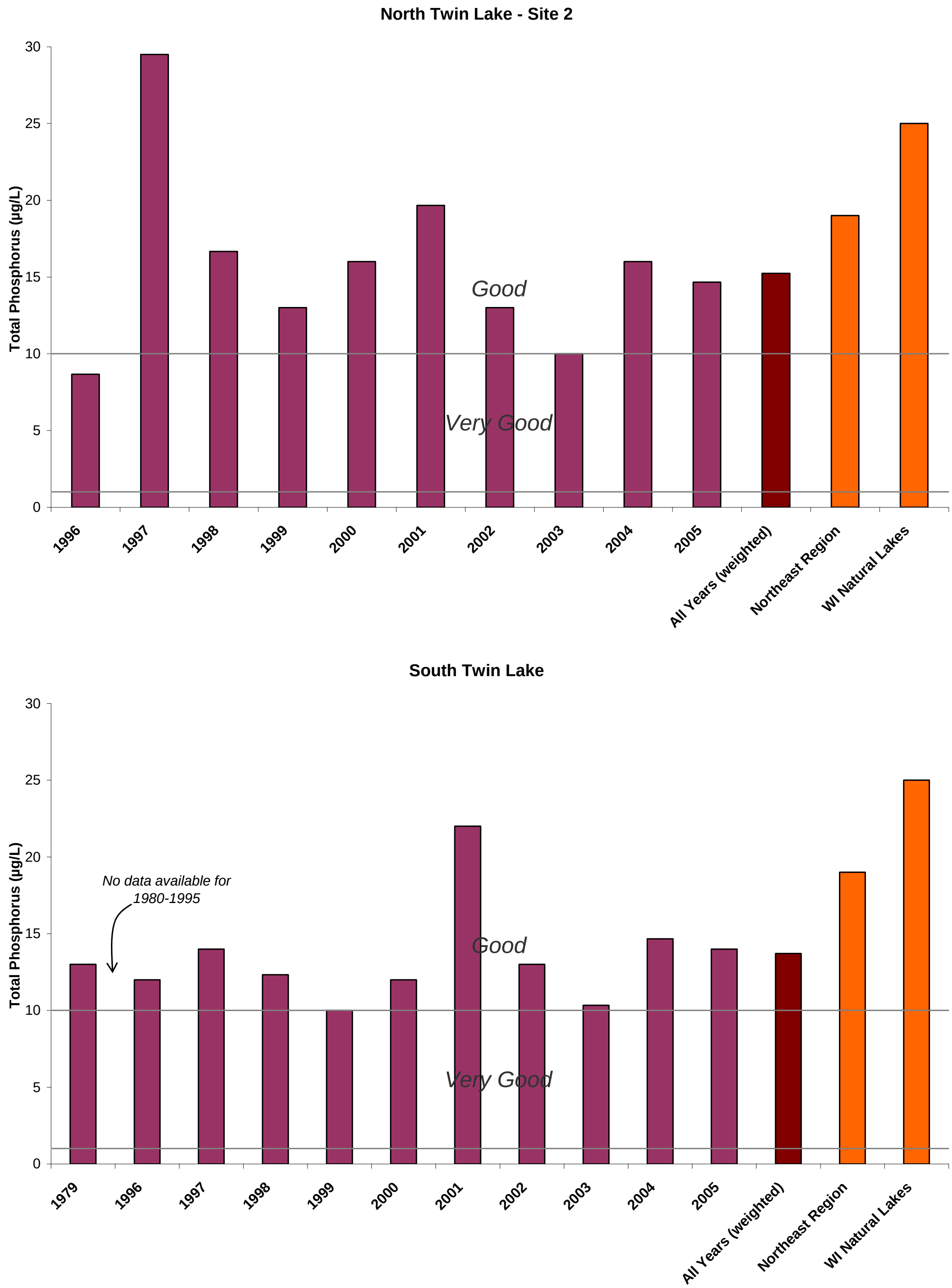
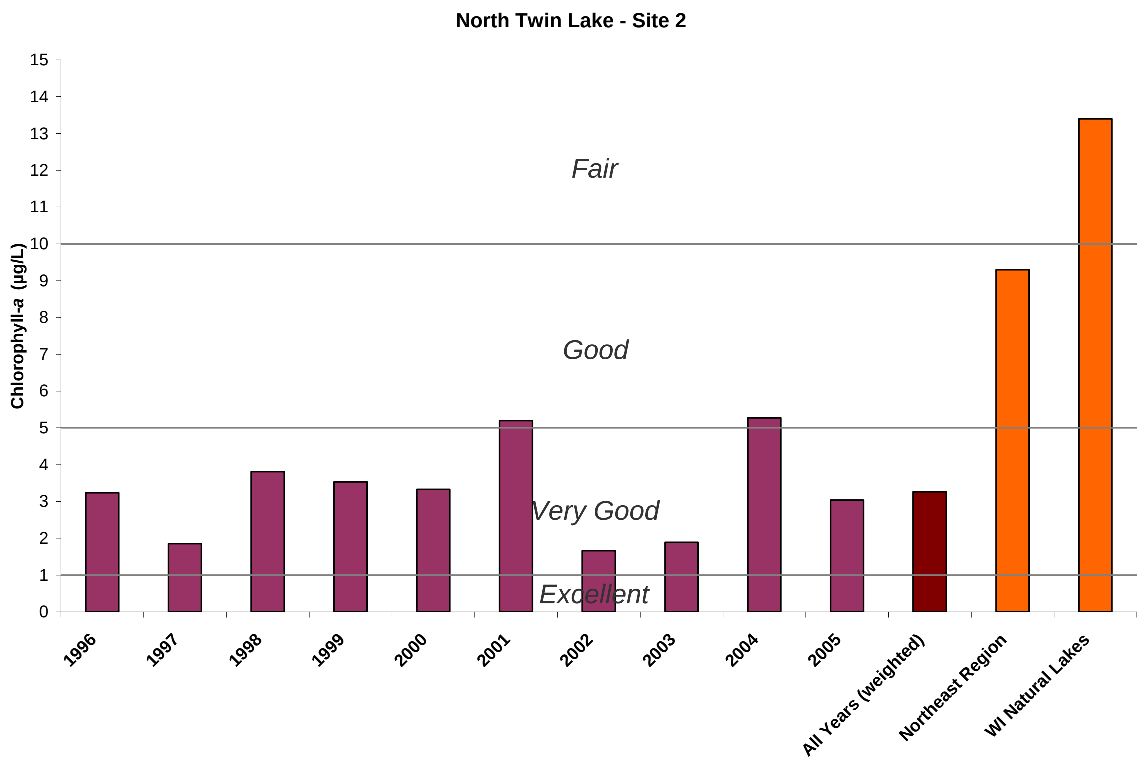


Figure 2. North and South Twin Lakes total phosphorus concentrations. Mean values calculated with summer month surface sample data. Water Quality Index values adapted from Lillie and Mason (1983).



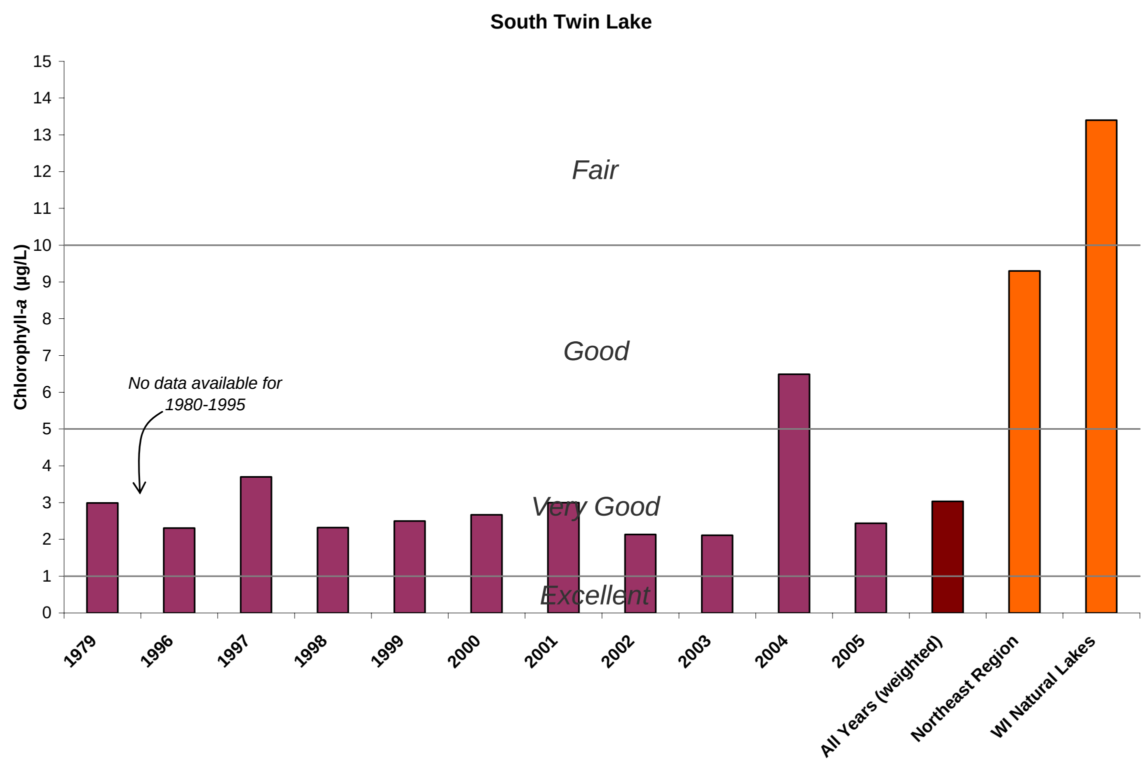
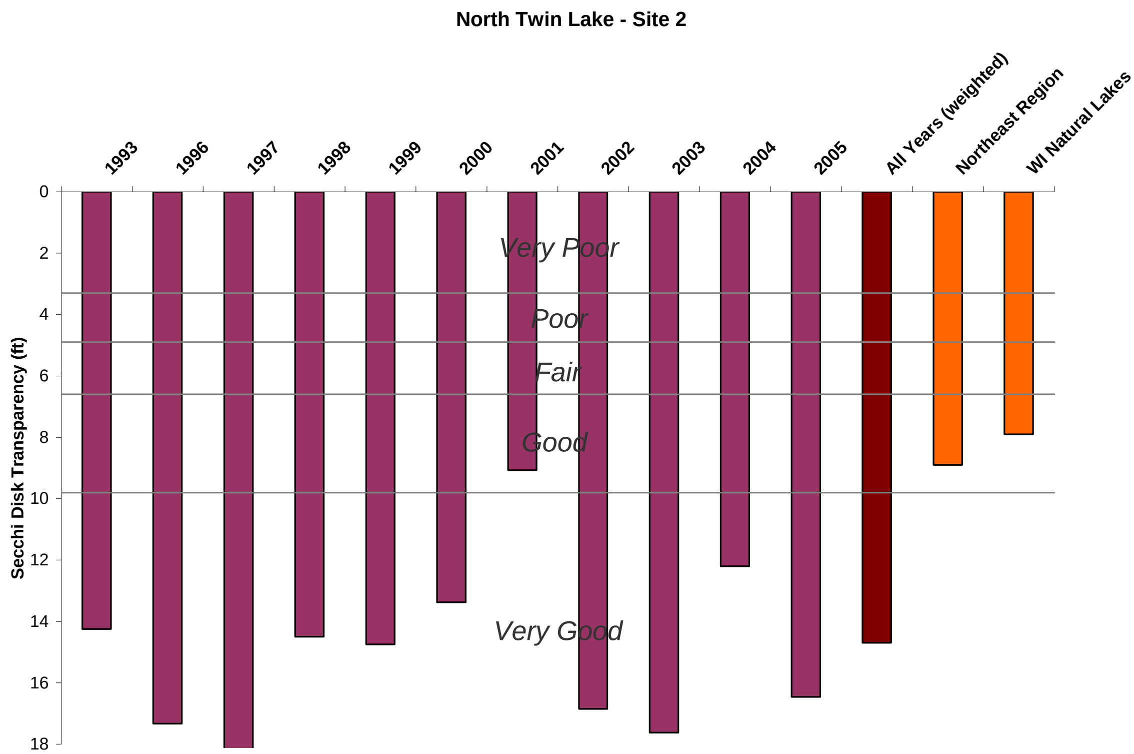


Figure 3. North and South Twin Lakes chlorophyll-*a* concentrations. Mean values calculated with summer month surface sample data. Water Quality Index values adapted from Lillie and Mason (1983).



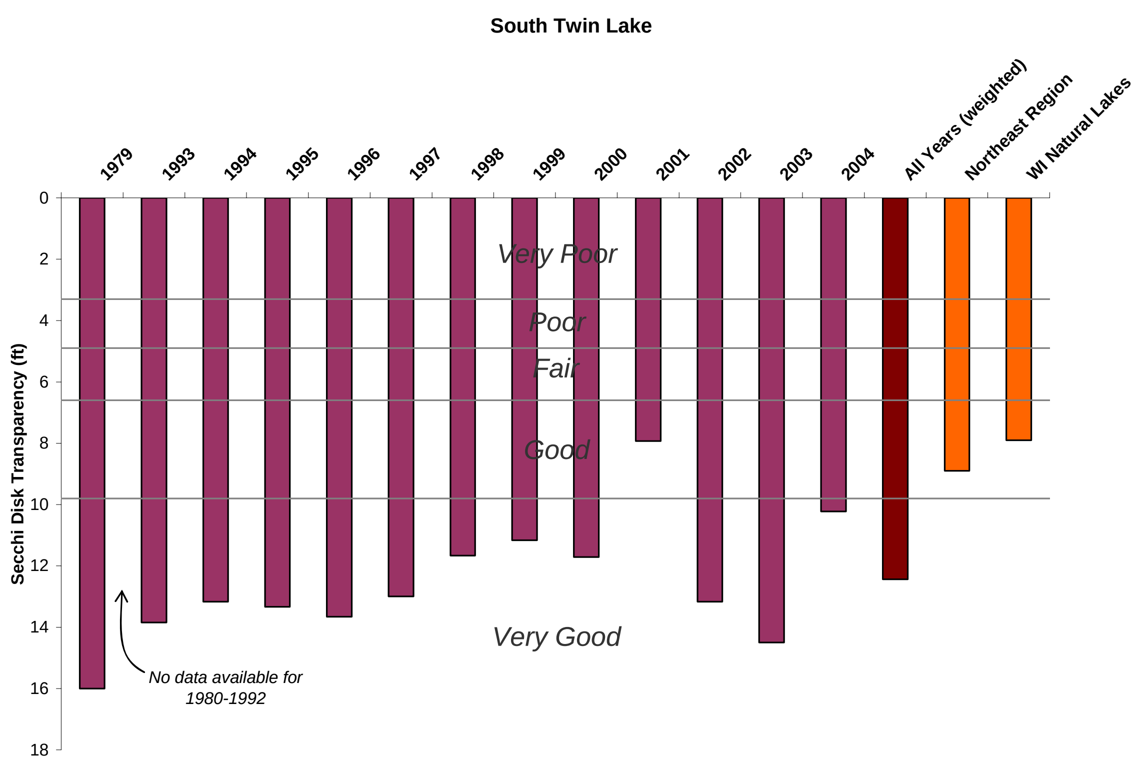


Figure 4. North and South Twin Lakes Secchi disk transparency values. Mean values calculated with summer month data. Water Quality Index values adapted from Lillie and Mason (1983).

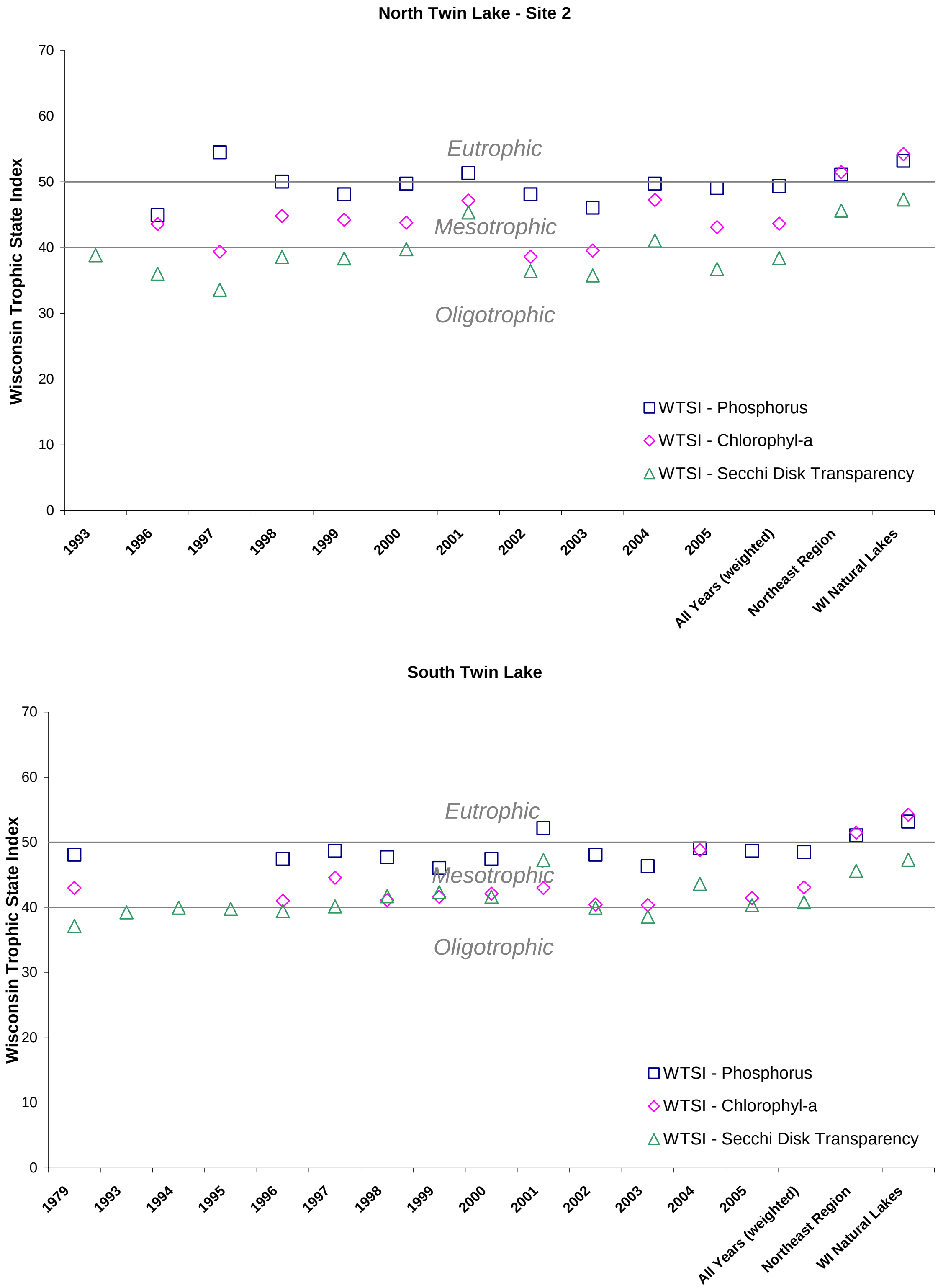


Figure 5. North and South Twin Lakes Wisconsin Trophic State Index values. Values calculated with summer month surface sample data using Lillie et al. (1993).

Aquatic Plants and the Lake Ecosystem

Although some lake users consider aquatic macrophytes to be “weeds” and a nuisance to the recreational use of the lake, they are actually an essential element in a healthy and functioning lake ecosystem. It is very important that the lake stakeholders understand the importance of lake plants and the many functions they serve in maintaining and protecting a lake ecosystem. With increased understanding and awareness, most lake users will recognize the importance of the aquatic plant community and their potential negative affects on it.

Diverse aquatic vegetation provides habitat and food for many kinds of aquatic life, including fish, insects, amphibians, waterfowl, and even terrestrial wildlife. For instance, wild celery (*Vallisneria americana)* and wild rice (*Zizania aquatica* and *Z. palustris*) both serve as excellent food sources for ducks and geese. Emergent stands of vegetation provide necessary spawning habitat for fish such as northern pike (*Esox lucius*) and yellow perch (*Perca flavescens*) In addition, many of the insects that are eaten by young fish rely heavily on aquatic plants and the *periphyton* attached to them as their primary food source. The plants also provide cover for feeder fish and *zooplankton*, stabilizing the predator-prey relationships within the system.

Furthermore, rooted aquatic plants prevent shoreline erosion and the resuspension of sediments and nutrients by absorbing wave energy and locking sediments within their root masses. In areas were plants do not exist, waves can resuspend bottom sediments decreasing water clarity and increasing plant nutrient levels that may lead to algae blooms. Lake plants also produce oxygen through photosynthesis and use nutrients that may otherwise be used by *phytoplankton*, which helps to minimize nuisance algal blooms.

Under certain conditions, a few species may become a problem and require control measures. Excessive plant growth can limit recreational use by deterring navigation, swimming, and fishing activities. It can also lead to changes in fish population structure by providing too much cover for feeder fish resulting in reduced numbers of predator fish and a stunted pan-fish population. *Exotic* plant species, such as Eurasian water-milfoil (*Myriophyllum spicatum*) and curly-leaf pondweed (*Potamogeton crispus*) can also upset the delicate balance of a lake ecosystem by out competing *native* plants and reducing *species diversity*. These *invasive* plant species can form dense stands that are a nuisance to humans and provide low-value habitat for fish and other wildlife.

When plant abundance negatively affects the lake ecosystem and limits the use of the resource, plant management and control may be necessary. The management goals should always include the control of invasive species and restoration of native communities through environmentally sensitive and economically feasible methods. No lake management plan should only contain methods to control plants, they should also contain methods on how to protect and possibly enhance the important plant communities within the lake. Unfortunately, the latter is often neglected and the ecosystem suffers as a result.

Introduction to Aquatic Plant Management and Protection

Many times an aquatic plant management plan is aimed at only controlling nuisance plant growth that has limited the recreational use of the lake, usually navigation, fishing, and swimming. It is important to remember the vital benefits that native aquatic plants provide to lake users and the lake ecosystem, as described above. Therefore, all aquatic plant management plans also need to address the enhancement and protection of the aquatic plant community. Below are general descriptions of the many techniques that can be utilized to control and enhance aquatic plants. Each alternative has benefits and limitations that are explained in its description. Please note that only legal and commonly used methods are included. For instance, the herbivorous grass carp (*Ctenopharyngodon idella*) is illegal in Wisconsin and rotovation, a process by which the lake bottom is tilled, is not a commonly accepted practice. Unfortunately, there are no "silver bullets" that can completely cure all aquatic plant problems, which makes planning a crucial step in any aquatic plant management activity. Many of the plant management and protection techniques commonly used in Wisconsin are described below.

Please note: Although many of the control techniques outlined in this section are not applicable to either North & South Twin Lake at this time, it is still important for lake users to have a basic understanding of all the techniques so they can better comprehend why particular methods are or are not applicable in their lake**.**

Permits

The signing of the 2001-2003 State Budget by Gov. McCallum enacted many aquatic plant management regulations. The rules for the regulations have been set forth by the WDNR as NR 107 and 109. A major change includes that all forms of aquatic plant management, even those that did not require a permit in the past, require a permit now, including manual and mechanical plant removal. Manual cutting and raking are exempt from the permit requirement if the area of plant removal is no more than 30 feet wide and any piers, boatlifts, swim rafts, and other recreational and water use devices are located within that length. Furthermore, installation of aquatic plants, even natives, requires approval from the WDNR. It is important to note that local permits and U.S. Army Corps of Engineers regulations may also apply. For more information on permit requirements, please contact the WDNR Regional Water Management Specialist or Aquatic Plant Management and Protection Specialist.

Native Species Enhancement

The development of Wisconsin's shorelands has increased dramatically over the last century and with this increase in development a decrease in water quality and wildlife habitat has occurred. Many people that move to or build in shoreland areas attempt to replicate the suburban landscapes they are accustomed to by converting natural shoreland areas to the "neat and clean" appearance of manicured lawns and flowerbeds. The conversion of these areas immediately leads to destruction of habitat utilized by birds, mammals, reptiles, amphibians, and insects. The maintenance of the newly created area helps to decrease water quality by considerably increasing inputs of phosphorus and sediments into the lake. The negative impact of human development does not stop at the shoreline. Removal of native plants and dead, fallen timbers from shallow, near-shore areas for boating and swimming activities destroys habitat used by fish, mammals, birds, insects, and amphibians, while leaving bottom and shoreline sediments vulnerable to wave action caused by boating and wind. Many homeowners significantly decrease the number of trees and shrubs along the water's edge in an effort to increase their view of the lake. However, this has been shown to locally increase water temperatures, and decrease infiltration rates of potentially harmful nutrients and pollutants. Furthermore, the dumping of sand to create beach areas destroys spawning, cover and feeding areas utilized by aquatic wildlife.

In recent years, many lakefront property owners have realized increased aesthetics, fisheries, property values, and water quality by restoring portions of their shoreland to mimic its unaltered state. An area of shore restored to its natural condition, both in the water and on shore, is commonly called a *shoreland buffer zone.* The shoreland buffer zone creates or restores the ecological habitat and benefits lost by traditional suburban landscaping. Simply not mowing within the buffer zone does wonders to restore some the shoreland's natural function.

Enhancement activities also include additions of *submergent*, *emergent*, and *floating-leaf* plants within the lake itself. These additions can provide greater species diversity and may compete against exotic species.

Cost

The cost of native, aquatic and shoreland plant restorations is highly variable and depend on the size of the restoration area, planting densities, the species planted, and the type of planting (e.g. seeds, bare-roots, plugs, live-stakes) being conducted. Other factors may include extensive grading requirements, removal of shoreland stabilization (e.g., rip-rap, seawall), and protective measures used to guard the newly planted area from wildlife predation, wave-action, and erosion. In general, a restoration project with the characteristics described below would have an estimated materials and supplies cost of approximately $4,200.

- The single site used for the estimate indicated above has the following characteristics:
  - An upland buffer zone measuring 35' x 100'.
  - An aquatic zone with shallow-water and deep-water areas of 10' x 100' each.
  - Site is assumed to need little invasive species removal prior to restoration.
  - Site has a moderate slope.
  - Trees and shrubs would be planted at a density of 435 plants/acre and 1210 plants/acre, respectively.
  - Plant spacing for the aquatic zone would be 3 feet.
  - Each site would need 100' of biolog to protect the bank toe and each site would need 100' of wavebreak and goose netting to protect aquatic plantings.
  - Each site would need 100' of erosion control fabric to protect plants and sediment near the shoreline (the remainder of the site would be mulched).
  - There is no hard-armor (rip-rap or seawall) that would need to be removed.
  - The property owner would maintain the site for weed control and watering.

Advantages

Improves the aquatic ecosystem through species diversification and habitat enhancement.
Assists native plant populations to compete with exotic species.
Increases natural aesthetics sought by many lake users.
Decreases sediment and nutrient loads entering the lake from developed properties.
Reduces bottom sediment resuspension and shoreline erosion.
Lower cost when compared to rip-rap and seawalls.
Restoration projects can be completed in phases to spread out costs.
Many educational and volunteer opportunities are available with each project.

Disadvantages

Property owners need to be educated on the benefits of native plant restoration before they are willing to participate.
Stakeholders must be willing to wait 3-4 years for restoration areas to mature and fill-in.
Monitoring and maintenance are required to assure that newly planted areas will thrive.
Harsh environmental conditions (e.g., drought, intense storms) may partially or completely destroy project plantings before they become well established.

Manual Removal

Manual removal methods include hand-pulling, raking, and hand-cutting. Hand-pulling involves the manual removal of whole plants, including roots, from the area of concern and disposing them out of the waterbody. Raking entails the removal of partial and whole plants from the lake by dragging a rake with a rope tied to it through plant beds. Specially designed rakes are available from commercial sources or an asphalt rake can be used. Hand-cutting differs from the other two manual methods because the entire plant is not removed, rather the plants are cut similar to mowing a lawn; however Wisconsin law states that all plant fragments must be removed. One manual cutting technique involves throwing a specialized "V" shaped cutter into the plant bed and retrieving it with a rope. The raking method entails the use of a two-sided straight blade on a telescoping pole that is swiped back and forth at the base of the undesired plants.

In addition to the hand-cutting methods described above, powered cutters are now available for mounting on boats. Some are mounted in a similar fashion to electric trolling motors and offer a 4-foot cutting width, while larger models require complicated mounting procedures, but offer an 8-foot cutting width.

When using the methods outlined above, it is very important to remove all plant fragments from the lake to prevent re-rooting and drifting onshore followed by decomposition. It is also important to preserve fish spawning habitat by timing the treatment activities after spawning. In Wisconsin, a general rule would be to not start these activities until after June 15th.

Cost

Commercially available hand-cutters and rakes range in cost from $85 to $150. Power-cutters range in cost from $1200 to $11,000.

Advantages

Very cost effective for clearing areas around docks, piers, and swimming areas.
Relatively environmentally safe if treatment is conducted after June 15th.
Allows for selective removal of undesirable plant species.
Provides immediate relief in localized area.
Plant biomass is removed from waterbody.

Disadvantages

Labor intensive.
Impractical for larger areas or dense plant beds.
Subsequent treatments may be needed as plants recolonize and/or continue to grow.
Uprooting of plants stirs bottom sediments making it difficult to harvest remaining plants
May disturb *benthic* organisms and fish-spawning areas.
Risk of spreading invasive species if fragments are not removed.

Bottom Screens

Bottom screens are very much like landscaping fabric used to block weed growth in flowerbeds. The gas-permeable screen is placed over the plant bed and anchored to the lake bottom by staking or weights. Only gas-permeable screen can be used or large pockets of gas will form under the mat as the result of plant decomposition. This could lead to portions of the screen becoming detached from the lake bottom, creating a navigational hazard. Normally the screens are removed and cleaned at the end of the growing season and then placed back in the lake the following spring. If they are not removed, sediments may build up on them and allow for plant colonization on top of the screen.

Cost

Material costs range between $.20 and $1.25 per square-foot. Installation cost can vary largely, but may roughly cost $750 to have 1,000 square feet of bottom screen installed. Maintenance costs can also vary, but an estimate for a waterfront lot are about $120 each year.

Advantages

Immediate and sustainable control.
Long-term costs are low.
Excellent for small areas and around obstructions.
Materials are reusable.
Prevents fragmentation and subsequent spread of plants to other areas.

Disadvantages

Installation may be difficult over dense plant beds and in deep water.
Not species specific.
Disrupts benthic fauna.
May be navigational hazard in shallow water.
Initial costs are high.
Labor intensive due to the seasonal removal and reinstallation requirements.
Does not remove plant biomass from lake.
Not practical in large-scale situations.

Water Level Drawdown

The primary manner of plant control through water level drawdown is the exposure of sediments and plant roots/tubers to desiccation and either heating or freezing depending on the timing of the treatment. Winter drawdowns are more common in temperate climates like that of Wisconsin and usually occur in reservoirs because of the ease of water removal through the outlet structure. An important fact to remember when considering the use of this technique is that only certain species are controlled and that some species may even be enhanced. Furthermore, the process will likely need to be repeated every two or three years to keep target species in check.

Cost

The cost of this alternative is highly variable. If an outlet structure exists, the cost of lowering the water level would be minimal; however, if there is not an outlet, the cost of pumping water to the desirable level could be very expensive.

Advantages

Inexpensive if outlet structure exists.
May control populations of certain species, like Eurasian water-milfoil for up to two years.
Allows some loose sediments to consolidate.
May enhance growth of desirable emergent species.
Other work, like dock and pier repair may be completed more easily and at a lower cost while water levels are down.

Disadvantages

May be cost prohibitive if pumping is required to lower water levels.
Has the potential to upset the lake ecosystem and have significant affects on fish and other aquatic wildlife.
Adjacent wetlands may be altered due to lower water levels.
Disrupts recreational, hydroelectric, irrigation and water supply uses.
May enhance the spread of certain undesirable species, like common reed (*Phragmites australis*) and reed canary grass (*Phalaris arundinacea*).
Permitting process requires an environmental assessment that may take months to prepare.
Unselective.

Harvesting

Aquatic plant harvesting is frequently used in Wisconsin and involves the cutting and removal of plants much like mowing and bagging a lawn. Harvesters are produced in many sizes that can cut to depths ranging from 3 to 6 feet with cutting widths of 4 to 10 feet. Plant harvesting speeds vary with the size of the harvester, density and types of plants, and the distance to the off-loading area. Equipment requirements do not end with the harvester. In addition to the harvester, a shore-conveyor would be required to transfer plant material from the harvester to a dump truck for transport to a landfill or compost site. Furthermore, if off-loading sites are limited and/or the lake is large, a transport barge may be needed to move the harvested plants from the harvester to the shore in order to cut back on the time that the harvester spends traveling to the shore conveyor.

Some lake organizations contract to have nuisance plants harvested, while others choose to purchase their own equipment. If the later route is chosen, it is especially important for the lake group to be very organized and realize that there is a great deal of work and expense involved with the purchase, operation, maintenance, and storage of an aquatic plant harvester. In either case, planning is very important to minimize environmental effects and maximize benefits.

Costs

Equipment costs vary with the size and features of the harvester, but in general, standard harvesters range between $45,000 and $100,000. Larger harvesters or stainless steel models may cost as much as $200,000. Shore conveyors cost approximately $20,000 and trailers range from $7,000 to $20,000. Storage, maintenance, insurance, and operator salaries vary greatly.

Advantages

Immediate results.
Plant biomass and associated nutrients are removed from the lake.
Select areas can be treated, leaving sensitive areas intact.
Plants are not completely removed and can still provide some habitat benefits.
Opening of cruise lanes can increase predator pressure and reduce stunted fish populations.
Removal of plant biomass can improve the oxygen balance in the littoral zone.
Harvested plant materials produce excellent compost.

Disadvantages

Initial costs and maintenance are high if the lake organization intends to own and operate the equipment.
Multiple treatments may be required during the growing season because lower portions of the plant and root systems are left intact.
Many small fish, amphibians and invertebrates may be harvested along with plants.
There is little or no reduction in plant density with harvesting.
Invasive and exotic species may spread because of plant fragmentation associated with harvester operation.
Larger harvesters are not easily maneuverable in shallow water or near docks and piers.
Bottom sediments may be resuspended leading to increased turbidity and water column nutrient levels.

Chemical Treatment

There are many herbicides available for controlling aquatic macrophytes and each compound is sold under many brand names. Aquatic herbicides fall into two general classifications:

1. *Contact herbicides* act by causing extensive cellular damage, but usually do not affect the areas that were not in contact with the chemical. This allows them to work much faster, but does not result in a sustained effect because the root crowns, roots, or rhizomes are not killed.
2. *Systemic herbicides* spread throughout the entire plant and often result in complete mortality if applied at the right time of the year.

Both types are commonly used throughout Wisconsin with varying degrees of success. The use of herbicides is potentially hazardous to the applicator, fish, amphibians, reptiles, birds, and non-target plant species, so all lake organizations should seek consultation and/or services from professional applicators with training and experience in aquatic herbicide use. The lake group must also take into consideration that even though these chemicals are labeled for aquatic use by the Environmental Protection Agency for use in aquatic systems, there are still inherent risks in their use because they have not been tested under all possible environmental conditions.

Below are brief descriptions of the aquatic herbicides currently registered for use in Wisconsin.

Fluridone (Sonar®, Avast!®) Broad spectrum, systemic herbicide that is effective on most submersed and emergent macrophytes. It is also effective on duckweed and at low concentrations has been shown to selectively remove Eurasian water-milfoil. Fluridone slowly kills macrophytes over a 30-90 day period and is only applicable in whole lake treatments or in bays and backwaters were dilution can be controlled. Required length of contact time makes this chemical inapplicable for use in flowages and impoundments. Irrigation restrictions apply.

Glyphosate (Rodeo®) Broad spectrum, systemic herbicide used in conjunction with a *surfactant* to control emergent and floating-leaved macrophytes. It acts in 7-10 days and is not used for submergent species This chemical is commonly used for controlling purple loosestrife (*Lythrum salicaria*).. Glyphosate is also marketed under the name Roundup®; this formulation is not permited for use near aquatic environments because of its harmful effects on fish, amphibians, and other aquatic orgainsims.

Diquat (Reward®, Weedtrine-D®) Broad spectrum, contact herbicide that is effective on all aquatic plants and can be sprayed directly on foliage (with surfactant) or injected in the water. It is very fast acting, requiring only 12-36 hours of exposure time. Diquat readily binds with clay particles, so it is not appropriate for use in turbid waters. Consumption restrictions apply.

Endothal (Hydrothol®, Aquathol®) Broad spectrum, contact herbicides used for spot treatments of submersed plants. The mono-salt form of Endothal (Hydrothol®) is more toxic to fish and aquatic invertebrates, so the dipotassium salt (Aquathol®) is most often used. Fish consumption, drinking, and irrigation restrictions apply.

2,4-D (Navigate®, Aqua-Kleen®, etc.) Selective, systemic herbicide that only works on broad-leaf plants. The selectivity of 2,4-D towards broad-leaved plants (dicots) allows it to be used for Eurasian water milfoil without affecting the majority of our native plants, which are narrowleaved species (monocots). However, some native species, like northern water milfoil, coontail, and bladderwort, are dicots; therefore great care must be taken when using 2,4-D in proximity of these important plants. Many times, treating in early spring, before native species start to grow, can reduce the risk to native dicots considerably. Drinking and irrigation restrictions may apply.

Advantages

Herbicides are easily applied in restricted areas, like around docks and boatlifts.
If certain chemicals are applied at the correct dosages and at the right time of year, they can selectively control certain invasive species, such as Eurasian water-milfoil.
Some herbicides can be used effectively in spot treatments.

Disadvantages

Fast-acting herbicides may cause fishkills due to rapid plant decomposition if not applied correctly.
Many people adamantly object to the use of herbicides in the aquatic environment; therefore, all stakeholders should be included in the decision to use them.
Many herbicides are nonselective.
Most herbicides have a combination of use restrictions that must be followed after their application.
Many herbicides are slow-acting and may require multiple treatments throughout the growing season.

Cost

Herbicide application charges vary greatly between $400 to $1000 per acre depending on the chemical used, who applies it, permitting procedures, and the size of the treatment area.

Biological Controls

There are many insects, fish and pathogens within the United States that are used as biological controls for aquatic macrophytes. For instance, the herbivorous grass carp has been used for years in many states to control aquatic plants with some success and some failures. However, it is illegal to possess grass carp within Wisconsin because their use can create problems worse than the plants that they were used to control. Other states have also used insects to battle invasive plants, such as waterhyacinth weevils (*Neochetina spp.*) and hydrilla stem weevil (*Bagous spp.*) to control waterhyacinth (*Eichhornia crassipes*) and hydrilla (*Hydrilla verticillata)*, respectively. Fortunately, it is assumed that Wisconsin's climate is a bit harsh for these two invasive plants, so there is not need for either biocontrol insect. However, Wisconsin, along with many other states, is currently experiencing the expansion of lakes infested with Eurasian water-milfoil and as a result has supported the experimentation and use of the milfoil weevil (*Euhrychiopsis lecontei*) within its lakes. The milfoil weevil is a native weevil that has shown promise in reducing Eurasian water-milfoil stands in Wisconsin, Washington, Vermont, and other states. Research is currently being conducted to discover the best situations for the use of the insect in battling Eurasian water-milfoil. Wisconsin is also using two species of leaf-eating beetles (*Galerucella calmariensis* and *G. pusilla*) to battle purple loosestrife. These biocontrol insects are not covered here because purple loosestrife is predominantly a wetland species.

Advantages

Milfoil weevils occur naturally in Wisconsin.
This is likely an environmentally safe alternative for controlling Eurasian water-milfoil.

Disadvantages

Stocking and monitoring costs are high.
This is an unproven and experimental treatment.
There is a chance that a large amount of money could be spent with little or no change in Eurasian water-milfoil density.

Cost

Stocking with adult weevils costs about $1.20/weevil and they are usually stocked in lots of 1000 or more.

Analysis of Current Aquatic Plant Data

Aquatic plants are a fundamental element in every healthy lake. Changes in lake ecosystems are often first seen in the lake's plant community. Whether these changes are positive, like variable water levels or negative, like increased shoreland development or the introduction of an exotic species, the plant community will respond. Plant communities respond in a variety of ways; there may be a loss of one or more species, certain life forms, such as emergents or floating-leaf communities may disappear from certain areas of the lake, or there may be a shift in plant dominance between species. With periodic monitoring and proper analysis, these changes are relatively easy to detect and provide critical information for management decisions.

As described in more detail in the methods section, two aquatic plant surveys were completed on North & South Twin Lakes during 2004; the first looked strictly for curly-leaf pondweed, and the second inventoried all aquatic species found in the lake. Combined, these surveys produce a great deal of information about the aquatic vegetation of the lake. These data are analyzed and presented in numerous ways; each is discussed in more detail below.

Primer on Data Analysis & Data Interpretation

Species List

The species list is simply a list of all of the species that were found within the lake, both exotic and native. The list also contains the life-form of each plant found, its scientific name, and its coefficient of conservatism. The latter is discussed in more detail below. Changes in this list over time, whether it is differences in total species present, gains and loses of individual species, or changes in life-forms that are present, can be an early indicator of changes in the health of the lake ecosystem.

Frequency of Occurrence

Frequency of occurrence describes how often a certain species is found within a lake. Obviously, all of the plants cannot be counted in a lake, so samples are collected from pre-determined areas. In the case of North & South Twin Lakes, plant samples were collected from plots laid out on transects that extended perpendicularly from each lake's shoreline. Using the data collected from these plots, an estimate of occurrence of each plant species can be determined. In this section, relative frequency of occurrence is used to describe how often each species occurred in the plots that contained vegetation. These values are presented in percentages and if all of the values were added up, they would equal 100%. For example, if water lily had a relative frequency of 0.1 and we described that value as a percentage, it would mean that water lily made up 10% of the population.

In the end, this analysis indicates the species that dominate the plant community within the lake. Shifts in dominant plants over time may indicate disturbances in the ecosystem. For instance, low water levels over several years may increase the occurrence of emergent species while decreasing the occurrence of floating-leaf species. Introductions of invasive exotic species may result in major shifts as they crowd out native plants within the system.

Species Diversity

Species diversity is probably the most misused value in ecology because it is often confused with species richness. Species richness is simply the number of species found within a system or community. Although these values are related, they are far from the same because diversity also takes into account how evenly the species occur within the system. A lake with 25 species may not be more diverse than a lake with 10 if the first lake is highly dominated by one or two species and the second lake has a more even distribution.

A lake with high species diversity is much more stable than a lake with a low diversity. This is analogous to diverse financial portfolio in that a diverse lake plant community can withstand environmental fluctuations much like a diverse portfolio can handle economic fluctuations. For example, a lake with a diverse plant community is much better suited to compete against exotic infestation than a lake with a lower diversity.

Floristic Quality Assessment

Floristic Quality Assessment (FQA) is used to evaluate the closeness of a lake's aquatic plant community to that of an undisturbed, or pristine lake. The higher the floristic quality, the closer a lake is to an undisturbed system. FQA is an excellent tool for comparing individual lakes and the same lake over time. In this section, the floristic quality indices of North & South Twin Lakes are compared to lakes in the same ecoregion (Figure 6) and in the state.

Ecoregions are areas related by similar climate, physiography, hydrology, vegetation and wildlife potential. Comparing ecosystems in the same ecoregion is sounder than comparing systems within manmade boundaries such as counties, towns, or states.

The floristic quality of a lake is calculated using its species richness and average species conservatism. As mentioned above, species richness is simply the number of species that occur in the lake, for this analysis, only native species are utilized. Average species conservatism utilizes the coefficient of conservatism values for each of those species in its calculation. A species' coefficient of conservatism value indicates that species' likelihood of being found in an undisturbed (pristine) system. The values range from one to ten. Species that are normally found in disturbed systems have lower coefficients, while species frequently found in pristine systems have higher values. For example, cattail, an invasive native species, has a value of 1, while common hard and softstem bulrush have values of 5, and Oakes pondweed, a sensitive and rare species, has a value of 10. On their own, the species richness and average conservatism values for a lake are useful in assessing a lake's plant community; however, the best assessment of the lake's plant community health is determined when the two values are used to calculate the lake's floristic quality.

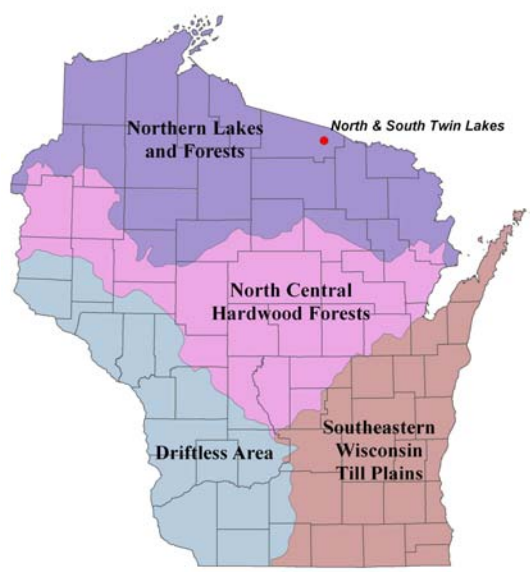


Figure 6. Location of North & South Twin Lakes within the ecoregions of Wisconsin. After Nichols 1999.

Community Mapping

A key component of the aquatic plant survey is the creation of an aquatic plant community map. The map represents a snapshot of the important plant communities in the lake as they existed during the survey and is valuable in the development of the management plan and in comparisons with future surveys. A mapped community can consist of submergent, floating-leaf, or emergent plants, or a combination of these life-forms. Examples of submergent plants include wild celery and pondweeds; while emergents include cattails, bulrushes, and arrowheads, and floating-leaf species include white and yellow pond lilies. Emergents and floating-leaf communities lend themselves well to mapping because there are distinct boundaries between communities. Submergent species are often mixed throughout large areas of the lake and are seldom completely visible from the surface; therefore, mapping of submergent communities is more difficult and often impossible.

Exotic Plants

Because of their tendency to upset the natural balance of an aquatic ecosystem, exotic species are paid particular attention to during the aquatic plant surveys. Two exotics, curly-leaf pondweed and Eurasian water milfoil are the primary targets of this extra attention.

Figure 7. Spread of Eurasian water milfoil within WI counties. WDNR Data 2006 mapped by Onterra.

Eurasian water-milfoil is an invasive species, native to Europe, Asia and North Africa, that has spread to most Wisconsin counties (Figure 7). Eurasian water-milfoil is unique in that its primary mode of propagation is not by seed. It actually spreads mostly by shoot fragmentation, which has supported its transport between lakes via boats and other equipment. In addition to its propagation method, Eurasian water-milfoil has two other competitive advantages over native aquatic plants, 1) it starts growing very early in the spring when water temperatures are too cold for most native plants to grow, and 2) once its stems reach the water surface, it does not stop growing like most native plants, instead it continues to grow along the surface creating a canopy that blocks light from reaching native plants. Eurasian water-milfoil can create dense stands and dominate submergent communities, reducing important natural habitat for fish and other wildlife, and impeding recreational activities such as swimming, fishing, and boating.

Curly-leaf pondweed is a European exotic first discovered in Wisconsin in the early 1900's that has an unconventional lifecycle giving it a competitive advantage over our native plants. Curly – leaf pondweed begins growing almost immediately after ice-out and by mid-June is at peak biomass. While it is growing, each plant produces many turions (asexual reproductive shoots) along its stem. By mid-July most of the plants have senesced, or died-back, leaving the turions in the sediment. The turions lie dormant until fall when they germinate to produce winter foliage, which thrives under the winter snow and ice. It remains in this state until spring foliage is produced in early May, giving the plant a significant jump on native vegetation. Like Eurasian water-milfoil, curly-leaf pondweed can become so abundant that it hampers recreational activities within the lake. Furthermore, its mid-summer die back can cause algal blooms spurred from the nutrients released during the plant's decomposition.

Because of its odd life-cycle, a special survey is conducted early in the growing season to inventory and map curly-leaf pondweed occurrence within the lake. Although Eurasian water milfoil starts to grow earlier than our native plants, it is at peak biomass during most of the summer, so it is inventoried during the comprehensive aquatic plant survey completed in mid to late summer.

2004 Comprehensive Survey Results

The aquatic plant surveys completed in 2004 located 28 aquatic plant species within North Twin Lake and 24 species within South Twin Lake (Table 1). No curly-leaf pondweed was located during the surveys completed on June 3 and 8, 2004. Eurasian water milfoil was located in both lakes during the comprehensive surveys completed on July 21-22 and 26-27, 2004 and is expanded upon below.

Table 1. Aquatic plant species located in North and South Twin Lakes during 2004 surveys.

Life Form	Scientific Name	Common Name	Coefficient of Conservatism (c)	Species Present North Twin	Species Present South Twin
Emergent	*Iris versicolor*	Northern blue flag	5		✓*
Emergent	*Schoenoplectus tabernaemontani*[1]	Softstem bulrush	4	✓*	
Emergent	*Typha latifolia*	Broad-leaved cattail	1	✓*	
Emergent	*Ranunculus flammula*	Creeping spearwort	9	✓	
Emergent	*Schoenoplectus acutus*[2]	Hardstem bulrush	5	✓	✓*
Emergent	*Ranunculus aquatilis*	White water-crowfoot	8	✓	
FL	*Nuphar variegata*	Spatterdock	6	✓	
FL/E	*Sparganium angustifolium*	Narrow-leaf bur-reed	9	✓	
Submergent	*Potamogeton amplifolius*	Large-leaf pondweed	7		✓
Submergent	*Utricularia purpurea*	Large purple bladderwort	9	✓	
Submergent	*Heteranthera dubia*[3]	Water stargrass	6	✓	✓
Submergent	*Chara sp.*	Muskgrasses	7	✓	✓
Submergent	*Myriophyllum alterniflorum*	Alternate-flowered water milfoil	10	✓	✓
Submergent	*Myriophyllum sibiricum*	Northern water milfoil	7	✓	✓
Submergent	*Myriophyllum spicatum*	Eurasian water milfoil	Exotic	✓	✓
Submergent	*Potamogeton praelongus*	White-stem pondweed	8	✓	✓
Submergent	*Potamogeton foliosus*	Leafy pondweed	6		✓
Submergent	*Megalodonta beckii*[4]	Water marigold	8		✓
Submergent	*Isoetes lacustris*	Lake quillwort	8	✓	✓
Submergent	*Elodea canadensis*	Common waterweed	3	✓	✓
Submergent	*Ceratophyllum demersum*	Coontail, hornwort	3	✓	✓
Submergent	*Potamogeton robbinsii*	Fern pondweed	8	✓	✓
Submergent	*Potamogeton illinoensis*	Illinois pondweed	6	✓	✓
Submergent	*Potamogeton pectinatus*[5]	Sago pondweed	3	✓	✓
Submergent	*Najas flexilis*	Slender naiad	6	✓	✓
Submergent	*Potamogeton zosteriformis*	Flat-stem pondweed	6	✓	✓
Submergent	*Potamogeton gramineus*	Variable pondweed	7	✓	✓
Submergent	*Potamogeton richardsonii*	Clasping-leaf pondweed	5	✓	✓
Submergent	*Vallisneria americana*	Wild celery	6	✓	✓
S/E	*Eleocharis acicularis*	Needle spikerush	5	✓	✓
S/E	*Sagittaria graminea*	Grass-leaved arrowhead	9	✓	✓

FL = Floating Leaf
FL/E = Floating Leaf and Emergent
S/E = Submergent and Emergent
* = Incidental

[1]Formally known as *Scirpus validus.*
[2]Formally known as *Scirpus acutus.*
[3]Formally known as *Zosterella dubia.*
[4]Formally known as *Bidens beckii.*
[5]Formally known as *Potamogeton pectinatus.*

The occurrence analysis results for North Twin Lake (Figure 8) indicate that the lake highly dominated by wild celery with lesser occurrences of clasping-leaf pondweed and variable pondweed. Wild celery and variable pondweed prefer harder substrates (Nichols 1999), like the sandy and sandy-rock areas that almost completely dominate North Twin Lake (NSTLRA 2000).

Clasping-leaf pondweed shows no substrate preference (Nichols 1999); therefore, it also thrives in North Twin Lake. Although North Twin Lake has high species richness, the uneven distribution of plants results in a moderately high Simpson's species diversity of 0.85.

Median Value is the value that roughly half of the data are less and half the data are higher. A median is used when a few data are so large or so small that they skew the average value to the point that it would not represent the population as a whole.

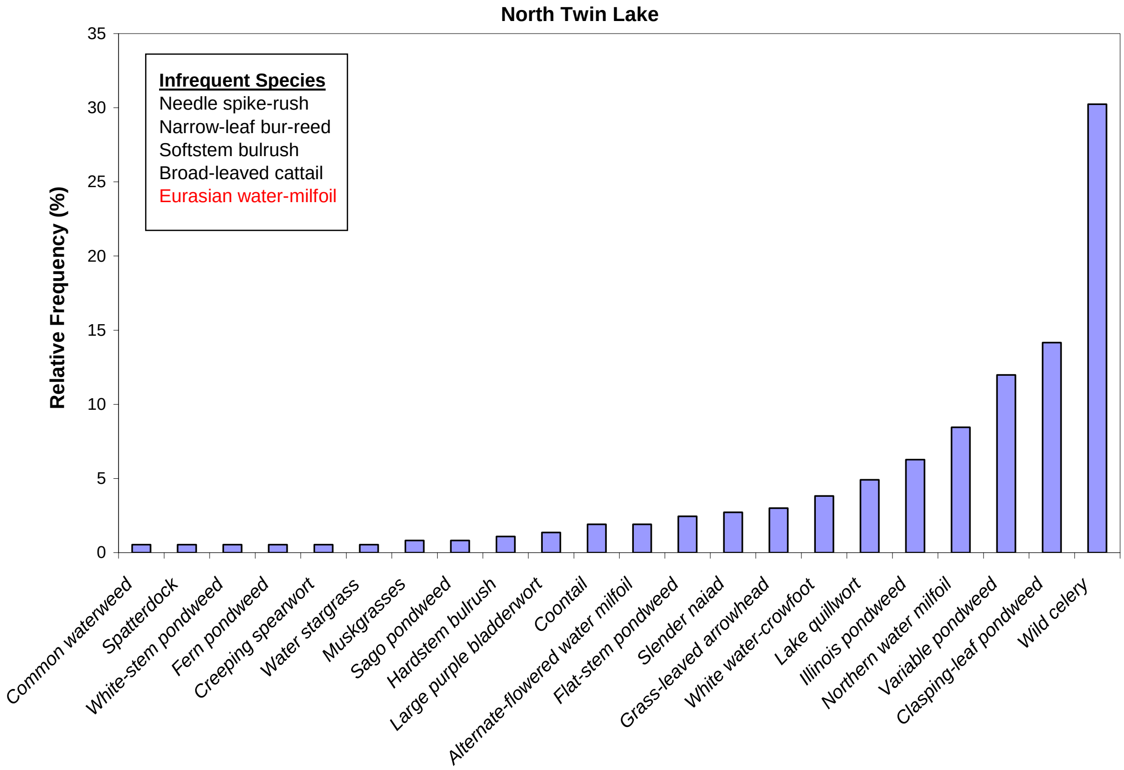
South Twin Lake has a much more even distribution of plants and is not highly dominated by a single species. Like North Twin Lake, South Twin has high occurrences of wild celery, clasping-leaf pondweed, and variable pondweed, but species such as northern water milfoil, slender naiad, and flat-stem pondweed also occur frequently. The substrate of South Twin Lake is more variable than that of North Twin Lake in that softer substrates occur in deeper depths in South Twin and basically no soft sediments occur in North Twin Lake. In fact, in South Twin Lake, 44% of the plots sampled in 5-10 feet of water contained muck or muck/sand, 72% of the plots sampled in depths greater than 10 feet contained muck or muck/sand, and no plots sampled at depths less than 5 feet contained any muck component.. These variable substrates allow different species to occur more frequently in different areas of the lake based upon the substrate.

Although South Twin Lake's species richness is less than North Twin's, its more even distribution of occurrence among its species results in a higher species diversity of 0.92. South Twin Lake's diversity would be considered quite high.

Figure 9 contains the results of the Floristic Quality Analysis completed using data collected during the surveys completed in 1996/97 (Phase I studies) and 2004. Both surveys completed on North and South Twin Lake resulted in much higher species richness values than median values for the ecoregion and the state. The slight differences in species richness results between the surveys completed during 1996/97 and 2004 should not be taken as loss of species between those times, but rather are likely the result of different naming conventions and levels of identification. The average conservatism values for both lakes during both surveys were slightly lower than the median values for the ecoregion and higher than those found in the state. As described above, species conservatism is related to species ability to survive in a disturbed or undisturbed system. Many of the lakes within the Northern Lakes and Forests Ecoregion are relatively undisturbed, so it would be expected that its median value for average conservatism would be high. Considering the amount of shoreland development on both lakes and their level of recreational use, North and South Twin would both be considered somewhat disturbed. This level of disturbance results in a lower average conservatism for both lakes when compared to other lakes in the ecoregion.

Combining the high species richness of the lakes with the average conservatism values results in very high floristic quality values for both North and South Twin Lakes. In fact, these values are within the upper quartile of values for lakes within the ecoregion (75% quartile = 30.2) and indicate the true outstanding nature of the plant communities of North and South Twin Lakes.

Overall, the plant communities of the Twin Lake Chain should be considered outstanding because of their high plant diversity and floristic quality. The community maps (Maps 2 and 3) also support the outstanding nature of the chain's plant habitat with their limited floating-leaf communities and expanded emergent communities.



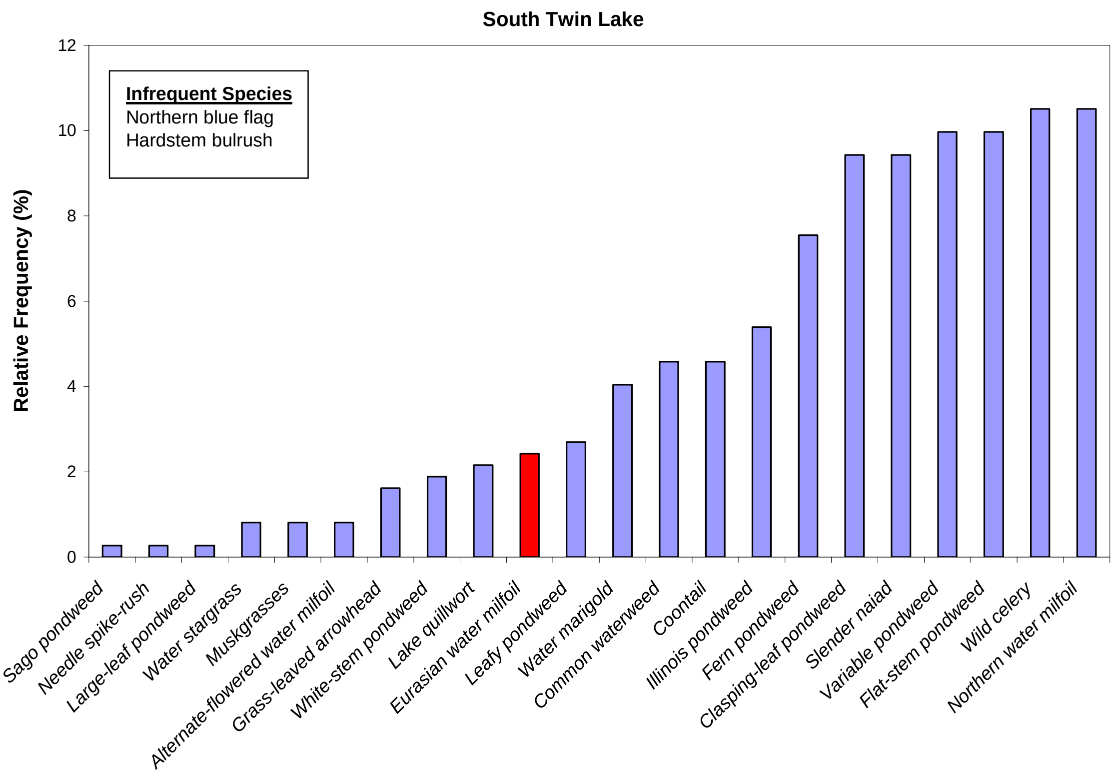


Figure 8. Occurrence analysis results for North and South Twin Lakes 2004 surveys. Exotic species indicated with red.

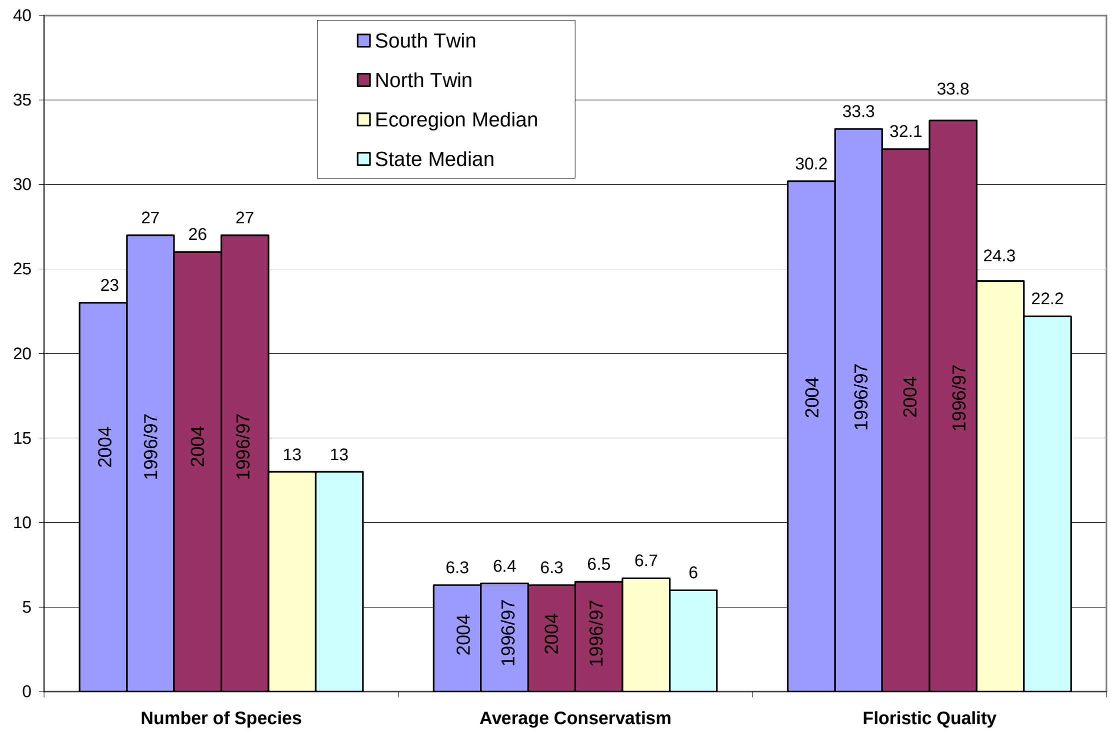


Figure 9. Floristic Quality Analysis results for North and South Twin Lakes. Values calculated following Nichols (1999).

Eurasian Water Milfoil

Map 4 displays the occurrences of Eurasian water milfoil within North and South Twin Lakes during the 2004, 2005, and 2006 growing seasons. Some of the data displayed were collected by NSTLRA volunteers during 2002-2003. Coordinates were provided to Onterra staff and all positions were verified as still containing Eurasian water milfoil during the 2004 surveys.

During 2004, two occurrences of Eurasian water milfoil were mapped in North Twin, a dense colony west of the large island and a small clump off the lake's southern shore west of the entrance to South Twin. In South Twin, colonies were mapped primarily following the extents of the bulrush stands. Scattered occurrences consisting of single plants or clumps of plants were found to exist between the bulrush stands and extending approximately half way around the lake (2004 Extent of Occurrence, Map 4). The greatest occurrences were found from the bulrush stands to just west of the girl's camp on the lake's south shore.

In both lakes, the Eurasian water milfoil existed in depths between 5 and 12 feet and in sediment types consisting of sand, muck, and sandy muck. Because the plant was found in so many different sediment types, depth appears to more of a limiting factor.

During August 2005, an informal survey was completed to document an increase or decrease in the Eurasian water milfoil infestation in both lakes. In North Twin Lake, the colony located west of the island remained about the same, indicating that it is likely highly limited by depth. However, the small clump located off the lake's south shore was found to have expanded dramatically. Additionally, a narrow colony closer to the South Twin Lake entrance and two large clumps east of the shoal between the island and shoreline were mapped.

In South Twin, the occurrences mapped around the bulrush stands were found to have approximately the same extents, but were denser. This was especially true for areas marked on the north and south sides of the northern most stand. With in the stands, Eurasian water milfoil dominated the submergent community. More clumps and larger clumps also occurred between the stands. This also held true for the area south of the bulrush stands and north of the girl's camp. Between the girl's camp and around the shoreline to the extent of occurrence found in 2004, there were more clumps and single plants found than the previous year. Furthermore, the extent of occurrence was found to extend around to the north side of the lake ending approximately 700 feet west of the boat landing (2005 Extent of Occurrence, Map 4).

During September 2006, the lakes were visited once again to reassess the infestation. As with the 2005 survey, the colony located west of the island in North Twin was found to have approximately the same extents; however, it appeared to be denser, and for the first time, portions of the colony were canopied. The area east of the shoal was found to contain a few more large clumps of Eurasian water milfoil compared to the 2005 survey when the area was first visited. The most alarming finding was that the two colonies mapped on the lake's south shore during 2005 had expanded sufficiently to be mapped as one colony. Furthermore, this colony, which was easily visible from the surface during all three years, had expanded greatly to the east.

In South Twin Lake, the dense area located north of the northern most bulrush stand was found to have expanded to the northeast and like the colony on the south side of the stand, had become much denser and was now matted to the point that navigating a boat through it was very difficult. Between and south of the stands, the occurrence of single plants and clumps appeared to be greater and several clumps had expanded to the point that they were then mappable with polygons. Several of these areas were found to be canopied. The area west of the girl's camp, extending to the 2004 extent, was found to be about the same as during the 2005 survey with the exception of the mapping of one dense colony. The area between the 2004 extent and the boat landing was perceived as having more occurrences, especially in the areas were two dense colonies were mapped.

Watershed Analysis

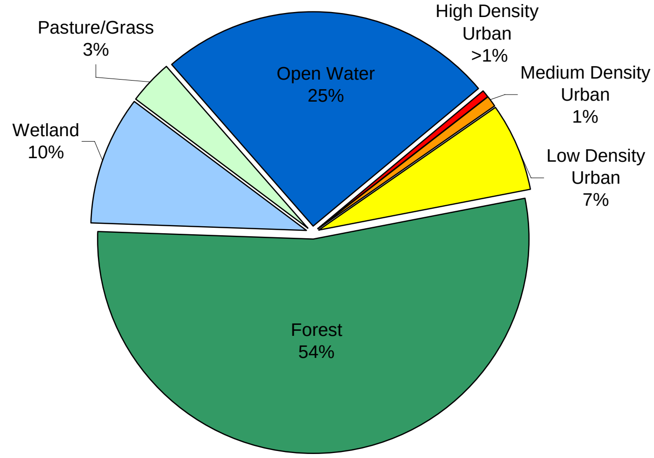


Figure 10. North & South Twin Lakes watershed land cover types. WISCLAND data.

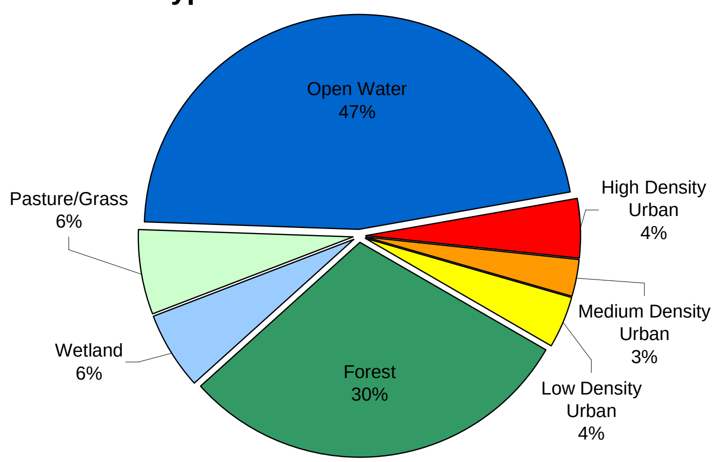


Figure 11. North & South Twin Lakes watershed phosphorus loading by land cover type. WiLMS data.

Because of their close proximity, North and South Twin Lakes are essentially one lake, and during this analysis are treated as such. In systems where two lakes share much of the same watershed and are connected through a stream or channel, the lakes can be modeled separately by first modeling the watershed contributions to the upper lake and then "feeding" them into the lower lake as a point source. The proximity of the two Twin Lakes makes this nearly impossible because South Twin acts almost as a large bay of North Twin.

The North and South Twin Lakes' watershed, excluding lake surface area, is approximately 10,426 acres (roughly 16.3 mi^2), yielding a watershed to lake area ratio of approximately 3:1, a relatively low ratio. Lakes with lower ratios tend to have lower phosphorus concentrations when compared to lakes with higher ratios. For lakes with higher ratios, those above 10:1, there is more land delivering (loading) sediments and nutrients to the lake through its tributaries. The actual amount of pollutants (nutrients, sediment, toxins, etc.) depends greatly on how the land within the watershed is used. Vegetated areas, such as forests, grasslands, and meadows, allow the water to permeate the ground and do not produce much surface runoff. On the other hand, agricultural areas, particularly row crops, along with residential/urban areas reduce infiltration and increase surface runoff. The increased surface runoff associated with these land cover types leads to increased pollutant loading; which, in turn, can lead to nuisance algal blooms, increased sedimentation, and/or overabundant macrophyte populations.

Adjusted land cover data from the Wisconsin Initiative for Statewide Cooperation on Landscape Analysis and Data (WISCLAND) for the North and South Twin Lakes watershed are displayed in Map 5. The original WISCLAND coverages were slightly modified using orthophotography and zoning/land use data supplied by Vilas County. Not surprisingly, the majority (over 54% including the surface area of the lakes) is forested, with much lesser amounts in wetlands, pasture/grass, and varying degrees of residential development (Figure 10). Modeling of these land cover types along with their respective acreages using the Wisconsin Lake Modeling Suite

(WiLMS) indicates that approximately 2,016 lbs of phosphorus enters the Twin Lakes from their watershed annually (Appendix D).

Figure 11 displays the percent contribution of each of the cover types found within the watershed. Interestingly, nearly half of the total phosphorus load enters the lake-system at its surface through atmospheric fallout of dust particles and precipitation. Forested areas provide approximately 600 lbs, accounting for nearly a third of the annual load. This may seem like quite a bit of phosphorus; however, it would only require 273 acres of agricultural row crops, less than 4% of the forested area in the Twin Lakes' watershed, to load the same amount of phosphorus to the lakes. Obviously, having much of its watershed in a forested condition is a tremendous benefit to the well being of the lakes. In fact, short of reforesting the remaining areas of the watershed, it is apparent that there is not much room for improving the phosphorus loads to the lake through its tributaries. In fact, the most apparent target for improvement is surface runoff from the lakes' immediate shorelands. Eleven percent of the system's phosphorus arrives from developed areas (urban category, Figure 11). Although this is a minor portion of the whole, there is room for improvement, especially concerning impervious surfaces, which increase runoff and loss of natural buffers that filter polluted runoff before it enters the lake. However, surface runoff is not the only source of phosphorus to a lake; subsurface flows can also deliver considerable amounts of phosphorus to a lake – especially if failing septic systems are in the vicinity.

Assessing the current conditions of shoreland septic systems around North and South Twin Lakes is well beyond the scope of this project; however, potential impacts can be estimated using WiLMS. In order to complete the modeling, an estimate of septic system use must be determined. In WiLMS, septic system phosphorus loading is estimated using drain field outflow values in kilograms/capita-year. One capita-year is equal to one person occupying a dwelling for a period of one year. If a family of four used their shoreland property of 6 months out of the year that would yield a use of 2 capita-years.

The direction of groundwater flow is also important in determining if private septic systems are impacting the phosphorus load to a lake. Essentially, if the groundwater does not flow across the property towards the lake, that property's septic system will not impact the lake. Map 6 indicates generalized groundwater flow direction as indicated in the Phase I plan. Much of the area's groundwater flows into North Twin Lake, indicating that the majority of the properties surrounding the lake could potentially provide phosphorus loads through their septic systems. However, much of the northern portion of North Twin Lake is included in the Town of Phelps Sanitary District (Map 6); therefore, these properties do not have septic systems that could potentially impact the lake. In fact, using the sanitary sewer boundaries with the groundwater flow data, indicates that approximately 90 properties would be considered to have a potential impact on the North and South Twin Lake phosphorus load via their septic systems.

The property owner survey completed as a part of the Phase I plan development indicates an average property use of 24 weeks annually by an average of 3.37 people. Using those figures for 90 properties results in a capita-year value of 140. Plugging that figure into the WiLMS septic tank modeling module indicates that if all the systems were functioning and removing 73% of the phosphorus entering them (based upon soil types described in the Phase I plan), a potential increase of approximately 42 lbs of phosphorus (roughly 2%) is being added to the North and South Twin Lake's annual load. This is negligible when compared to the amount entering the lakes from their watershed. Even if all of the septic systems were considered failing and only removing 40% of the phosphorus entering them, the total increase would be only 4.5% or 92 lbs. Again, this is negligible compared to the loads that enter the lake through its drainage basin.

Fisheries and Wildlife

The WDNR has completed many fisheries surveys on North and South Twin Lakes. Summaries of these studies, including the full text of the Creel Survey Report can be found in the main text and appendices of the Phase I Plan.

Brief discussions of wildlife associated with the Twin Lakes Chain can be found in the Phase I plan and the WDNR Sensitive Area Designation Report (WDNR 2002).

SUMMARY AND CONCLUSIONS

The results of the studies associated with this project and those described in the Phase I plan indicate that in general, North and South Twin Lakes are in good health. The watershed assessment and modeling efforts show that the phosphorus loads entering the lake are not unexpectedly high and are likely the positive result of the large amount of forest cover that exists within the watershed and the low watershed to lake area ratio. Even though over a ton of phosphorus enters North and South Twin Lakes via surface runoff annually, the combination of the system's large volume and flushing rate allows the lakes to maintain their relatively low production rates. Adding potential septic system impacts to the annual phosphorus load raises it slightly, but likely not enough to impact the productivity of the system. Having much of North Twin Lake within the Phelps Sanitary District is a great benefit to both North and South Twin because it basically removes much of the shoreland area that could impact the lakes through faulty septic systems. The potentiometric map included in the Phase I plan indicates that little or no water enters South Twin Lake through groundwater. As a result, the private septic systems on South Twin, whether functioning or not, likely have little or no impact on the lake's phosphorus budget because the potentially impacted groundwater does not enter the lake.

Data collected over the past two decades indicate that both North and South Twin Lakes have very good water quality, and in general, is better than mean values found in the region and in the state. Trophic state analysis indicates that both lakes would be considered moderately productive, or mesotrophic. Because a lake is actually a mirror of its watershed, the quality of the water in North and South Twin can be attributed to the quality of the watershed that feeds it.

Surveys completed during this project and those completed during the Phase I project and during the WDNR Sensitive Area Designation (WDNR 2000) found the aquatic vegetation communities of both lakes to not only be healthy, but outstanding. Floristic quality assessment values for both lakes in the upper quartile when compared to other lakes in the ecoregion and the state. South Twin Lake's variable bottom substrates support a bit higher diversity of species than that of North Twin's mostly hard substrates but, both lakes would be considered quite diverse.

As elaborated upon in the Phase I plan and the Sensitive Area Designation report, both lakes support excellent fisheries and wildlife communities. Loons, bald eagles, and ospreys also use these waters and shorelands for nesting and foraging. The fishery is highlighted by sustainable walleye and muskellunge populations and as a result, the creel survey completed in the late 1990's indicated that the lakes are highly utilized by anglers in search of these species. In fact, both North and South Twin Lakes are considered Class A2, Category 2 muskellunge waters by the WDNR.

The fish and wildlife populations, along with the pleasing aesthetics and recreational opportunities that are so highly valued by stakeholders are supported by the lakes' outstanding water quality and aquatic plant communities. Unfortunately, these positive attributes are threatened in many ways. Continued shoreland development and urban-like maintenance lead to decreased habitat value and increased nutrient enrichment through increased impervious surfaces and decreased buffering capacity. Radomski and Goeman (2001) found a 66% reduction in vegetation coverage on developed shorelines when compared to undeveloped shorelines in Minnesota Lakes. They also found a significant reduction in abundance and size of northern pike (*Esox lucius*), bluegill (*Lepomis macrochirus*), and pumpkinseed (*Lepomis gibbosus*) associated with these developed shorelines. The removal of woody debris, such as fallen trees and logs also reduce fishery habitat. Unfortunately, many property owners remove this important structure because they consider it an eyesore. Protecting natural shorelands, restoring unnatural shorelands, and minimizing impervious surfaces should be an important consideration in every lake management plan in order to protect valuable habitat and water quality.

An additional threat to the health of the North and South Twin ecosystem is rusty crayfish (*Orconectes rusticus*). Rusty crayfish are native to some portions of the southern Great Lakes States, but are considered exotic and highly invasive in the waters of Wisconsin, Minnesota, and Ontario. It is generally believed that this crustacean was introduced by anglers using them as bait. Rusty crayfish are much more aggressive and have higher feeding rates when compared to native crayfish. As a result, these intruders have reduced macrophyte and invertebrate abundance and diversity while displacing native crayfish species. They have also impacted fish populations by competing for forage with young fish, reducing habitat value, and possibly through egg predation. Unfortunately, there is currently no method of control available, although research is being completed testing the affects of different fisheries management strategies and trapping efforts on rusty crayfish populations.

Rusty crayfish were seen during the comprehensive aquatic plant survey in both North and South Twin Lakes. The greatest occurrence was noted on the North Twin's north shore west of Phelps. The true impact of the rusty crayfish on North and South Twin remains undetermined, but it can be assumed that they are having negative affects. The appropriate plan of action for the NSTLRA at this time, regarding rusty crayfish, would be monitoring developments in control strategies and possibly becoming involved with WDNR population monitoring studies.

In the long-term, continued and uninhibited shoreland development and recreational use are the largest threat to the health of North and South Twin Lakes. As described above, these activities impact the lakes in many ways – from water quality to habitat destruction. However, in the short-term and in the context of realistic management alternatives, Eurasian water milfoil also poses a large threat to the ecological stability of the Twin Lakes Chain. At this time, recreational activities are not affected because the dense colonies are small and other areas have only scattered occurrences of the invasive. However, surveys completed in 2004, 2005, and 2006 document the spread of Eurasian water milfoil within both lakes. This is especially true in South Twin Lake where the plant continues to spread and thrive within nearly all areas of the lake's littoral zone. It may take many years, perhaps decades for the infestation to reach nuisance levels within either lake, but as the infestation worsens, native plant species abundances are being impacted and the high quality plant habitat discussed in the Aquatic Plant Section is being lost. This means that the foundation of the outstanding ecosystem that is discussed throughout this report is being deteriorated, and if it continues, negative alterations to the system's fishery, wildlife population, aesthetics, and recreational value can be expected.

Controlling the spread of Eurasian water milfoil on a lake wide basis is a difficult and complicated undertaking. Basically, five somewhat realistic alternatives exist for controlling Eurasian water milfoil within the Twin Lakes Chain; drawdown, mechanical harvesting, weevil introduction, herbicides (specifically 2,4-D), and hand-removal. Drawdown is not a feasible option because the lakes could only be lowered 3-5' using the dam and spillway as they currently exist. Without even considering impact on native plants, the fishery, and recreation, dewatering the lakes to the current 5-foot contour line would have little impact on the current Eurasian water milfoil because much of it exists in deeper waters. Harvesting is not appropriate because Eurasian water milfoil does not occur at nuisance levels in either lake and most importantly, it would accelerate the spread of the infestation. The milfoil weevil (*Euhrychiopsis lecontei*) is not an apposite option because of high costs and the limited over-wintering habitat that occurs along the shorelines of both lakes. Hand-removal's effectiveness would be limited to very small areas and/or in conjunction with herbicide use. At this time, the use of chemical herbicides stands out as the most viable option for achieving control.

Based upon guidance in the sensitive area survey and directly from WDNR specialists, multiple 2,4-D treatments were completed between 2001 and 2003, with the largest area, approximately 50 acres, being treated in August 2003. The treatments in 2001 and 2002 were basically spot treatments, with the 2001 treatments totaling 7 acres and the 2002 treatments totaling 6.35 acres. The 50-acre treatment completed in 2003 was located on the west side of South Twin Lake from the girl's camp north to about half way up the shoreline to the North Twin entrance. Anecdotal reports indicate that the smaller treatments met with only limited success, while the final, larger treatment was more successful. Unfortunately, no structured monitoring was completed in conjunction with these treatments and little is truly known about their success or failure. It is evident based upon the 2004-2006 surveys that even after the treatments, the Eurasian water milfoil has continued to spread to new areas of the lakes and that original infestation sites have become denser.

The goal of a realistic chemical treatment plan cannot be to eradicate Eurasian water milfoil from North and South Twin Lakes. Instead, the goal must be to control the infestation. In this case, the term "control" includes halting the spread of the exotic and possibly reducing its occurrence on a lake wide basis. To meet this goal a suitable treatment plan must be devised and followed in order to control the Eurasian water milfoil while protecting existing native habitat and the system's current fish and wildlife communities.

An appropriate treatment plan would include many elements. Monitoring would need to occur before and after treatments to assure that applications are being completed at the appropriate time and only on areas that require them. Further, the monitoring would assure that native plant species are not being affected. This is extremely important aspect because the primary objective of the treatments is to protect native habitat. If native species, especially native milfoils are being impacted, it would reduce the native community's ability to regenerate and compete with Eurasian water milfoil. Fortunately, the WDNR is currently refining a standard protocol for the monitoring of chemical treatments.

The Twin Lakes Chain is considered to contain an outstanding fishery and in fact, is occasionally used as a harvest site for muskellunge eggs. Therefore, the treatment plan must also include the collaboration of WDNR fisheries specialists to assure that the system's fishery is protected and in turn, fisheries outside of North and South Twin Lake are not indirectly affected.

The plan must also include work to prevent further infestations through the lakes' public access. This applies to additional introductions of Eurasian water milfoil and other AIS to the Twin Lakes Chain *and* to other lakes in the area. In other words, it is important that AIS are prevented from entering and leaving North and South Twin Lakes. Allowing additional Eurasian water milfoil to enter the lakes and create new infestation areas would be highly counter-productive to the control efforts directed at the known sites. Furthermore, the introduction of other AIS would only serve to confound the situation and likely tax the already limited financial resources.

The control plan must be flexible enough to allow for unanticipated results in chemical treatment success. In many lakes, 2,4-D use has lead to control of Eurasian water milfoil; in others, consistent control is not achieved. The reasons for these inconsistencies is not fully understood, but may be related to the presence of hybrid milfoils, pH values, improper application, insufficient contact time, and/or insufficient dose concentrations. Obviously, the plan cannot assume that control would be achieved, and therefore must contain alternative paths to deal with insufficient control. Those changes may include increased dosage, modifying the treatment timing, and/or increasing or decreasing treatment extents. This is one of the reasons why monitoring, as described above, would be a crucial element of the treatment plan.

Finally, the plan must fit within the financial constraints of its sponsors, namely the NSTLRA and the WDNR. Treating the entire population of Eurasian water milfoil at once is likely not needed to realize an acceptable level of control over the next three to five years. On the other hand, without intense and planned management of Eurasian water milfoil at this time, the infestations could worsen and expand, resulting in more expensive and less successful control solutions down the road.

IMPLEMENTATION PLAN

As described within the Results and Discussion Section and within the Conclusions, in general, North and South Twin Lakes are believed to be in very good health. Protecting those healthy aspects of the ecosystem are as important to the NSTLRA as controlling Eurasian water milfoil. As a result, the Implementation Plan contains goals and actions to maintain the lakes' health through preventative actions, monitoring, and indirectly through the control of Eurasian water milfoil.

Management Goal 1: Maintain Lake Water Quality

Management Action: Continue lake water quality monitoring and subsequent reporting of results to stakeholders and WDNR.

Timeframe: In progress

Facilitator: Current Citizen Lake Monitoring Network volunteers with support of additional volunteers as required.

Description: Considering the outstanding natural condition of the lake's drainage basin, it is likely that the water quality of the Twin Lakes Chain is the best that it can be at this point in time. Therefore, the monitoring results compiled in this report and that of the Phase I planning project, stands as an accurate baseline for comparisons with future results. The data collected through 2005 was essential in completing this management plan and future efforts will be important in determining if this goal is being met. Reporting of results during association meetings and via the newsletter is important in keeping stakeholders engaged in this effort.

Action Steps:

1. Continue monitoring under current WDNR Citizen Lakes Monitoring Network protocols.
2. Provide periodic reports comparing results to stakeholders.
3. Consult with WDNR water resource specialists if unusual trends, either positive or negative, develop in the dataset.

Management Goal 2: Minimize Watershed Nutrient Loads to North and South Twin Lakes

Management Action: Provide education and information to shoreland property owners regarding shoreline protection and restoration, including shoreland protection/restoration and minimizing impact of impervious surfaces.

Timeframe: 2008

Facilitator: Education Committee?

Description: Assuming the watershed outside of the immediate shorelines of North and South Twin Lakes remain in its current, natural condition, the most likely source of increased nutrient loading to the lake is shoreland properties. Many of the current developed areas surrounding the lakes are in acceptable condition to buffer the lakes from increased nutrient loads. However, as properties exchange owners, or the perceived needs of current riparians change, modifications to existing buffer areas may impact the lakes. The education of current and new land owners concerning their property's impact to the chain is important in minimizing this threat. WDNR Lake Protection Grants would be an appropriate source to provide partial funding of this initiative.

Action Steps:

1. Using existing information and materials available from UW-Extension, the WDNR, and Vilas County, along with data and conclusions included in the management plan to create a guide to shoreland property ownership on North and South Twin Lakes.
2. Distribute guide to current property owners.
3. Monitor sales of existing properties and provide copies of the guide to the new owners.

Management Goal 3: Control Eurasian Water Milfoil Infestation and Prevent other Aquatic Invasive Species Infestations

Management Action: Continue watercraft inspections at North and South Twin Lakes access points.

Timeframe: In progress

Facilitator: Ms. Ginny Parker with help from other volunteers.

Description: Members of the NSTLRA have attended Clean Boats Clean Waters training sessions and have participated in boat inspections at Twin Lake Chain landings. Boat landings, including those within resort properties, are high-risk areas for the introduction of aquatic invasive species to the Twin Lakes Chain. Continued participation in this program is a critical component in not only preventing the introduction of additional aquatic invasive species, but also in the prevention of acting as a source of infestation to other area lakes and the promotion of aquatic invasives awareness among all lake users.

Action Steps:

1. Continue periodic boat inspections during high-risk weekends as volunteer capacity allows.
2. Report results to NSTLRA and WDNR.
3. Promote enlistment and training of new of volunteers to keep program fresh.

Management Action: Initiate in-lake invasive species monitoring.

Timeframe: 2007

Facilitator: Mr. Tom Hickson (needs to be confirmed)

Description: Early detection of aquatic invasive species is key to preventing the establishment of these species if introduction were to occur. This task includes the monitoring of the entire Twin Lakes Chain for Eurasian water milfoil (primarily new infestation sites), curly-leaf pondweed, purple loosestrife, and adult zebra mussel infestations. The monitoring would be completed using the protocols created by the WDNR and UW-Extension.

Action Steps:

1. Train a core group of volunteers based upon the WDNR/UW-Extension protocols. This group can then train others to assist in the monitoring efforts.
2. Perform annual lake inspections for invasives.
3. Report annual results to NSTLRA and WDNR and adjust invasives control plan accordingly.
4. Promote enlistment and training of new of volunteers to keep invasives monitoring program fresh.

Management Action: Plan and initiate Eurasian water milfoil control program.
Timeframe: Begin in 2007
Facilitator: Board of Directors
Description: As described in the conclusions, the most realistic strategy for the control of Eurasian water milfoil on the Twin Lakes Chain would need to involve chemical treatments. The following list of action steps outlines a generalized plan for chemical treatments and associated monitoring spanning 2007 and 2008. The control plan is designed to treat the densest infestations first along with a single scattered area (Map 7) while meeting the financial restrictions of the NSTLRA. As described in the conclusions, as the financial situation of the association changes, the plan will be adjusted to maximize the effectiveness of the control project.

Chemical Treatment Areas

Sites A-I These sites represent the densest areas of infestation based upon the September 2006 survey. They were chosen as treatment areas because they are known to be expanding and are the most likely source of fragments that allow further spread of the plant within the lakes' littoral zone.

Site J This single scattered site was chosen to test the effectiveness of treatments on areas that do not contain dense colonies. It is anticipated that as the control plan is carried through, dense areas will be limited within the lakes, therefore; the information from this test area will be valuable in making decisions regarding future treatments of Eurasian water milfoil.

Treatment Monitoring

Monitoring is based upon the guidelines provided by the WDNR in Aquatic Plant Management In Wisconsin – Draft (WDNR 2006). All treatment areas would be monitored before and after treatments using a 20-meter point spacing and through the methods described on Map 3.

Pretreatment Surveys Surveys would begin by verifying the extents of the treatment areas. If the treatment areas require adjustment, the point-intercept spacing will be adjusted accordingly before the monitoring is completed. Furthermore, the WDNR would be notified of any treatment area refinements so all permitting requirements would be met.

Post Treatment Surveys These surveys would be completed during July or August following the treatments and would utilize the same points used in the pretreatment survey. The results of the surveys will be used to determine the effectiveness of the treatments, which in turn, will aid in the development of future treatment plans.

Treatment Program Goal The goal of the treatment program is to reduce occurrences of Eurasian water milfoil within the Twin Lakes Chain with the primary intent of protecting and restoring the valuable native habitat that currently exists within the system. As described above, due to financial restraints, this program spans two years, but it is anticipated to be expanded well into the future as the infestation is altered. In other words, the NSTLRA is well aware that Eurasian water milfoil will not be eradicated from North and South Twin Lakes as a result of this treatment program and as such, will adjust the treatment program as needed to keep the infestation in control.

Chemical treatments would be completed by a competent, licensed contractor, while the monitoring efforts may be completed by professionals, volunteers, or a combination there of.

Action Steps:

1. Complete Year 1 (2007) monitoring and treatments (using 2,4-D at a rate of 100 lbs/ac.).
   Treatment timing would be completed under the guidance of the WDNR aquatic plant management and fisheries staff.
2. Use results from Year 1 monitoring to create treatment plan for Year 2 (2008).
   The adjustments to the Year 2 treatment plan will be based upon the results of the monitoring associated with the Year 1 treatment. If the treatments are found to effective (obvious decrease in densities and occurrences within treated areas), the Year 2 plan would include treatments of additional areas (within the financial restraints of the NSTLRA) to further reduce Eurasian water milfoil occurrences. If effectiveness were found to be poor (no obvious decrease in densities and occurrences within treated areas), the Year 2 treatment plan will be altered accordingly. The adjustments may include increased dosage rates, changes in treatment timing, and/or the expansion of treatment extents.
3. Complete Year 2 monitoring and treatment following guidelines described above.
4. Determine future management strategies based upon combined results of Year 1 and 2 treatments.

METHODS

Aquatic Vegetation

Curly-leaf Pondweed Survey

Surveys of curly-leaf pondweed were completed on North and South Twin Lake during June 3 and June 8, 2004 field visits, respectively, in order to correspond with the anticipated peak growth of the plant. Visual inspections were completed throughout the lake by completing a meander survey by boat and wading.

Transect Surveys and Macrophyte Community Mapping

A quantitative aquatic vegetation survey was conducted July 21-22 & 25-26, 2004 by sampling 204 points along 41 transects located along the shoreline of North Twin Lake and 90 points along 18 transects along the shoreline of South Twin Lakes. Sampling was completed via boating, wading, and snorkeling. In order to map the macrophyte communities and to assist in determining the frequency and location of transects, visual inspections were completed throughout the lake using a combination of sketches and notes created on hardcopy maps and position data recorded with a Trimble GeoExplorer 3 GPS Datacollector. On each transect, a ten-foot diameter circle was sampled within each of five different depth ranges (Table 2). The maximum depth of sampling was determined through field observation of the approximate maximum depth of aquatic vegetation growth. At each sampling location, substrate type and species composition were recorded.

Table 2. Depth codes and ranges sampled during transect surveys.

Depth Code	Depth Range (feet)
1	0.0-1.5
2	1.5-3.0
3	3.0-5.0
4	5.0-10.0
5	10+

A visual estimate of percent foliage cover for each species was also recorded at the sampling locations. Coverage is determined as the perpendicular projection to the substrate from the outline of the aerial parts of the plant species and is typically reported as the percent of total area (e.g., substrate or water surface) covered (Brower et al. 1990). For emergent and floating-leaf vegetation, the percent of water surface covered was used in the visual estimate, and for submergent vegetation the percent of substrate covered was used. After the collection of field data, the Daubenmire Classification Scheme (Mueller-Dumbois and Ellenberg 1974) was used to rank each species observed according to estimated foliage cover (Table 3). By providing a range of percent foliage cover for each rank, the Daubenmire Classification Scheme helps to minimize errors due to observer bias, visual estimation, etc.

Table 3. Daubenmire Classification Scheme: Foliage cover ranking system.

Percent Foliage Cover	Rank
0-5	1
5-25	2
25-50	3
50-75	4
75-95	5
95-100	6

The collected transect data were used to estimate frequency of occurrence and relative frequency of occurrence for each species observed. The frequency of occurrence is defined as the number of times a given species occurred on the total plots of all transects sampled. The relative frequency of occurrence is the frequency of that species divided by the sum of the frequencies of all species in the community (Brower et al. 1990).

Watershed Analysis

The watershed analysis began with an accurate delineation of North and South Twin Lake's drainage area using U.S.G.S. topographic survey maps and existing data from Vilas County, WDNR, and the Phase I Plan. The watershed delineation was then transferred to a Geographic Information System (GIS). These data, along with land cover data from the Wisconsin initiative for Statewide Cooperation on Landscape Analysis and Data (WISCLAND) were then combined to determine the preliminary watershed land cover classifications. The watershed delineation and land use classifications were modified using aerial photography and zoning information provided by Vilas County. Watershed area and acreages for each land cover were calculated and those data, along with historic and current water quality data were inputted into the Wisconsin Lake Modeling Suite (WiLMS, Panuska and Kreider 2003) (Appendix D) to determine potential phosphorus loads to the lake.

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