Nelson Lake

Sawyer County, Wisconsin

Comprehensive Lake Management Plan

June 2006

Sponsored by:

Nelson Lake Association

&

Wisconsin Department of Natural Resources
Lake Management Grant Program

LPL-965-05 & LPL-966-05

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Onterra LLC
Lake Management Planning

Nelson Lake

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Comprehensive Management Plan

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

Nelson Lake Association

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Wisconsin Department of Natural Resources

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INTRODUCTION

Nelson Lake is an approximate 2,502-acre, shallow flowage with a maximum depth of 33-feet and a mean depth of approximately 9.5-feet. The Nelson Lake Association (NLA), created in 1983, has been active in the lake's management since its inception. Recently, the NLA successfully applied for a Small-scale Planning Grant to collect water quality data within the lake and its primary inlet. The association has also been active in the lake's fishery management through stocking and close contact with the Wisconsin Department of Natural Resources.

Through this work, the NLA has realized the importance of reliable and comprehensive information in the effective management of the lake. However, little baseline data is available concerning the lake's watershed, its aquatic plant community, and its water quality. Therefore the association initiated the management planning project reported on here.

The document is divided into three primary sections and each section is written for the understanding of laypersons and professionals alike. The Results and Discussion Section outlines the results of the water quality analysis, watershed assessment, and numerous aquatic plant surveys that were completed on the lake. It also discusses this information in terms of Nelson Lake and in terms of raising the reader's understanding of lakes and their function in a more general sense.

The Summary and Conclusions Section is written to be somewhat of a *stand-alone* document. It highlights the important results of the project and elaborates upon their implications regarding the management of the lake. This section also sets the tone for the Implementation Plan.

The Implementation Plan is essentially the path the NLA will use to manage the lake over the next few years. The lifespan of the Implementation Plan is intentionally ambiguous because it is intended to be a living document that can flex and change with the needs of the group and those of the lake ecosystem. It is based upon realistic *management goals*. Each management goal contains *management actions* designed to lead the NLA to the meeting of that goal. Specific *action steps* are listed as a part of each management action. The management actions also contain a *timeline* and *facilitator* to guide its implementation.

As stated above, this document, especially the Implementation Plan, is intended to be a living document. This means that its findings and actions must be continuously revisited to ensure that the original management goals are being met and changes to the lake and the needs of the group are being accounted for in the lake's future management.

STAKEHOLDER PARTICIPATION

Effective natural resource planning relies on a blend of science and sociology. The social component of this project included three types of stakeholder participation:

1. The conveying of general and specific project information, such as why the project is important, what activities would take place, and what the results were.
2. Stakeholder education on general lake ecology and other important topics related to appropriate lake stewardship.
3. Direct stakeholder input to the development of the management plan.

A description of each stakeholder participation event can be found below, while supporting materials can be found in Appendix A.

Kick-off Meeting

On June 11, 2005 a special meeting was held with the NLA to inform association members about the project that was to begin that spring. Tim Hoyman of Onterra presented background as to why the project was being completed, discussed fundamental aspects of lake ecology and lake management, and answered questions from the audience.

Planning Meeting I

Tim Hoyman met with the NLA Planning Committee prior to the Kick-off Meeting. The primary goal of the meeting was to outline what the committee's role would be in the completion of the management plan. It also provided an opportunity for committee members to ask specific questions about Nelson Lake and the planning process.

Project Update

A project update was provided to the NLA and published in their newsletter during the fall of 2005. The article discussed the tasks that had been completed and expanded upon a specific question asked by the association's Citizens Lake Monitoring volunteer.

Planning Meeting II

The second planning meeting was held on June 9, 2006. The meeting included a detailed presentation of the project results and a discussion of the draft implementation plan created by Onterra and Dale Anderson. By the end of the meeting, only minor details of the Implementation Plan needed to be settled.

Project Wrap-up Meeting

The Project Wrap-up Meeting was held on June 10, 2006 in conjunction with the NLA Annual Meeting. Over 50 people attended the meeting which included a presentation by Tim Hoyman outlining the project's study results and the draft Implementation Plan. A dozen or more members asked questions about their lake.

Newspaper Article

The June 14, 2006 edition of the Sawyer County Record contained an article regarding the Nelson Lake management planning project and its results. It discussed the fact that the studies indicated the lake is in good shape, but the NLA and other stakeholders must continue working to keep it that way.

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 health 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.

The complete results of these three parameters and the other chemical data that were collected at Nelson Lake 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

Figure 1. Location of Nelson Lake within the regions utilized by Lillie and Mason (1983).

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. Sawyer County lakes are included within the study's Northwest Region (Figure 1) and are among 242 lakes randomly picked from the region that were analyzed for water clarity (Secchi disk), chlorophyll-*a*, and total phosphorus. These data along with data corresponding to statewide impoundment means, historic, current, and average data from Nelson Lake's two sampling sites are displayed in Figures 2-4. Please note that the data in these graphs represent concentrations and depths taken only during the growing season (April-October) or 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.

Unfortunately, little chemical data exists for Nelson Lake. However, water quality samples have been collected since 2003 at the lake's west sample site. During those years, total phosphorus levels (Figure 2) have remained steady and at comparable concentrations with samples collected at the lake's east sample site. Particular to the growing season mean value of 2005, this value is considered suspect because the May 3, 2005 sample was unusually high at 67 µg/L. Excluding the growing season mean of 2005, all of the mean concentrations would be considered good within Lillie and Mason's (1983) Water Quality Index (WQI). The total phosphorus values are also comparable with other lakes in the Northwest Region and much better than what we would expect to see in other impoundments around the state.

Mean chlorophyll-*a* levels (Figure 3) at the west sample site hovered around the 15-20 µg/L during 2003 and 2004, but dropped considerably in 2005. The 2005 mean is validated with similar concentrations at the east sample site. 2005 mean chlorophyll-*a* concentrations from both the east and west basin are inline with other lakes in the region and much lower than those found on average in the state's impoundments. These values would be considered in the good to fair category of the WQI. Conversely, the 2003 and 2004 values from the west basin would be considered poor and similar to those found in other Wisconsin impoundments, but higher than those values found in Northwest Region lakes.

Average Secchi disk depths are variable at both sites and have ranged from very poor to good between 2001 and 2005. Based upon Lillie and Mason (1983) these would be values we would expect to find in a Wisconsin impoundment, but lower than what we would find in the lake of the Northwest Region.

As described above, in most Wisconsin lakes, water clarity is primarily controlled by algal content in the water column (as measured by chlorophyll-*a*). This relationship is apparent in the data collected at the west sample site during 2003-2005. The growing season and summer chlorophyll-*a* values are similar for the 2003 and 2004 seasons. The similarity is also apparent in the Secchi disk means from the same time period. However, the average chlorophyll-*a* values drop considerably during 2005 and as a result, 2005 exhibited some of the best clarity values on record. This is especially noticeable when comparing growing season means.

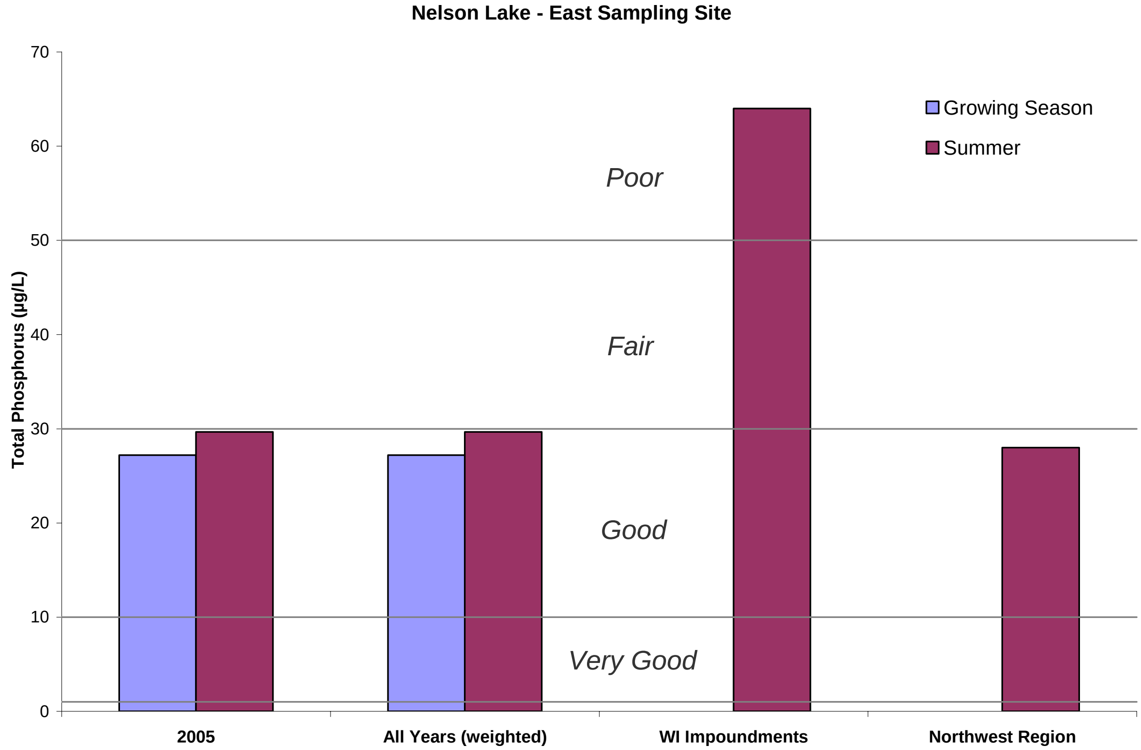
Nitrogen to phosphorus ratios indicate if algal growth within a lake is limited by nitrogen or phosphorus. If the ratio is greater than 15:1, the lake is considered phosphorus limited; if it is 10:1 or less, it is considered nitrogen limited. Ratios in between these values indicate that the lake likely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

Oddly, the mean total phosphorus values do not follow the same trend and appear to break with the relationship between algal abundance and total phosphorus concentrations described in the beginning of this section. One explanation for this may be that phosphorus is not the limiting nutrient within the lake and in fact, the algal growth may be limited by nitrogen. This is an unlikely scenario because 2005 mean summer values from the east basin indicate a nitrogen to phosphorus ratio (N:P) of approximately 18.7:1, signifying that phosphorus is the limiting nutrient. A more likely reason for the phenomenon is that even though the *total* phosphorus levels are high, the portion of that total available for use by algae is low. In other words, the measurement of *total phosphorus* includes all forms of phosphorus within the water column whether it is dissolved in the water, bound to an iron molecule, attached to a particle of clay, or even being used in living algae. However, algae normally only use *dissolved* phosphorus, which at times may be a very small portion of the total phosphorus. It is likely that even though the total phosphorus levels are similar between 2003 and 2005; the amount available in the dissolved form was in short supply during part of the summer of 2005.

An additional contributing factor in the relationship may be the color of Nelson Lake's water. The characteristic reddish-brown (stained) color of Nelson Lake caused by dissolved organic acids entering the lake from its watershed. The acids, which are not dangerous, are a product of plant decomposition and incidentally, are also the cause of the foam that may appear along the shoreline on windy days. The color decreases water clarity and as a result confounds the relationship between clarity and chlorophyll-*a* concentration.

Nelson Lake 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 the east and west sampling sites on Nelson Lake. 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 Citizen Lake Monitoring Network volunteers.



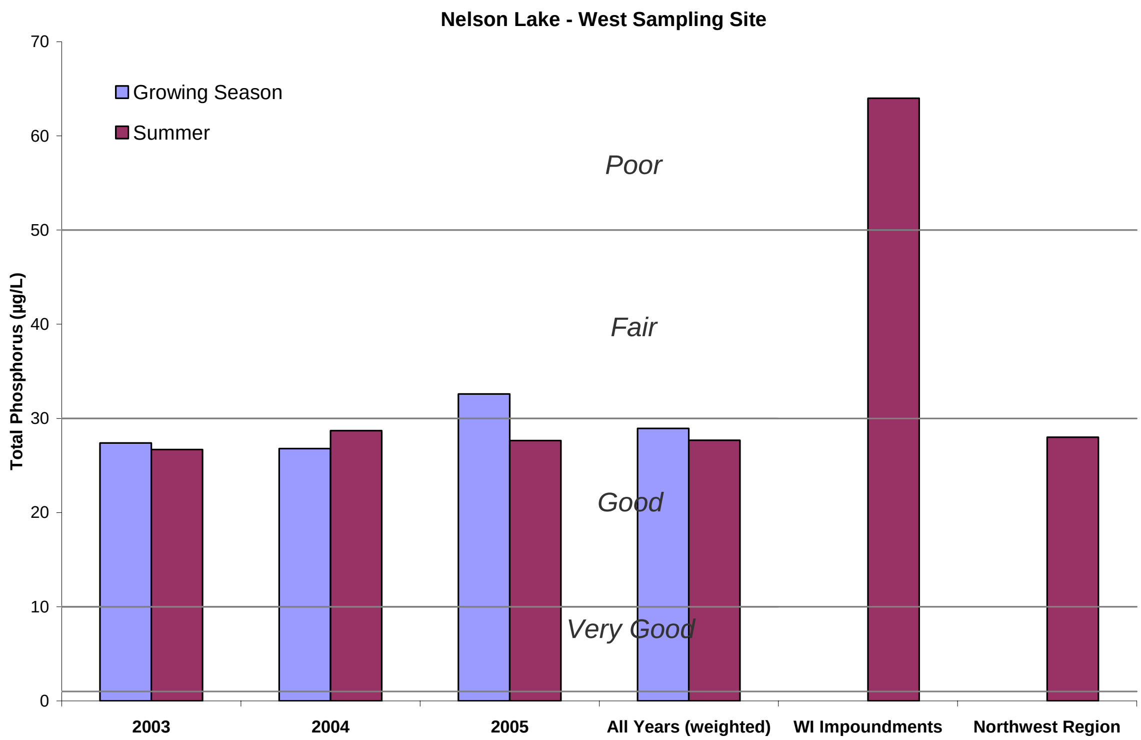
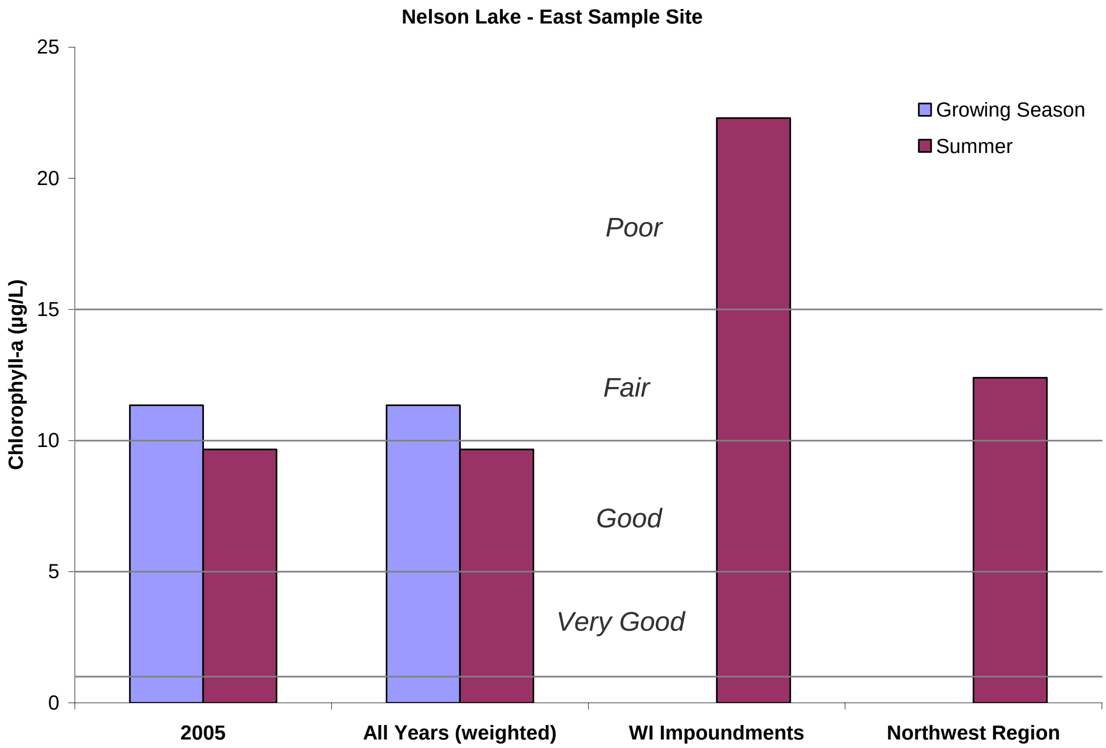


Figure 2. Nelson Lake total phosphorus concentrations. Growing season means include values recorded spring – fall and summer means include values recorded June - August**.** Apparent water quality index ratings and state and regional means after Lillie & Mason (1983).



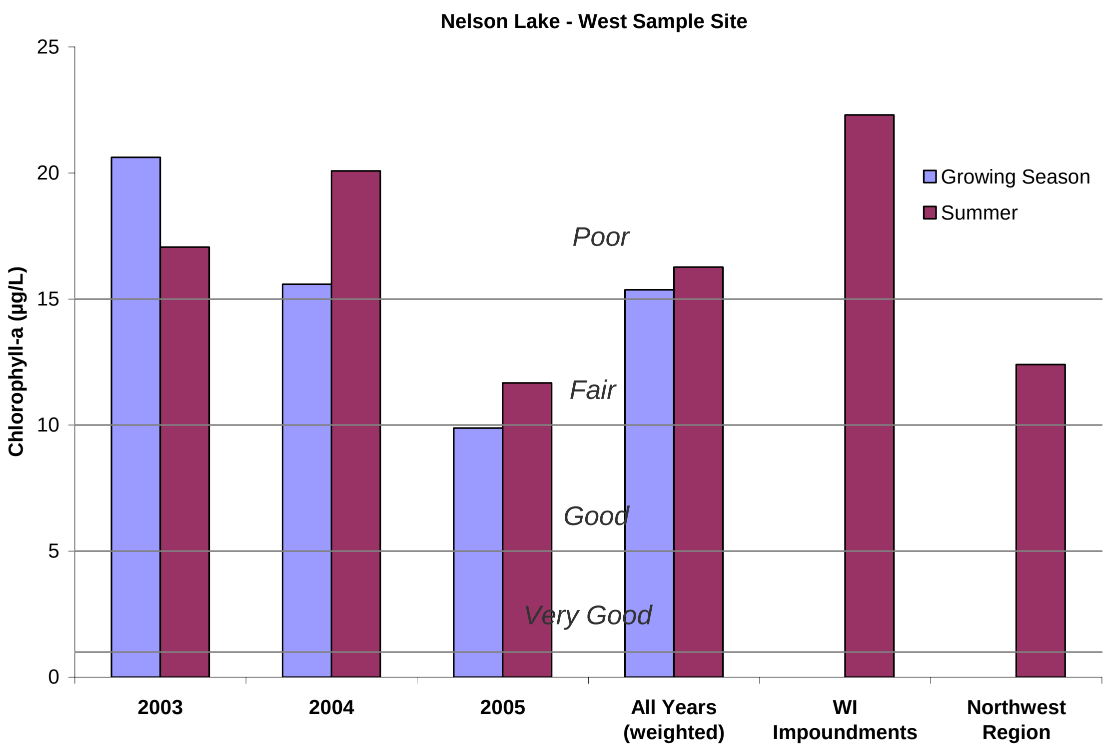
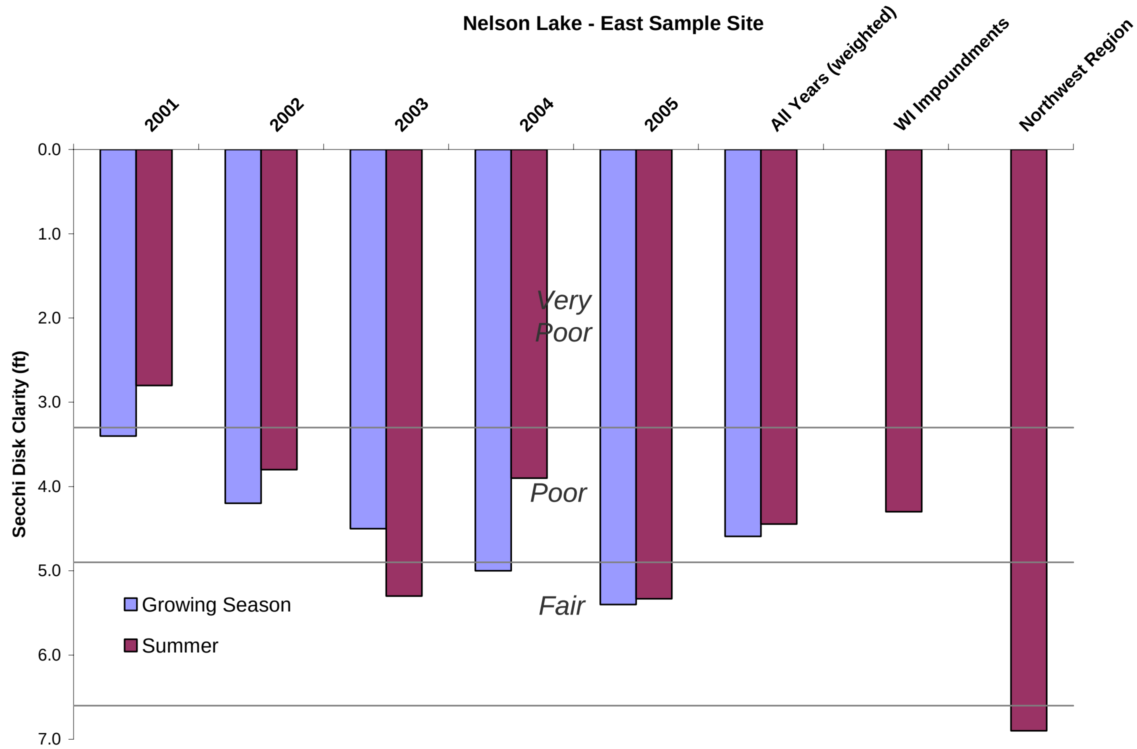


Figure 3. Nelson Lake chlorophyll-*a* concentrations. Growing season means include values recorded spring – fall and summer means include values recorded June - August**.** Apparent water quality index ratings and state and regional means after Lillie & Mason (1983).



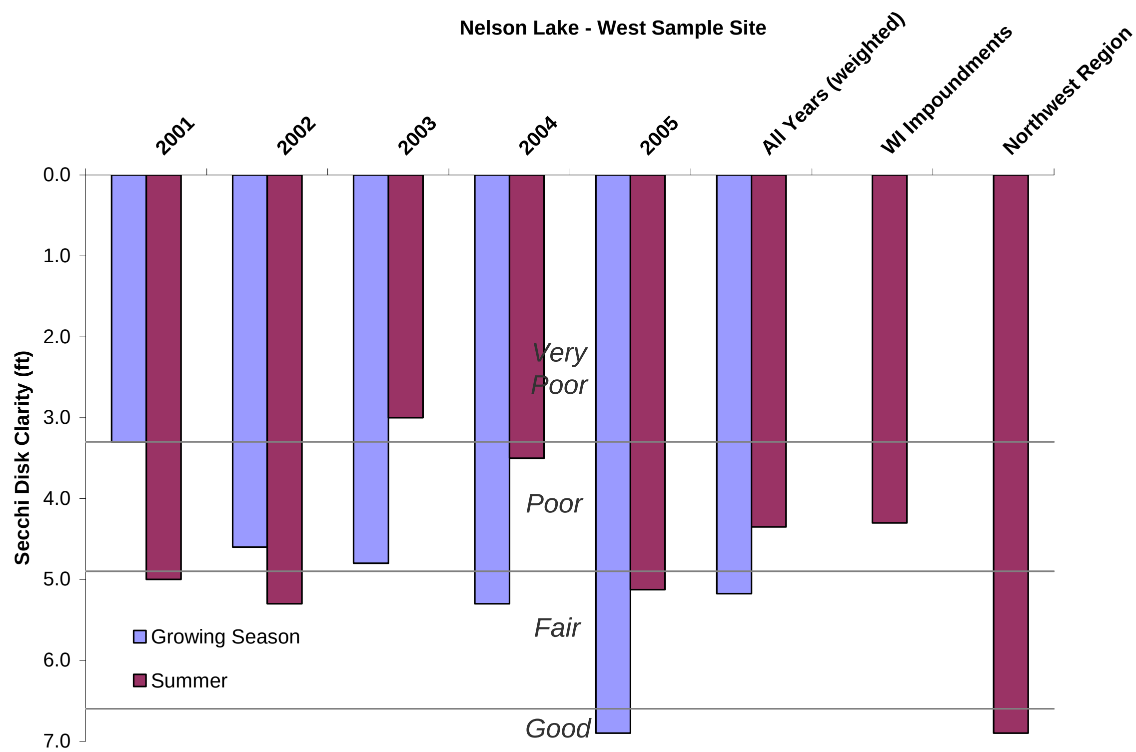
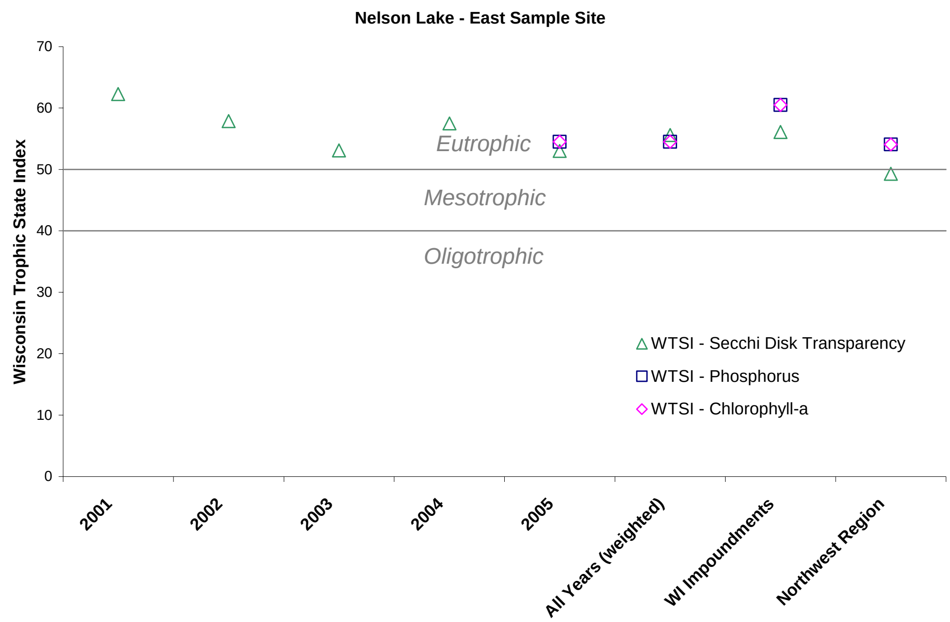


Figure 4. Nelson Lake Secchi disk clarity values. Growing season means include values recorded spring – fall and summer means include values recorded June - August**.** Apparent water quality index ratings and state and regional means after Lillie & Mason (1983).

The WTSI values for both the east and west sampling sites indicate that Nelson Lake is classified in a lower eutrophic state. There is very good agreement between the WTSI values generated from phosphorus and chlorophyll-*a* for both sites. The values calculated with Secchi disk transparency indicate that the lake is slightly more eutrophic; however, this increase is likely due to the stained water's influence on clarity values as discussed above. As with the other water quality data, Nelson Lake appears to be in a similar trophic state as other lakes in the Northwest Region and lower than other state impoundments.



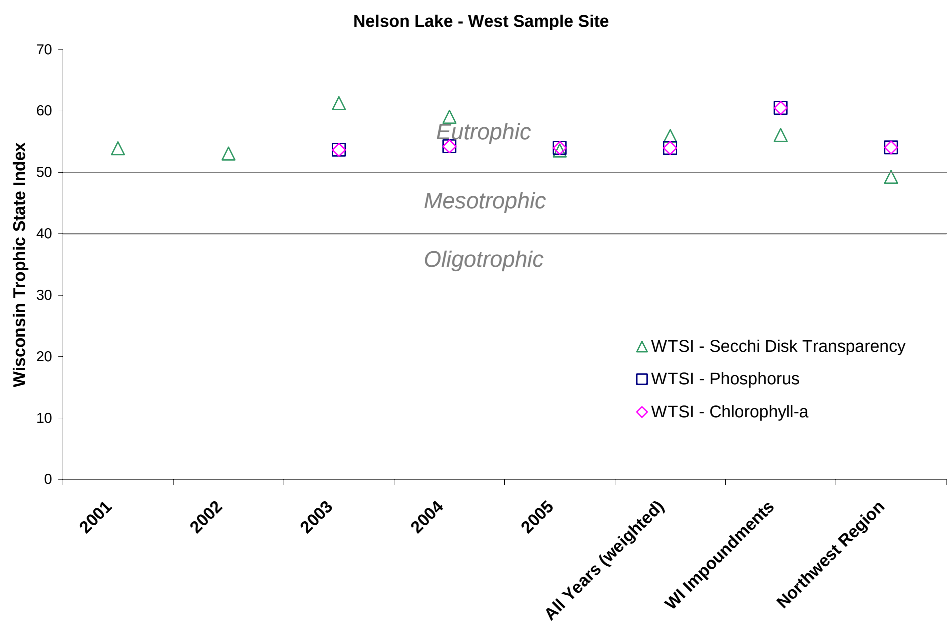


Figure 5. Nelson Lake Wisconsin Trophic State Index values. Calculations using summer surface and based upon Lillie, et al. (1993).

Aquatic Vegetation

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 Nelson 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 destroyed 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 litoral 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 both the applicator and the environment, so all lake organizations should seek consultation and/or services from professional applicators with training and experience in aquatic herbicide use.

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

<u>Fluridone</u> (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.

<u>Glyphosate</u> (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.

<u>Diquat</u> (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.

<u>Endothal</u> (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.

<u>2,4-D</u> (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 many of our native plants, which are monocots. Drinking and irrigation restrictions 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 an important 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 Nelson Lake. 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 Nelson Lake, plant samples were collected from plots laid out on a grid that covered the entire lake. 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 of Nelson Lake is 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.

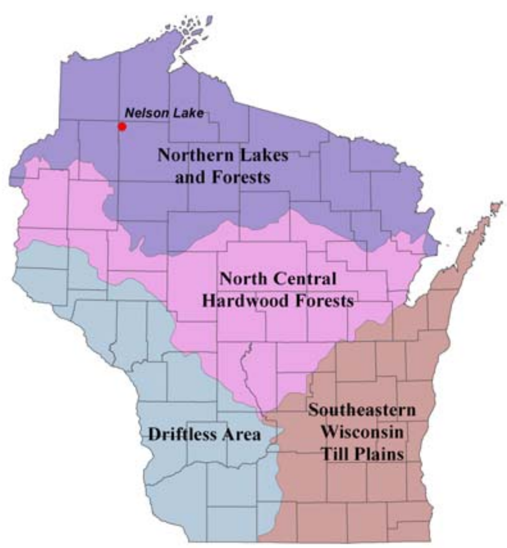


Figure 6. Location of Nelson Lake within the ecoregions of Wisconsin. After Nichols 1999.

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 surveys completed in the future. 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.

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 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.

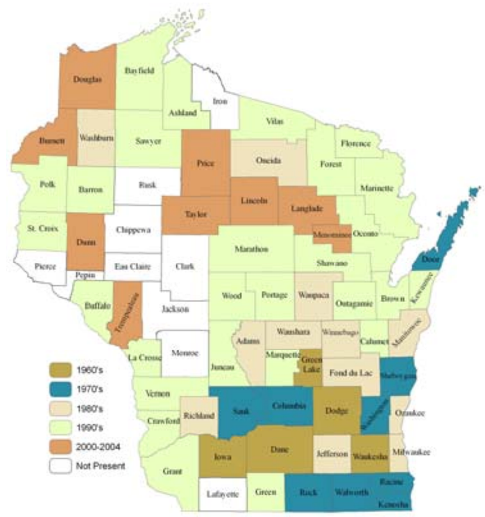


Figure 7. Spread of Eurasian water milfoil within WI counties. WDNR Data 2004 mapped by Onterra.

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.

2005 Surveys

The aquatic plant surveys completed in 2005 located 40 aquatic plant species within Nelson Lake (Table 1); of these, 38 were native species and two were exotics. The non-native species included single occurrences of purple loosestrife and an ornamental white water lily. The purple loosestrife was removed by hand following the study and same will occur with the ornamental species.

Table 1. Aquatic plant species located in Nelson Lake during the 2005 surveys.

Life Form	Scientific Name	Common Name	Coefficient of Conservatism (c)
Emergent	*Acorus calamus*	Sweetflag	7
	Calla palustris	Water arum	9
	Carex comosa	Bristly sedge	5
	Carex lacustris	Lake sedge	6
	Dulichium arundinaceum	Three-way sedge	9
	Eleocharis palustris	Creeping spikerush	6
	Equisetum fluviatile	Water horsetail	7
	Iris versicolor	Northern blue flag	5
	Lythrum salicaria	Purple loosestrife	Exotic
	Sagittaria graminea	Grass-leaved arrowhead	9
	Sagittaria latifolia	Common arrowhead	3
	Schoenoplectus tabernaemontani	Softstem bulrush	4
	Typha latifolia	Broad-leaved cattail	1
	Zizania palustris	Northern wild rice	8
FF	*Lemna trisulca*	Forked duckweed	6
	Spirodela polyrrhiza	Greater duckweed	5
FL	*Brasenia schreberi*	Watershield	7
	Nuphar variegata	Spatterdock	6
	Nymphaea odorata	White water lily	6
	Nymphaea odorata var. rosea	White water lily Ornamental	Exotic
FL/E	*Sparganium emersum*	Short-stemmed bur-reed	8
	Sparganium fluctuans	Floating-leaf bur-reed	10
Submergent	*Ceratophyllum demersum*	Coontail	3
	Elodea canadensis	Common waterweed	3
	Isoetes lacustris	Lake quillwort	8
	Megalodonta beckii	Water marigold	8
	Myriophyllum heterophyllum	Various-leaved water milfoil	7
	Myriophyllum sibiricum	Northern water milfoil	7
	Najas flexilis	Slender naiad	6
	Potamogeton amplifolius	Large-leaf pondweed	7
	Potamogeton epihydrus	Ribbon-leaf pondweed	8
	Potamogeton foliosus	Leafy pondweed	6
	Potamogeton gramineus	Variable pondweed	7
	Potamogeton natans	Floating-leaf pondweed	5
	Potamogeton richardsonii	Clasping-leaf pondweed	5
	Potamogeton robbinsii	Fern pondweed	8
	Potamogeton spirillus	Spiral-fruited pondweed	8
	Potamogeton zosteriformis	Flat-stem pondweed	6
	Utricularia vulgaris	Common bladderwort	7
	Vallisneria americana	Wild celery	6

FF = Free Floating
FL = Floating Leaf
FL/E = Floating Leaf and Emergent

Although Nelson Lake is largely dominated by fern pondweed and wild celery (Figure 8), it would still be considered a diverse system (Simpson's diversity = 0.90). Other common species that occur throughout much of the lake include clasping-leaf pondweed (often mistaken for curly-leaf pondweed), coontail, and spatterdock.

Overall, the FQA indicates that floristic quality of Nelson Lake (Figure 9) is excellent, especially when compared to median values for the state and ecoregion. As described above, floristic quality utilizes average conservatism value for all of the native species found in the lake and the total number of those species. Obviously, the high species richness of the lake is the major factor contributing to its excellent floristic quality as Nelson Lake's average conservatism value is slightly below the ecoregion median. The median values reported in Figure 8 were derived from a large dataset of plant studies from Wisconsin (Nichols 1999); however, only certain species were considered to be "lake plants" by the author and only those plants were assigned coefficient of conservatism values. The method states that if a species is included that is not in the list, then the average conservatism for the lake should be used as its coefficient of conservatism and the species richness should increase by one. Basically, this means that the species is given "credit" in the calculation only for being in the lake, but its fidelity towards a disturbed or undisturbed system (i.e., its coefficient of conservatism) is not considered. Recently, the WDNR has developed coefficients of conservatism for nearly every native plant in the state (WDNR 2003). Incidentally, the values listed in Nichols 1999 were used in the state values. The values reported in Figure 8 were calculated using the WDNR coefficients of conservatism for the plants that were not listed in Nichols (1999). In some cases, using the procedure in this way can inflate the species richness value to the point that comparisons with the median values developed by Nichols are unreasonable. In the case of Nelson Lake, only one species not included in Nichols (1999) was used in the calculations. Removing that species reduces the species richness to 37, leaves the average conservatism unaffected at 6.4, and decreases the floristic quality to 38.8. In the end, these are not significant changes; therefore, the values, as listed, are valid for comparison with the state and ecoregion medians.

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

The Nelson Lake average conservatism values are only slightly higher than the state and ecoregion medians. This indicates that many of the species present in the lake are indicative of a somewhat disturbed system. This is not a surprise considering Nelson Lake is an impoundment with portions of developed shoreline that experiences a great deal of recreational use. Still, the lake's plant community is outstanding as evidenced by the very high floristic quality and high index of diversity. The quality is also indicated by the high incidence of emergent and floating-leaf plant communities that occur in many areas of the lake (Draft Map 2). This is important, because these communities are often negatively affected by recreational use and shoreland development. Radomski and Goeman (2001) found a 66% reduction in vegetation coverage on developed shorelines when compared to undeveloped shorelines in Minnesota Lakes. Furthermore, 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. Many studies have documented the adverse affects of motorboat traffic on aquatic plants (e.g. Murphy and Eaton 1983, Vermaat and de Bruyne 1993, Mumma et al. 1996, Asplund and Cook 1997). In all of these studies, lower plant biomasses and/or declines and higher turbidity were associated with motorboat traffic.

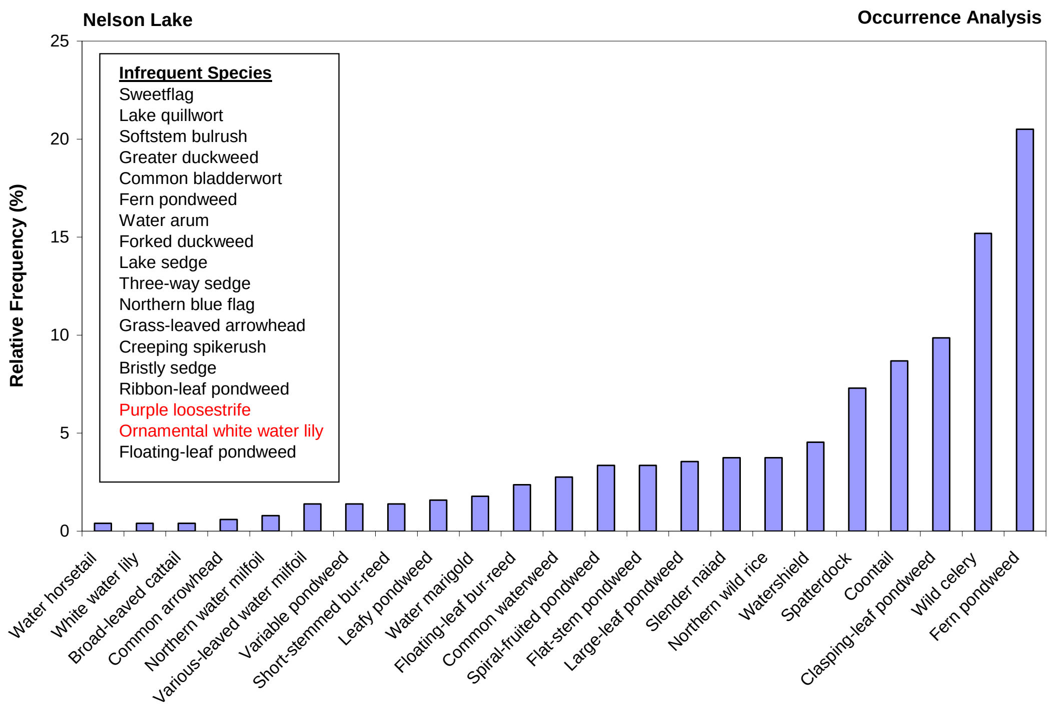


Figure 8. Nelson Lake aquatic plant occurrence analysis of 2005 survey data. Exotic species indicated with red.

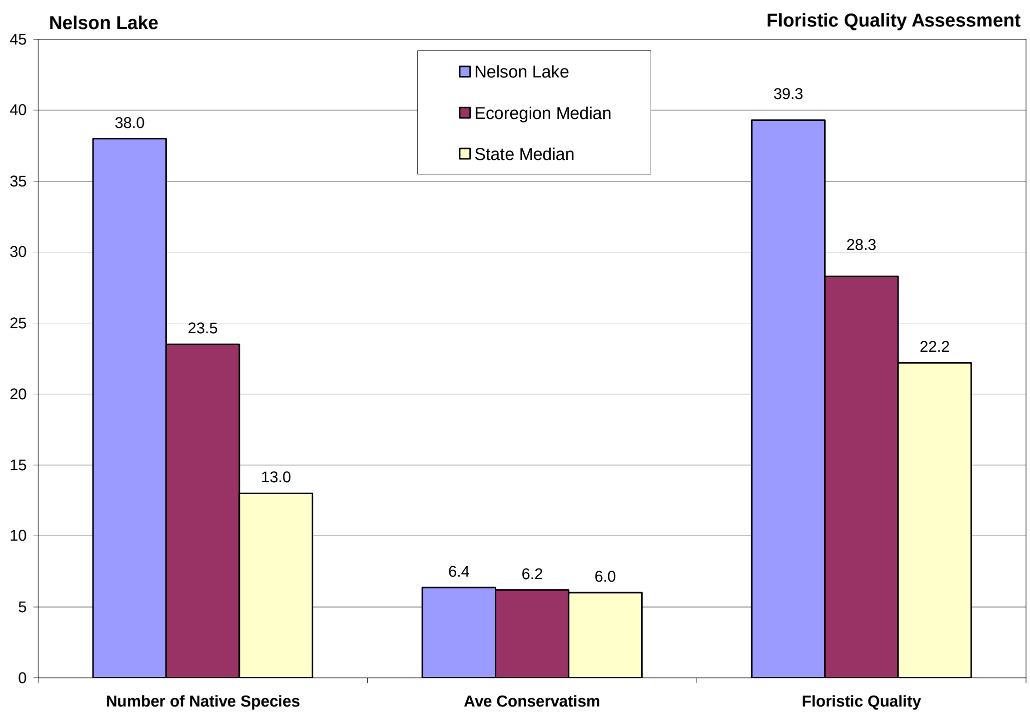


Figure 9. Floristic Quality Analysis using data from 2005 aquatic plant surveys completed on Nelson Lake. Analysis following Nichols 1999.

Watershed Analysis

Nelsons Lake's watershed (drainage basin), excluding the lake surface area, is approximately 32,137 acres (roughly 50 mi^2), yielding a watershed to lake area ratio of approximately 11.7:1. This is a relatively high ratio and lakes with higher ratios tend to have greater phosphorus concentrations relative to lakes with lower ratios. This is because 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 covers leads to increased pollutant loading; which, in turn, can lead to nuisance algal blooms, increased sedimentation, and/or overabundant macrophyte populations.

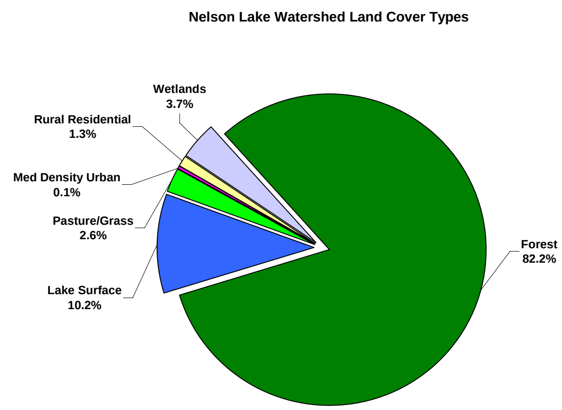


Figure 10. Nelson Lake watershed land cover types. WISCLAND data.

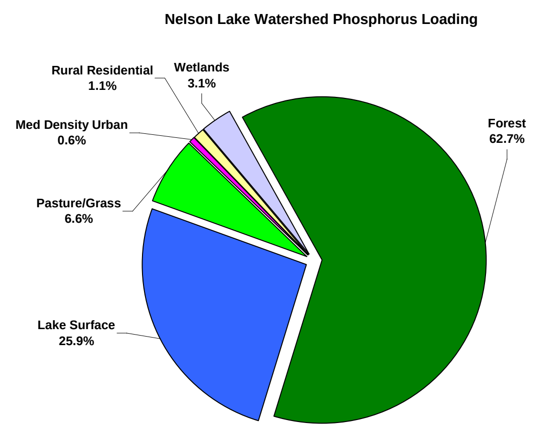


Figure 11. Nelson Lake watershed phosphorus loading by land cover type. WiLMS data.

Land cover data from the Wisconsin Initiative for Statewide Cooperation on Landscape Analysis and Data (WISCLAND) for the Nelson Lake watershed are displayed in Draft Map 3. Not surprisingly, the vast majority (over 82% including the surface area of the lake) 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 2,848 lbs of phosphorus enters Nelson Lake from its watershed annually. Further modeling through WiLMS indicates that the predicted load would result in mean growing season and spring overturn phosphorus concentrations of approximately 24 and 22 μg/L, respectively. The estimated concentrations correspond well to values collected at both the east and west sampling sites of Nelson Lake, indicating that the model portrays the system relatively well.

Figure 11 displays the percent contribution of each of the cover types found within the watershed. Interestingly, over a quarter of the total phosphorus load enters the lake at its surface through atmospheric fallout of dust particles and precipitation. Forested areas provide over

1,780 lbs, accounting for nearly 63% of the annual load. This may seem like quite a bit of phosphorus; however, it would only require 2002 acres of agricultural row crops, less than 10% of the forested area in Nelson Lake's watershed, to load the same amount of phosphorus to the lake. Obviously, having the vast majority of its watershed in a forested condition is a tremendous benefit to the well being of the lake. 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 and from surface runoff of the lake's immediate shorelands. 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 Nelson Lake 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 6 months out of the year, that would yield a use of 2 capita-years. Considering the residential development around the lake, the number of resorts, and the number of resorts that have been converted to condominium properties, a conservative estimate of 1200 capita-years would be appropriate for estimating the septic system impacts on Nelson Lake's phosphorus budget.

As a base estimate, the modeling was started by assuming that all of the septic systems were functioning and the septic fields retained 90% of the phosphorus passed through them. To demonstrate potential increases in loads, scenarios were modeled using specific percentages of system failure, specifically, 25%, 50%, and 75%. The results of the modeling are displayed in Figure 12.

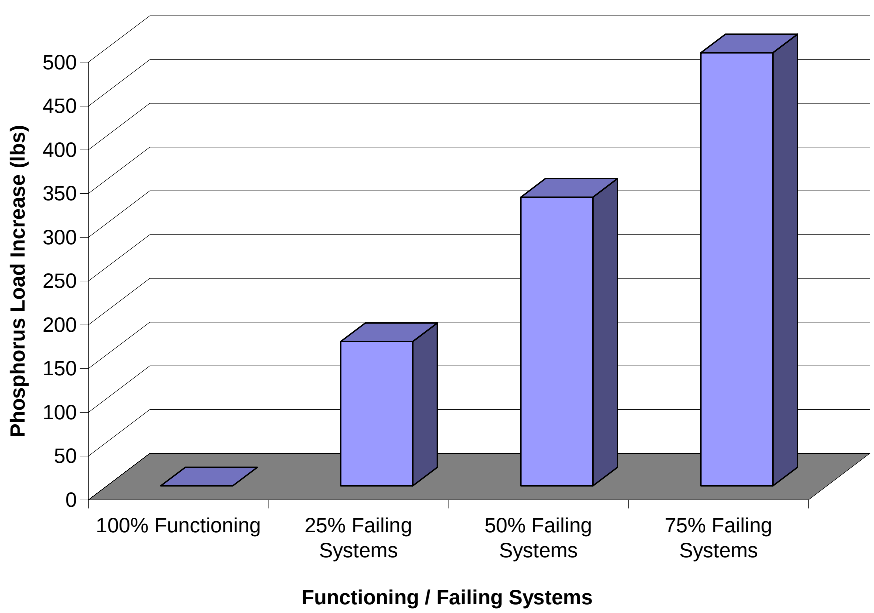


Figure 12. Potential phosphorus load increases to Nelson Lake with varying degrees of septic system failure. WiLMs data.

With only 25% of the systems failing (retaining only 40% of the phosphorus passing through them), there would be an additional 165 lbs of phosphorus added to Nelson Lake annually. The additional load doubles if 50% of the systems are failing and triples if 75% are failing. Considering the age of many of the properties and in turn, the age of their septic systems, a 25 to 50% failure rate may not be unreasonable. Taking into consideration that the system use estimates utilized in the modeling are likely very conservative, leads to the conclusion that these potential impacts could become reality.

Fisheries

In October 2004, the WDNR completed a fishery management plan for Nelson Lake (WDNR 2004). It should be noted here that the plan created for Nelson Lake is unique because it included a great deal of input from area anglers; a component that many fishery management plans lack. Fishery management is an important aspect in the comprehensive management of a lake ecosystem; therefore, a brief summary of the plan is included here as reference.

Historically, the Nelson Lake fishery was dominated by walleye and known for large panfish, pike, and even bullhead. In recent years, domination has shifted to largemouth bass. Wisconsin Natural Resources fisheries biologists believe minimum harvest length limits have caused the largemouth bass population to increase. They further believe that predation by largemouth bass on young pike and walleye has reduced the pike population and dramatically reduced the walleye population. Subsequently, lack of predation by walleye and pike on panfish has caused panfish populations to increase, but to be primarily comprised of smaller fish. Overharvest of moderately sized panfish may also have contributed to dense populations of small fish.

Among the goals of the WDNR management plan are an increase in the density of the Nelson Lake walleye population and an increase in the number of large panfish and pike. In order to attain these goals, extended-growth walleye will be stocked in Nelson Lake over a five-year period. In addition, the WDNR recommends that Nelson Lake water levels be kept at the optimum breeding levels, for walleye. The WDNR proposes strict harvest regulations for walleye, during the recovery period, and encourages even more conservative harvest than permitted by those strict regulations. The WDNR also strongly encourages people not to harvest small panfish, in order to allow for a greater number of individuals to reach a large size.

Perhaps the most critical component of the recovery of the Nelson Lake fishery is the reduction of the largemouth bass population. The most practical method of reducing the largemouth bass population is increased harvest. The WDNR encourages Nelson Lake fishermen to harvest every largemouth they catch. It is hoped that fewer largemouth bass, whose main foraging ground is the same vegetation used as a nursery by young walleye and pike, will increase the survival of young walleye and pike, and allow Nelson Lake to be the “special” fishery it once was, for many years.

SUMMARY AND CONCLUSIONS

The studies completed on Nelson Lake and its watershed indicates that the lake is in excellent condition. The lake is considered eutrophic, as indicated by the Wisconsin Trophic State Index; however, data from Lillie and Mason (1983) shows that lakes with watershed to lake area ratios between 8:1 and 15:1 normally exhibit summer total phosphorus levels between 33 and 48 µg/L. Nelson Lake's east basin averaged 29.7 µg/L total phosphorus during 2005 and the west basin averaged 27.7 µg/L during the summers of 2003-2005. Obviously, these values are much lower than would be expected and is likely the result of the forest-dominated watershed that feeds the lake.

Compared to other lakes in the ecoregion and the state, Nelson Lake's aquatic plant community is outstanding. This is exhibited by its high floristic quality index of 39.3 and its incredible Simpson's diversity index of 90.1. Furthermore, aquatic plant surveys completed in June and late July 2005 did not discover the occurrence of curly-leaf pondweed or Eurasian water milfoil, two of the most problematic aquatic invasive species in Wisconsin and the Midwest.

As mentioned above, the watershed of Nelson Lake is highly dominated by forest areas. Compared to other land cover types, forests export the least amount of phosphorus via surface runoff; therefore, having over 82% of the watershed in forest is very positive for the health of the lake. Furthermore, of the approximate 22,234 acres of forest, over 68% of it is in county forest land and nearly 21% is enlisted in the WDNR's Managed Forest Tax Law program (WDNR Forest Services Bureau 2005). This means that nearly 90% of the forest acreage is being managed and protected. With the exception of supporting the forestry programs at the state and local levels, urging private land owners to enroll in the programs or protect their properties in some other fashion, and encouraging the WDNR to continue pursuing the designation of portions of the Totogatic River as a Wisconsin Wild River, there is little that needs to be done to protect the watershed outside of those portions immediately surrounding the lake.

Currently, the three most important watershed threats that could negatively impact the lake's water quality, rest immediately around the lake and include:

1. Continued development of natural shoreline areas into residential and commercial areas.
2. The destruction of near-shore habitat that functions to buffer the lake from nutrient and sediment loads originating in developed areas.
3. Phosphorus leaching to the lake from failing shoreland septic systems.

The first two threats do not appear to be a great problem on the lake at this time, but may become more outstanding as properties change hands. Both can be minimized through the continued educational efforts of the Nelson Lake Association. The potential impacts of the third were demonstrated in the Watershed section and will require stakeholder education and most likely the inspection of private septic systems around Nelson Lake. Continued water quality monitoring is another important tool that can be utilized to minimize these threats.

By far, the greatest threat to the lake in general, its aquatic plant community, and in turn the important fisheries and wildlife habitat it provides, is the introduction and establishment of aquatic invasive species, such as, zebra and quagga mussels, curly-leaf pondweed, Eurasian water milfoil, purple loosestrife, and others. This threat can be minimized through lake user education that extends well beyond the members of the Nelson Lake Association and through diligent monitoring of the lake by volunteers and professionals.

IMPLEMENTATION PLAN

As described within the Results and Discussion Section and within the Conclusions, Nelson Lake is currently in good health; therefore, this implementation plan has been devised from the standpoint of lake *protection* as opposed to lake *restoration* or *enhancement*. Much of the work described here is already in progress; however, the Nelson Lake Association Planning Committee feels it is important to include these tasks within the implementation plan in order to document the association's efforts and to promote their continuation as active members turnover within the association.

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: Water Quality Committee

Description: Considering the outstanding natural condition of the lake's drainage basin, it is likely that the water quality of Nelson Lake is the best that it can be at this point in time. Therefore, the monitoring started in 2001 and continued through 2005 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 Small-scale Planning Grant through 2007.
2. Renew grant or enroll in similar program to continue monitoring efforts.
3. Provide periodic reports comparing results to stakeholders.
4. 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 Nelson Lake

Management Action: Provide education and information to shoreland property owners regarding shoreline protection and restoration.

Timeframe: In progress

Facilitator: Shoreline Preservation Committee

Description: Assuming the watershed outside of the immediate shoreline of Nelson Lake remains 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 lake are in acceptable condition to buffer the lake 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 lake. The education of current and new land owners concerning their property's impact to the lake 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 Sawyer County, along with data and conclusions included in the management plan to create a guide to shoreland property ownership on Nelson Lake.
2. Distribute guide to current property owners.
3. Monitor sales of existing properties and provide copies of the guide to the new owners.

Management Action: Promote land conservation in the Nelson Lake watershed.
Timeframe: In progress
Facilitator: Conservancy Committee
Description: Maintaining Nelson Lake's watershed in its current state is crucial to protecting the lake's current condition. Nearly 4% of the watershed is considered wetland and protected by state and federal regulations. Unfortunately, Wisconsin's forested areas are not protected by similar laws; therefore it is important to promote the conservation and proper management of the existing forest areas that make up over 82% of the Nelson Lake watershed.

Action Steps:

1. Encourage the WDNR to continue pursuing the designation of the Totogatic River as a Wisconsin Wild River.
2. Continue the partnership with the West Wisconsin Land Trust with the intention of urging key landowners within the watershed to protect their property's natural state through the development of easements and trusts.
3. Support Sawyer and Bayfield Counties and the WDNR in their quest to protect and properly manage existing woodlands through purchase and the Managed Forest Tax Program.

Management Action: Investigate feasibility of completing septic system inspections on shoreland and near-lake properties.
Timeframe: 2006
Facilitator: Water Quality Committee
Description: The potential negative impacts of failing shoreland septic systems are described in the Watershed Analysis section. In reality, this is likely the largest potential source of increased nutrient loading to Nelson Lake and as a result could lead to noticeable changes in the lake's condition in a relatively short period of time. Fortunately, Sawyer County has created a program that provides this service to lake groups if a majority of the shoreland property owners agree to participate. It is important to note here that this management action is intended only as a first step in this process and not initiative to begin the inspections.

Action Steps:

1. Discuss the potential need of these inspections with Mr. Merton Maki, Sawyer County Sanitarian.
2. If the need for inspections is justified, provide property owners with information concerning the program.
3. Conduct an informal poll to discover potential interest in the project.
4. If interest is apparent, complete formal petition of property owners.

Management Goal 3: Prevent Introduction and Establishment of Aquatic Invasive Species

Management Action: Continue in-lake invasive species monitoring.
Timeframe: In progress
Facilitator: Invasive Species Committee
Description: Early detection of aquatic invasive species is key to preventing the establishment of these species if introduction were to occur.
Action Steps:

1. Train a core group of volunteers in the identification of common aquatic invasives such as Eurasian water milfoil, curly-leaf pondweed, purple loosestrife, and zebra mussels. This group can then train others to assist in the monitoring efforts.
2. Perform annual lake inspections for invasives, including the maintenance of monitoring plates for zebra mussel detection.
3. Promote enlistment and training of new volunteers to keep invasives monitoring program fresh.
4. Continue trapping of rusty crayfish in cooperation with WDNR.

Management Action: Provide educational opportunities concerning aquatic invasive species.
Timeframe: In progress
Facilitator: Invasive Species Committee
Description: Promoting awareness among lake users is an important component in all aquatic invasive species prevention initiatives. This awareness can be promoted through educational opportunities that extend beyond shoreland property owners to frequent and occasional Nelson Lake visitors. Specific to Nelson Lake, awareness among resort owners and users is essential to the prevention of aquatic invasive species introductions. A portion of the costs associated with this management action would be applicable to the WDNR Aquatic Invasive Species Grant Program.
Action Steps:

1. Continue user education regarding aquatic invasives within the Nelson Lake newsletter. Occasional repeating of past informal articles will promote awareness among new members while solidifying knowledge of current members.
2. Renew key chain supplies displaying aquatic invasive species message to local boat dealers.
3. Provide specific information concerning aquatic invasive species to resort owners, including signage for rental units and boat landings.
4. Investigate other methods of promoting aquatic invasive species awareness, such as the insertion of invasives information within fishing licenses, restaurant placemats, etc.

Management Action: Continue periodic boat inspections at Nelson Lake access points.
Timeframe: In progress
Facilitator: T Invasive Species Committee
Description: Members of the Nelson Lake Association have attended Clean Boats Clean Waters training sessions and have participated in boat inspections at Nelson Lake landings. Boat landings, including those within resort properties, are high-risk areas for the introduction of aquatic invasive species. Continued participation in this program is a critical component in not only preventing the introduction of aquatic invasive species, but also in promotion of aquatic invasives awareness among all lake users.

Action Steps:

1. Continue period boat inspections during high-risk weekends as volunteer capacity allows.
2. Promote enlistment and training of new of volunteers to keep program fresh.

METHODS

Lake Water Quality

Baseline water quality conditions were studied to assist in identifying potential water quality problems in Nelson Lake (e.g., elevated phosphorus levels, anaerobic conditions, etc.). Water quality was monitored at two sites within Nelson Lake (Map 1). Samples were collected by Citizens Lake Monitoring Network volunteers and following WDNR protocols. The following sampling scheme was utilized by the volunteers at both sites.

Parameter	Spring		June		July		August		Fall	
	S	B	S	B	S	B	S	B	S	B
Total Phosphorus	●		●	●	●	●	●	●	●	
Chlorophyll a			●		●		●		●	
Total Kjeldahl Nitrogen	●	●	●	●	●	●	●	●	●	●
Nitrate-Nitrite Nitrogen	●	●	●	●	●	●	●	●	●	●
Laboratory Conductivity	●				●				●	
Laboratory pH	●				●				●	
Total Alkalinity	●				●				●	
Total Suspended Solids	●				●				●	

In addition, during each sampling event Secchi disk transparency was recorded and a temperature and dissolved oxygen profile was be completed.

Aquatic Vegetation

A quantitative aquatic vegetation survey was conducted during July 25-27, 2005 utilizing the point-intercept methodology described in "Appendix C" of the Wisconsin Department of Natural Resource document, Aquatic Plant Management in Wisconsin - Draft, (April 25, 2005) The points used during the 2005 surveys were originally based upon 2004 WDNR guidelines; however, points were added to the survey to bring the resolution more inline with the 2005 guidelines. A point spacing of 120 meters resulted in 768 potential sample plots. During the survey, 360 points were sampled, while 186 were only checked for depth and 222 were not sampled because they were unreachable or beyond littoral depth.

Watershed Analysis

The watershed analysis began with an accurate delineation of Nelson Lake's drainage area using U.S.G.S. topographic survey maps and base GIS data from the WDNR. The watershed delineation was then transferred to a Geographic Information System (GIS). These data, along with land cover data from WISCLAND were then combined to determine the preliminary watershed land cover classifications. Aerial photography and information provided by the NLA was used to rectify the land cover information before it was modeled using the WDNR's Wisconsin Lake Modeling Suite (WiLMS) (Panuska and Kreider 2003)

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