MUNGER & BEAR LAKES

OCONTO COUNTY, WISCONSIN

COMPREHENSIVE LAKE MANAGEMENT PLANS

Prepared for the

Munger Bear Lakes District

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Prepared through the collaborative efforts of

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SUMMARY

Comprehensive studies of Munger and Bear Lakes, Oconto County, Wisconsin (Map 1) were completed during 2003. The studies were completed to provide information concerning the lakes and their watersheds so comprehensive lake management plans could be written for each lake. Funding for this study and the development of the plan was provided by the Wisconsin Department of Natural Resources Lake Management Grant Program and the Munger Bear Lakes District (MBLD).

Data from this study were analyzed with data collected during past studies and yielded the following major results:

- Current and limited historic water quality analysis indicates that the water quality of Munger and Bear Lakes appear to be good to very good.
- The current trophic state of both lakes is in the mid *mesotrophic* level.
- Internal nutrient loading is not considered a significant source of phosphorus in either lake.
- Although neither lake has an usual aquatic plant community, they are both believed to be supporting healthy populations of native species.
- Neither Munger nor Bear Lake was found to contain non-native species.
- Watershed analysis and modeling indicated that the watersheds of both lakes are in land covers that supply the least amount of phosphorus to the lakes as possible.

An action plan was developed to guide the future management efforts for Munger and Bear Lakes and includes alternatives addressing lake water quality, aquatic plant protection, watershed issues, and the continued education of stakeholders; with the intent of protecting the current state of the lakes.

INTRODUCTION

Munger and Bear Lakes are natural drainage lakes in Oconto County consisting of 96 and 78 surface acres, respectively. Water levels of both lakes are maintained by a dam at the Munger Lake outlet. Bear Lake is a slow-no-wake lake with the only boat access being through a channel that attaches it to Munger Lake at its southeast end. Munger Lake is more developed and is not a slow-no-wake lake.

A study sponsored by the Town of Lakewood indicated through existing land use modeling that both lakes were in very good condition related to phosphorus inputs from the watershed. Although the data from the Town of Lakewood sponsored study is excellent for managing town-wide land use and its affects on lakes through town zoning ordinances, it was not focused sufficiently to provide the necessary information to begin the process of developing a lake management plans specifically for Munger and Bear Lakes and their watersheds. Furthermore, no detailed studies of either lake's watershed, water quality, or aquatic plant community had been recently completed. Therefore, the Munger Bear Lakes District (MBLD) elected to complete in-depth studies aimed at gathering the detailed information required to begin the plan development process.

Notes on the Format of this Document

This document serves two purposes; 1) it fulfills the requirements for final reporting of studies that were partially funded through Wisconsin Department of Natural Resources (WDNR) Lake Planning Grants, and 2) it is the Lake Management Plans for both Munger and Bear Lakes. Care has been taken to keep the technical aspects of the document on laymen's terms as much as possible. To facilitate the ease of reading, certain topics are expanded upon within the text and technical terms are defined in a glossary (Appendix D.). Furthermore, the reporting of specific data is kept to a minimum within the text, but is wholly contained within the appendices. The management plans were combined as much as possible to reduce redundancy; however, some sections were naturally separated because even though the lakes are geographically similar, they are different in many ways.

Each study contained four major components, watershed analysis, aquatic vegetation, water quality, and education. Each section of the report and plan are generally separated into these four components.

For ease of reading and document compilation, the large format (11"x17") maps are contained at the end of the main report, but before the appendices.

RESULTS AND DISCUSSION

Lake Water Quality

Judging the water quality of a lake is a complicated task because each lake is different and because laypeople, stakeholders, and scientists use different qualifications to assess positives and negatives of a particular lake's quality. For instance, a lake user may think a lake is of low quality because its water is not perfectly clear, while a fisheries biologist might think the lake is great because it has a balanced and healthy fishery. Looking at the same lake, an aquatic toxicologist may say the lake is polluted because the sediments contain mercury and a lake manager might think the lake is fine because it has a moderate nutrient load entering if from its watershed. Furthermore, dealing with water quality data is not straightforward because most people do not understand what a particular level or concentration of a parameter means to the health of the lake. Knowing that your cholesterol level is 250 does not mean a thing until you learn levels over 200 may indicate a higher risk of heart disease. Within the framework of a comprehensive management plan we are mostly concerned with the water quality attributes that help us understand the *trophic state* of the lake. Keeping that goal in mind, we can learn a great deal about the health of a lake by focusing on certain parameters and then by comparing those data to historic data from the same lake and data from similar lakes in the region. To complete this task, three water quality parameters are focused upon:

1. **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 growth rates of the plants within the lake.
2. **Chlorophyll-*a*** is the pigment in plants that is used during *photosynthesis*. Chlorophyll-*a* concentrations indicate algal abundance within a lake.
3. **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 lake health. 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; in other words, 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 described above does not give clear indication of where a lake really exists in its trophic progression because the divisions really cover a wide range of lakes. Two lakes that are both considered mesotrophic may be on opposite ends of the range and may look very different from each other. To solve this problem, the parameters measured above can be used in a *trophic state index*. That advantage of using an index is that the procedure actually indicates were the lake is in its trophic progression by producing a number that can be tracked over time. The higher the number, the more trophic the lake is.

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

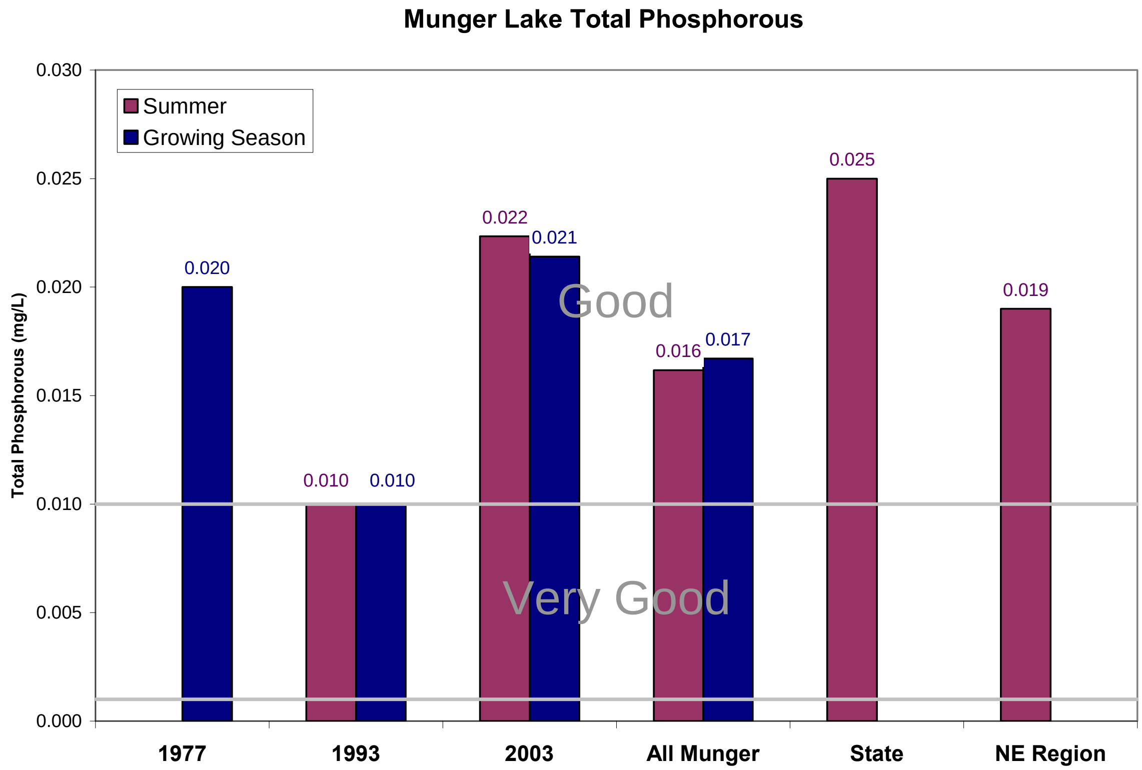
Water Quality Index

Lillie and Mason (1983) understood the difficulty of relaying information about lake water quality to the general public. As a solution, they developed an index of apparent water quality using the statewide database they compiled and studies completed by other researchers. Using their index, total phosphorus, chlorophyll-*a*, and water clarity values can be placed into ranges indicating if the level is **very poor**, **poor**, **fair**, **good**, **very good**, or **excellent**. These ranges are displayed with the data contained in Figures 1-3.

Comparisons with Other Datasets

A report compiled by Lillie and Mason (1983) is an excellent source for comparing lakes within specific regions of Wisconsin and within the state as a whole. They divided the state's lakes into five regions each having lakes of similar nature or apparent characteristics. Oconto County lakes are included within the study's Northeast Region and are among 243 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 means, historical, current, and average data from Munger and Bear Lakes are displayed in Figures 1-3. Please note that the data in these graphs represent samples taken only during the growing season (April-October) or summer months (June-August) in the deepest location in each lake (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 (see section on internal nutrient loading). Summer and growing season samples are used because it is during those months that the interactions between water clarity, nutrient levels, and algal biomass, as described above, are most apparent. It is also during those months that the most realistic trophic state can be determined.

Neither lake has sufficient historic data for the completion of sound long-term trend analysis, this is especially true concerning Bear Lake, for which no historic data is present. This is unfortunate because historic data provides insight to how changes within the lake's watershed or its recreational use may have affected the lake over time. Fortunately, both lakes have relatively good water quality, so the need for long-term data analysis is not as critical for the creation of a management plan as it would be with a lake that is exhibiting water quality problems such as nuisance algae blooms or excessive sedimentation.



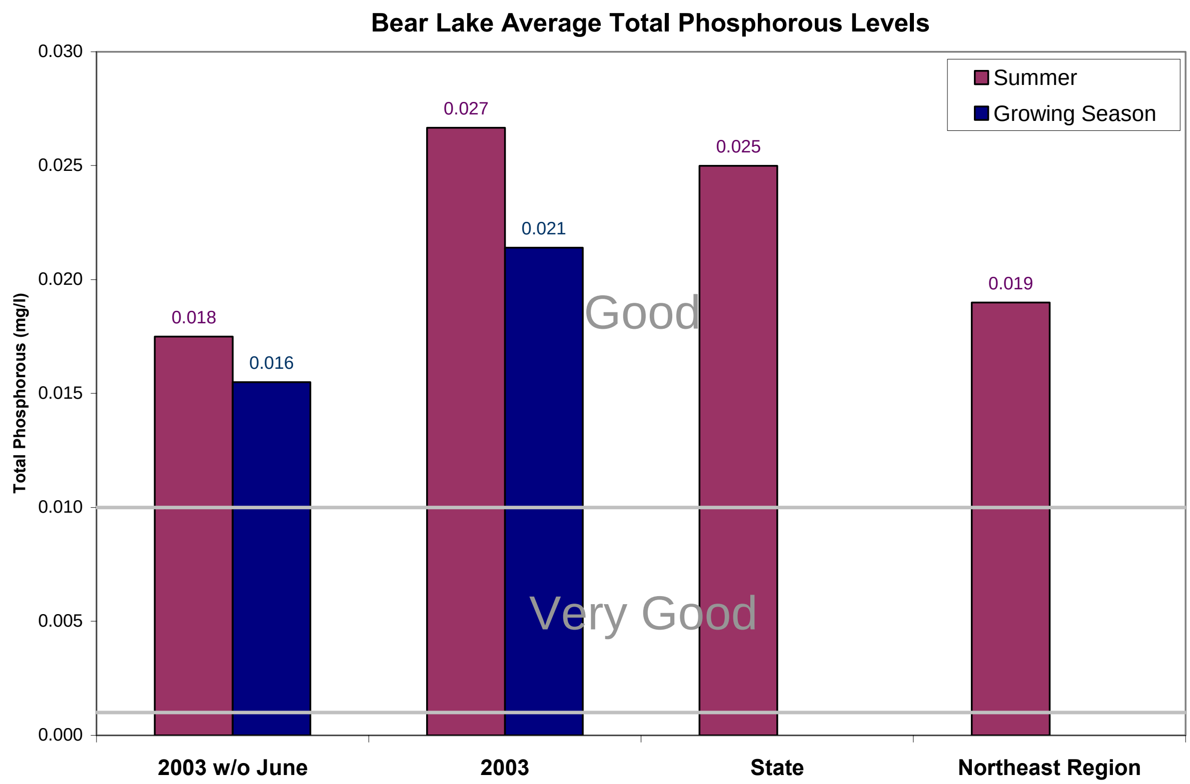
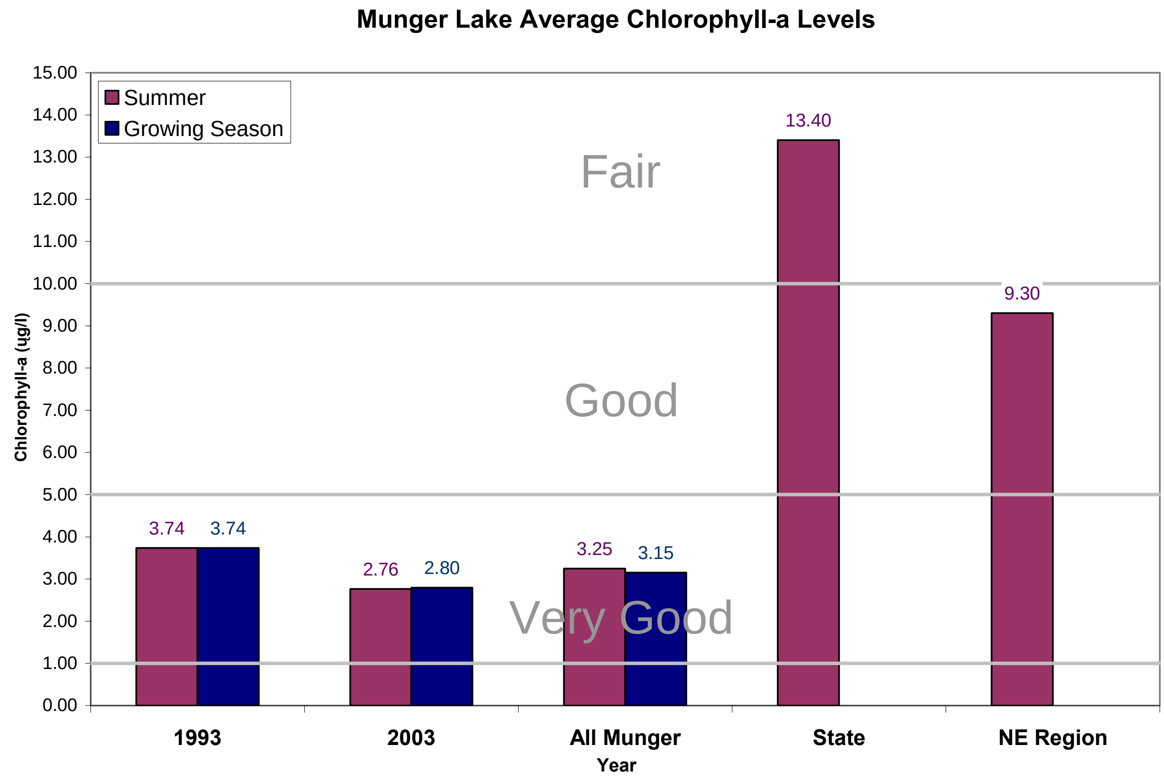


Figure 1. Mean total phosphorus concentrations from Munger and Bear Lakes, state and northeast region. All means were calculated from surface samples. Growing season includes April-October measurements. Lilly and Mason (1983) WQI indicated in gray typeface.



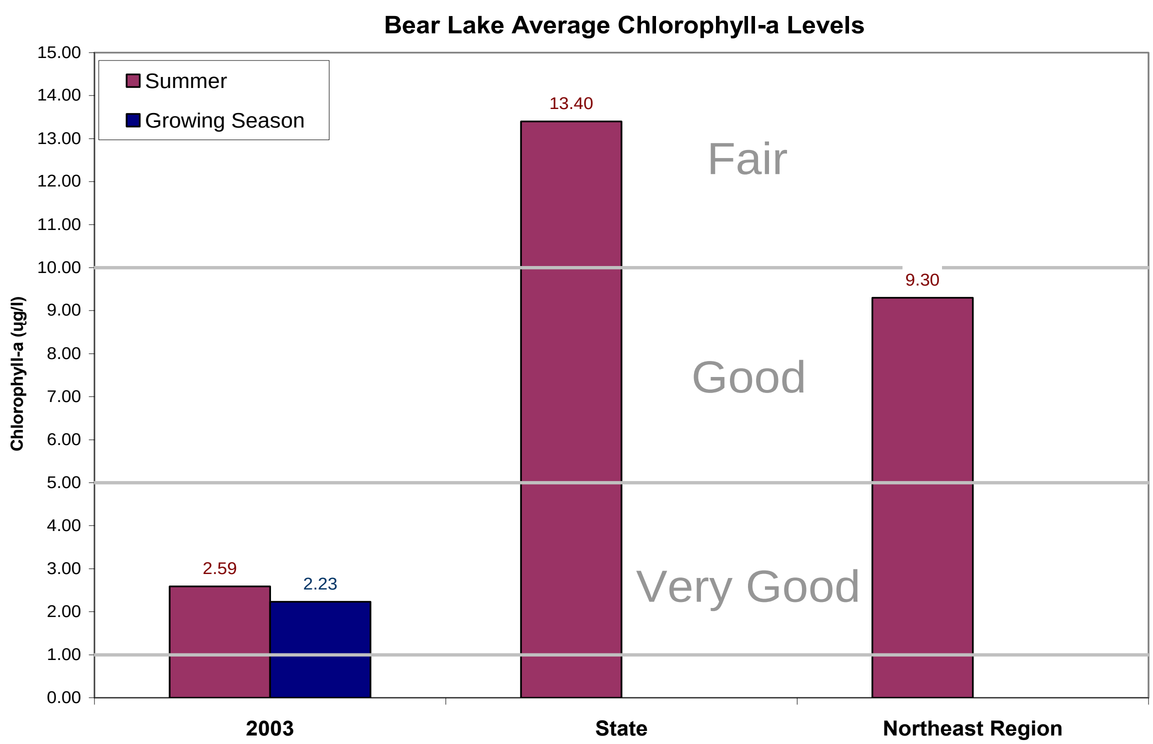
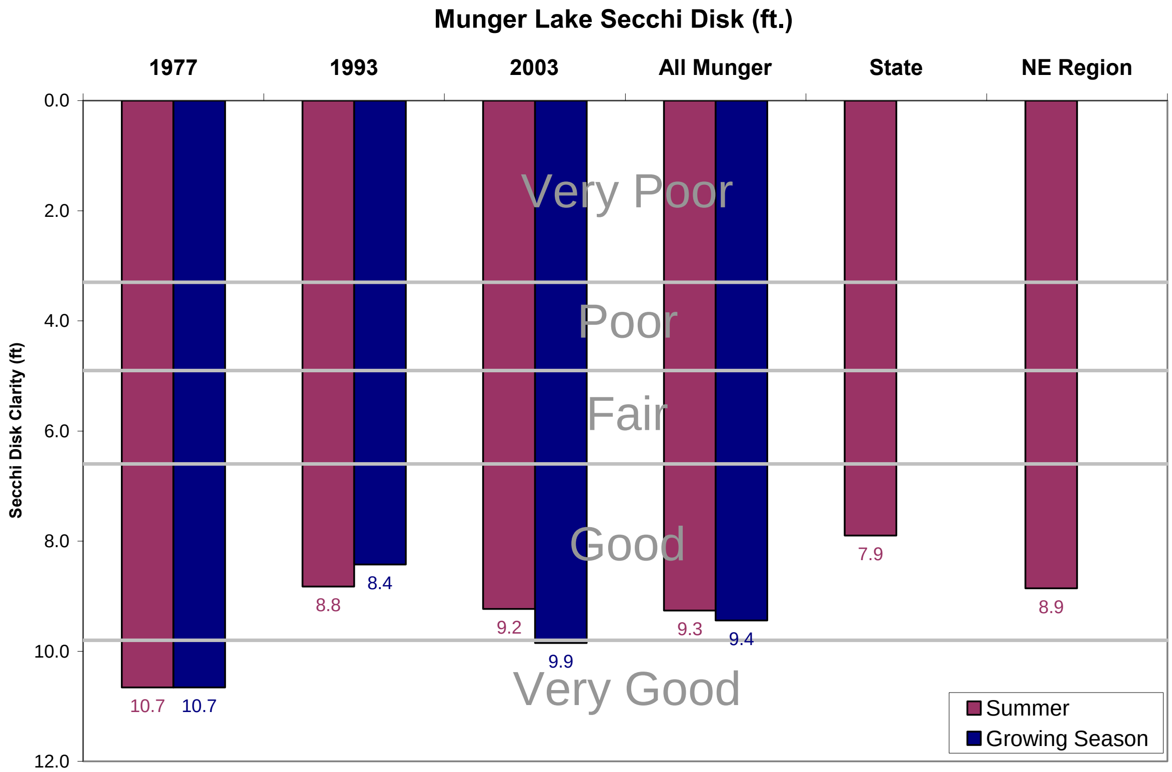


Figure 2. Mean chlorophyll-*a* concentrations from Munger and Bear Lakes, state and northeast region. All means were calculated from surface samples. Growing season includes April-October measurements. Lilly and Mason (1983) WQI indicated in gray typeface.



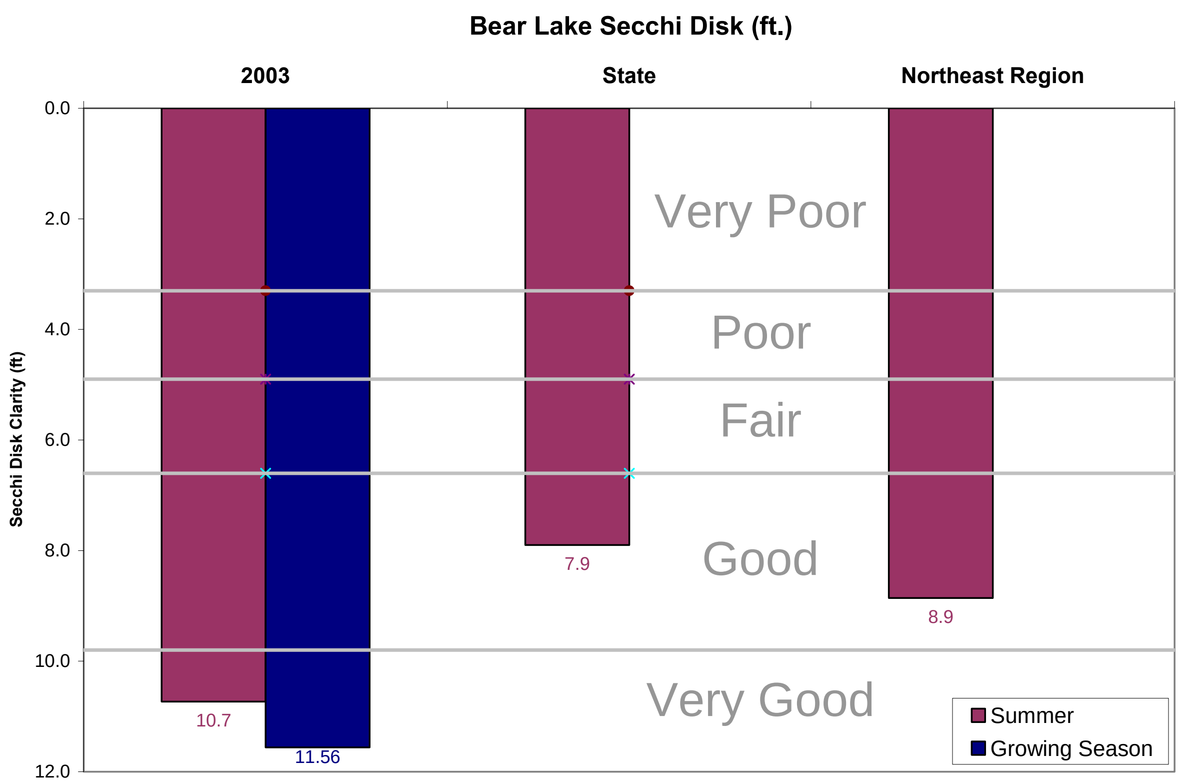


Figure 3. Mean Secchi disk transparencies from Munger and Bear Lakes, state and northeast region. Growing season includes April-October measurements. Lilly and Mason (1983) WQI indicated in gray typeface.

Examination of the graphs indicates that the water quality of both lakes fall into the "Good" to "Very Good" ranges and is normally better or even much better than those found in the state or region. The only exception to this fact is the total phosphorus data for Bear Lake. Using all the data collected in 2003 results in an average summer total phosphorus concentration of 0.027 mg/l and a growing season concentration of 0.021 mg/l (Figure 1). Although these averages would still be considered "Good", they are believed to be higher than would normally be found within the lake. Examination of the individual phosphorus samples from Bear Lake reveals that the surface, June 2003 total phosphorus level is unusually high (0.045 mg/l) when compared to the samples taken immediately before and after it (April: 0.011 mg/l and July: 0.016 mg/l). Fluctuations to this magnitude can take place naturally, but there would be an indication as to why it would have occurred. For example, a lake may mix and bring up high concentrations of phosphorus from bottom waters (see section on internal nutrient loading below) or a large load of phosphorus may enter the lake from its watershed as a result of an unusual precipitation event. However, neither of these are likely the case with Bear Lake. Examination of the oxygen profile (Figure 5) shows that the lake was not highly mixed at the time of the sample. Plus, the near bottom sample had a much lower concentration of total phosphorus at 0.016 mg/l. WDNR daily precipitation data from Lakewood were reviewed, and it was found that no precipitation was measured for the six days preceding the sampling event (June 18, 2003). As a result, it is believed that the sample was misanalyzed or contaminated in some manner; therefore, Figure 1 and the trophic state data used in the discussion below contain an addition average calculation for total phosphorus that did not include the Bear Lake June 2003 sample results. When that data point is not included in the calculation, the average phosphorus level falls well below the state and regional levels.

As mentioned above, sufficient data does not exist to determine if the water quality in either lake is improving or degrading. Even the historic data available for Munger Lake is not enough to tell us if the lake is better or worse than in the past. The situation outlined above concerning the June sample from Bear Lake and the inability to determine long-term trends in either lake emphasizes the need for the continued collection of data on both of these lakes.

Lake Trophic State and Limiting Nutrient

Figure 4 contains 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 in Munger and Bear 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. Using an index, such as the WTSI, allows the trophic state of a lake to be more easily understood and tracked by professionals and laypersons.

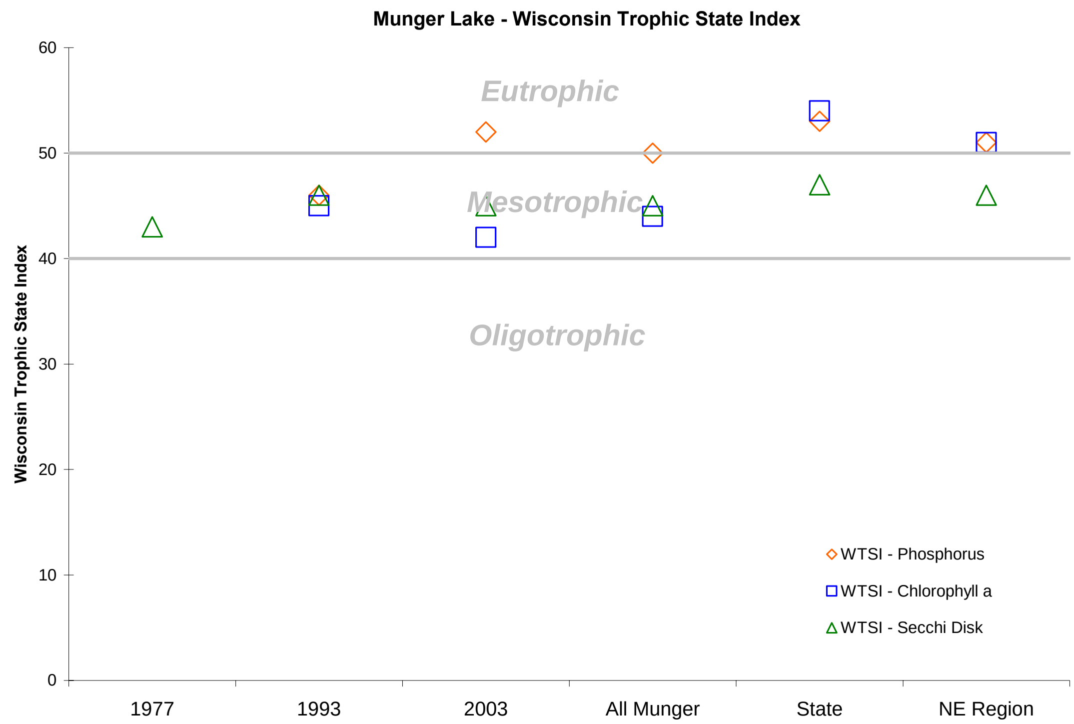
As described above, the trophic state of a lake is really the same as the productivity of the lake. Specifically, it is a function of primary production, which is basically the growth of plants. Within lakes, there are two basic groups of plants; macrophytes and algae. The whole concept of determining a lake's trophic status rests on the relationship between algae (chlorophyll-*a*), water clarity (Secchi disk depth), and nutrients (total phosphorus). Within this relationship, the indicator of primary production is the growth of algae as it is spurred on by phosphorus inputs. In many lakes algae is the most apparent primary producer; however, the majority of Wisconsin lakes are not overly dominated by algae; instead, most are dominated by macrophytes. In other words, the macrophytes are responsible for most of the primary production within the lake and therefore, responsible for most of the nutrient uptake. When macrophytes dominate a lake, they use the phosphorus that would be otherwise used by algae, and in the long run, keep the lake clearer. Not only does this have implications concerning trophic status, but it also shows one of the many reasons why a healthy macrophyte population is so important in a lake. Concerning trophic status, the competition between macrophytes and algae, among other complexities, means that we need to look at the whole picture concerning phosphorus levels, water clarity, and chlorophyll-*a*. A lake's trophic status cannot be reasonably determined using a single data point or parameter because so many things affect these parameters - precipitation, turnover events, recreational use, and exotic species, just to name a few.

The data displayed in Figure 4 indicates that both Munger and Bear Lakes are likely within the mesotrophic state. Considering the amount of macrophyte growth within each lake, it is likely that they are both in the mid-mesotrophic state, with Bear Lake being slightly lower on the scale. Interestingly, both lakes, one being more developed than the other and experiencing more recreational use, are similar concerning trophic state. This phenomenon is discussed more in the watershed section.

In most of Wisconsin's lakes, phosphorus is considered the *limiting nutrient* and Munger and Bear Lakes are no exception. Data collected during the growing summer of 2003 indicate a nitrogen to phosphorus ratio of 25:1 for both lakes (the June sample was not used in the Bear Lake calculation). Lakes with ratios exceeding 15:1 are considered to be phosphorus limited. Obviously, both lakes are phosphorus limited. Understanding the primary nutrient that controls plant growth within a lake is important because it helps to provide focus concerning lake management. If either lake was experiencing excessive plant growth, either macrophytic or algal, we would know to focus on minimizing phosphorus inputs opposed to nitrogen inputs.

Temperature and Dissolved Oxygen

Seven temperature and dissolved oxygen profiles were completed at each lake during 2003 (Figure 5). The profiles indicate that neither lake strongly stratifies during the summer months; however, it appears that moderate stratification may occur during the winter. At this time, the winter stratification does not appear to be a problem because neither lake develops a large volume of *anoxic* water, which in turn, limits the danger of fishkills. These statements must be qualified by emphasizing that they are made with limited data and that there is still a possibility that fishkills could occur in the future.



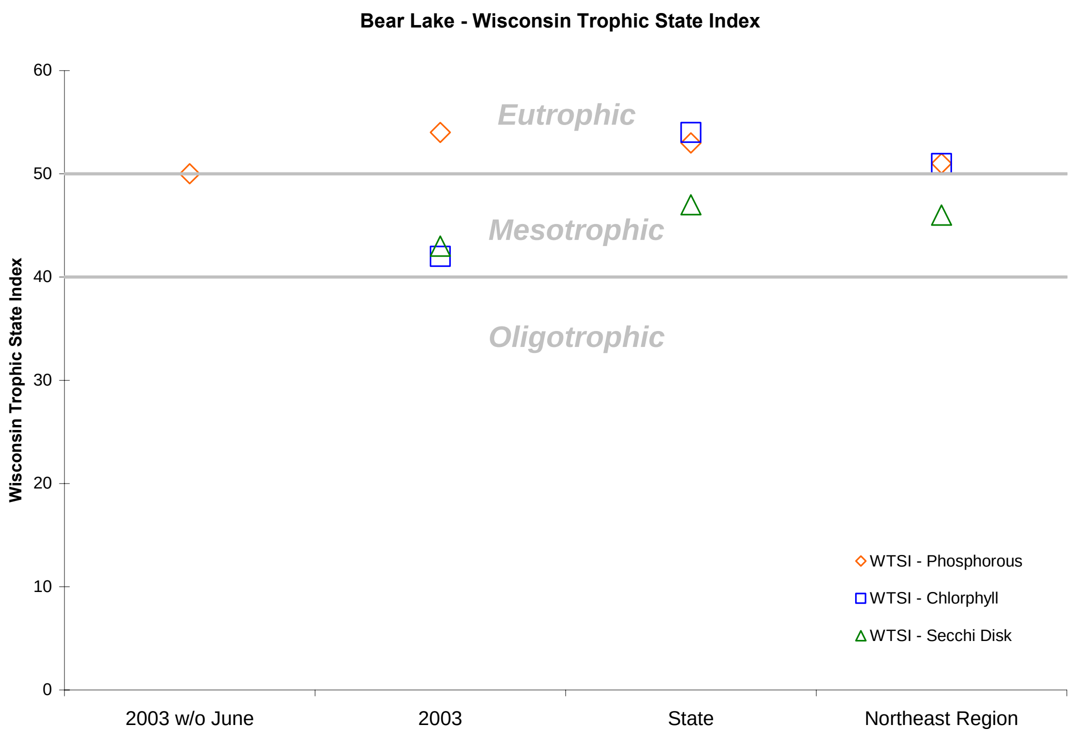


Figure 4. Wisconsin State Trophic Index results for Munger and Bear Lakes.

Internal Phosphorus Loading

In lakes that have strong stratification, the *hypolimnion*, can become *anoxic* both in the water column and within the sediment. When this occurs, iron changes from a form that normally binds phosphorus within the sediment to a form that releases it to the overlaying water. This can result in very high concentrations of phosphorus in the hypolimnion. Then, during the spring and fall turnover events, these high concentrations of phosphorus are mixed within the lake and utilized by algae. This cycle continues year after year and is termed "internal phosphorus loading;" a phenomenon that can support nuisance algae blooms decades after external sources are controlled. Internal nutrient loading is especially troubling in seepage lakes because the nutrients are not flushed out of the system, but remain to be recycled every year.

The analysis of three sets of data reveals that internal nutrient cycling is negligible within both lakes:

1. The temperature and dissolved oxygen profiles from both lakes indicates only moderate stratification. During stratification only a small portion of each volume is anoxic, if at all; therefore, only a minor volume of water would be available to hold unbound phosphorus for release to the lake as a whole during the spring turnover.
2. In general, lakes with hypolimnetic phosphorus levels below 0.050 mg/l do not exhibit high rates of internal loading. Both Munger and Bear Lakes were found to have levels below this threshold with values of 0.043 and 0.037 mg/l, respectively during March 2003.
3. As described in the Watershed section, the watershed modeling procedure indicated good agreement with standard lake phosphorus models. In other words, there is not an excessive amount of phosphorus within either lake that cannot be accounted for by the watershed phosphorus loading model.

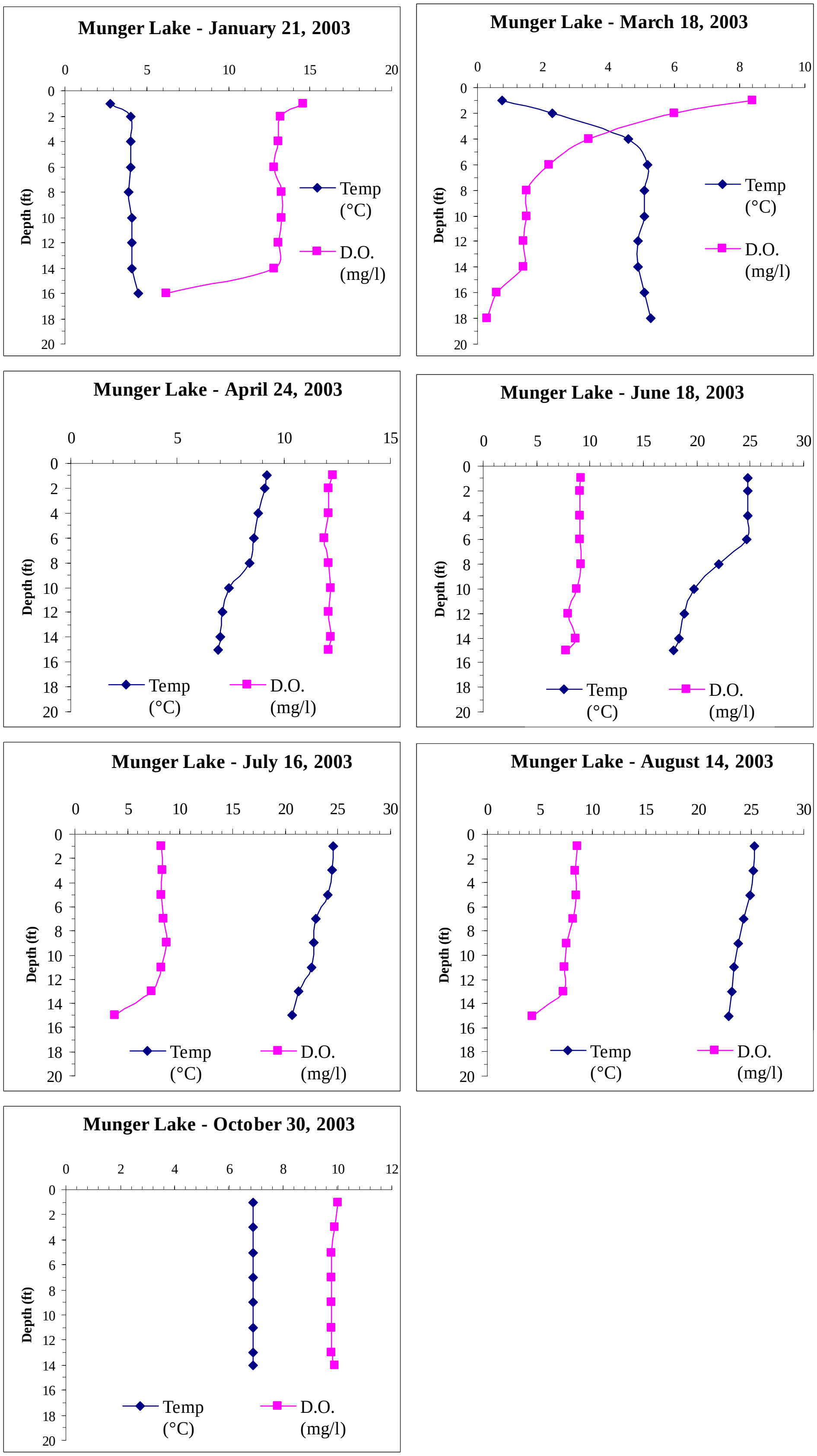


Figure 5. Dissolved oxygen and temperature profiles created during 2003 for Munger and Bear Lakes.

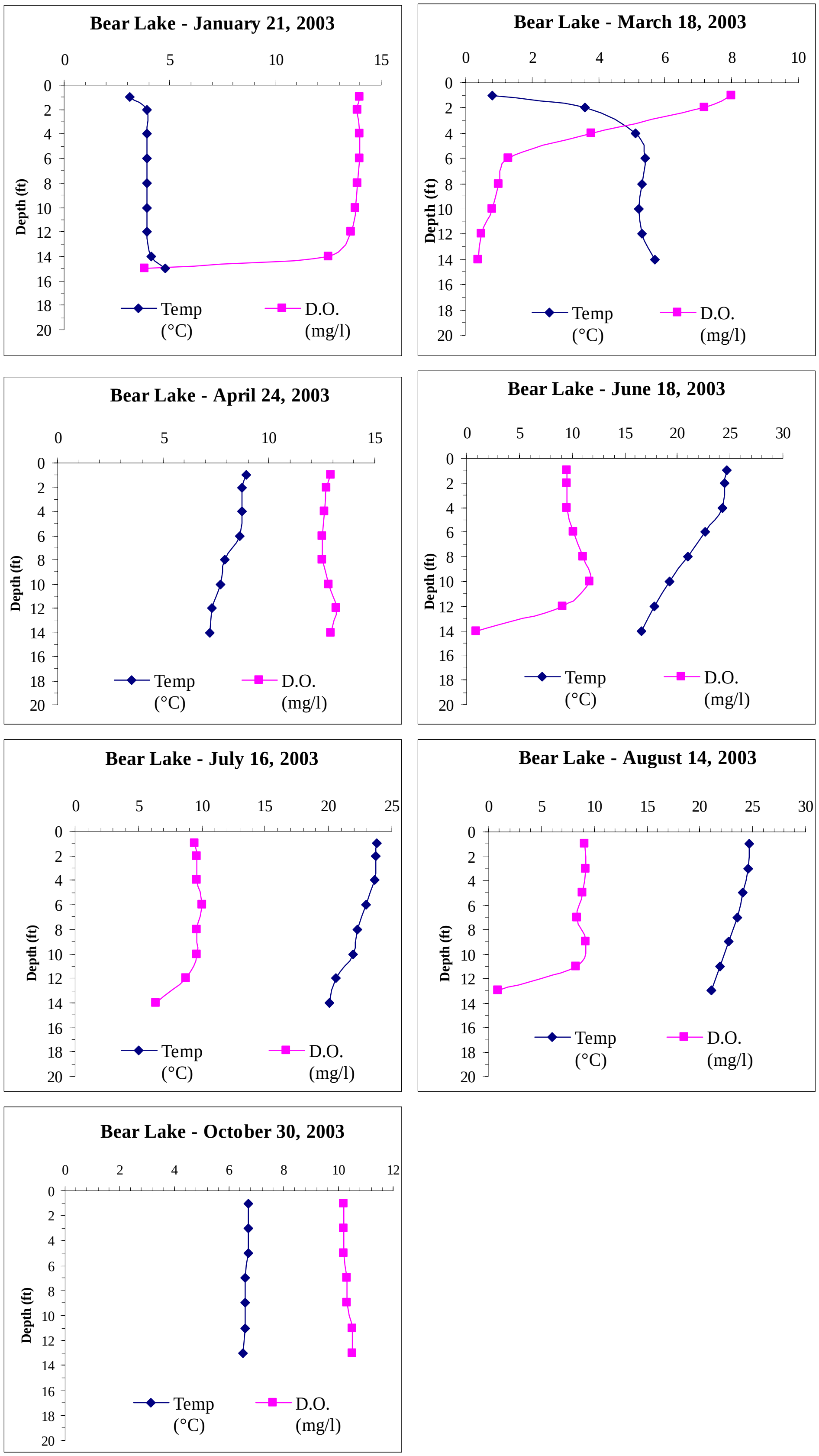


Figure 5 (continued). Dissolved oxygen and temperature profiles created during 2003 for Munger and Bear Lakes.

Aquatic Vegetation

Although many 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, 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 *Zizania palustris*) both serve as excellent food sources for ducks and geese. 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 where 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 plant 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 biomass negatively affects the lake ecosystem and limits the use of the resource, plant management 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.

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, grass carp (*Ctenopharyngodon idella*) are illegal in Wisconsin and rotovation is not commonly used. 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. **Although all of these techniques may not be applicable to Munger or Bear Lakes, it is still important for lake users to have a basic understanding of all the techniques so they can better understand why they are or are not applicable.**

Permits

The signing of the 2001-2003 State Budget by Gov. McCallum enacted many new aquatic plant management regulations. The rules for the new regulations have been set forth by the WDNR as NR 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 removal. Manual cutting and raking are exempt from the permit requirement if the area of plant removal is no more than 30 feet along the shoreline and all piers, boatlifts, swim rafts, and other recreational and water use devices are located within the 30 feet. Furthermore, installation of aquatic plants, even natives, requires approval from the WDNR. 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 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. 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 grading requirements, removal of shoreland stabilization (e.g., rip-rap, seawall), measures used to protect 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 $4,050.

- 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.

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.

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 other cutting method entails a two-sided straight blade on a telescoping pole that is swiped back and forth at the base of the 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 rerooting 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 recolonization on top of the screen.

Cost

Material costs range between $.20 and $1.25 per square-foot. Installation costs vary greatly depending on the size of the area to be covered and the depth of overlaying water.

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.
Installation in deep water may require SCUBA.
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.

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 and/or dredging 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.
Drastically upsets lake ecosystem with 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*).
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 very 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.
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.

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®) 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. 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*).

<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.

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 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, 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. 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, Wisconsin's climate is a bit harsh for these two invasive plants, so we do not use 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 to 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 $1.00/weevil and they are usually stocked in lots of 1000 or more.

Nutrient Reduction

Every plant, whether it is algal or vascular, requires nutrients to grow. The three primary, macronutrients include phosphorus, nitrogen, and carbon. Under normal conditions, lakes in Wisconsin are phosphorus limited and occasionally, nitrogen limited. If more of the nutrient is added to the system, the plant population expands; if the nutrient is taken away, the plant population decreases. However, rooted, vascular plants will not respond to nutrient reductions in the open water as quickly as algal populations will because they have the ability to take up nutrients from the sediment, and unfortunately, there is not a method currently available that will reduce or deactivate phosphorus and nitrogen in lake sediments. Nevertheless, it should be the goal of every lake organization to promote the minimization of all sources of nutrients and pollution entering the lake, whether they are in the form of a *nonpoint-source pollution* like runoff from agricultural and residential lands or *point-source pollution*, like an agricultural drain tile or storm sewer outfall. The reduction of these pollutants will slow the filling of the lake and reduce plant growth in the long-term.

Analysis of Current Aquatic Plant Data

Determining the health or condition of a lake by examining its aquatic plant community is a complex process because each community can consist of a variety of species at different densities. Historically, a lake's plant community was described by examining *species richness* and *species diversity*. Using these terms limits how plant communities from different lakes or plant data from the same lake, but from different time periods can be compared. For instance, two lakes could have completely different plant communities, one being made up of species that only grow in pristine systems and the other made of species that can grow in highly disturbed systems; yet these two lakes could have the same number of species and the same level of diversity. As a result, the comparison of these two lakes would yield that they are of the same quality, when obviously the more pristine lake is of higher quality.

A better method for evaluating a lake's quality through its plant community is by utilizing Nichols' (1999) Floristic Quality Assessment (FQA). Essentially, the FQA is a procedure that uses species conservatism, or a species' likelihood of occurring in an undisturbed system, along with the number of native species found in the lake to calculate the lake's Floristic Quality Index (FQI). The higher the FQI value, the closer the lake is to an undisturbed system. By using the FQA, a lake's quality can be compared to a "baseline" lake that would be considered high quality because it is pristine (undisturbed). Different lakes can also be compared because both are being referenced to the same baseline. The drawback is the fact that every lake is, in actuality, being compared to a pristine system. If a lake is not pristine, does this mean that it is not healthy or not functional? No, it just means that we have to use the FQA rationally by comparing similar lakes to each other. We do this by comparing lakes within the same ecoregion (Figure 6) and at most, within the same state.

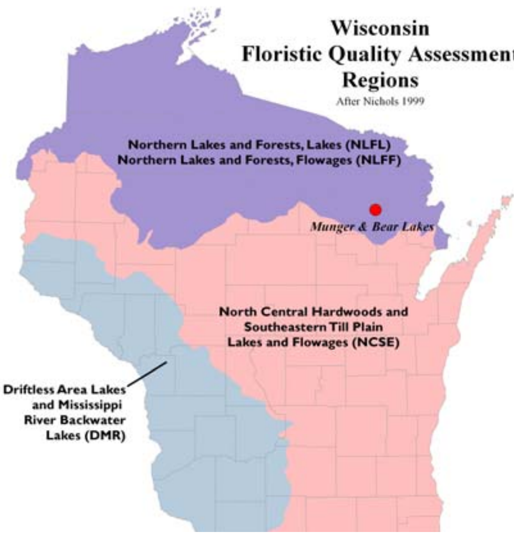
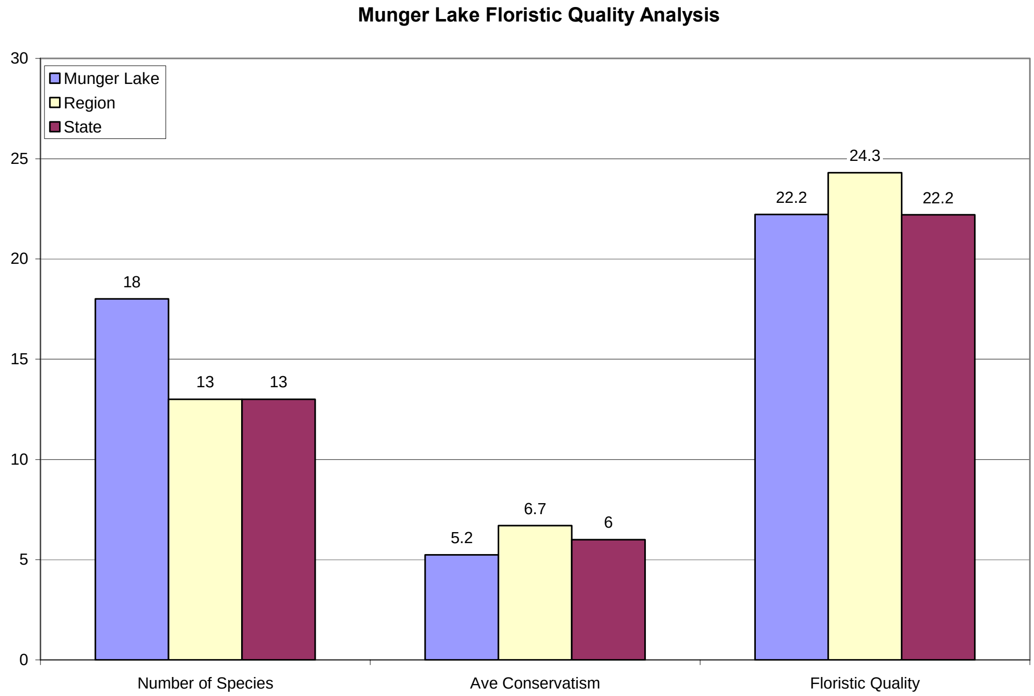


Figure 6. Wisconsin Floristic Quality Assessment Regions After Nichols 1999.

The FQA for Munger and Bear Lakes indicates that both lakes have healthy, but unremarkable plant communities when compared to other lakes in the ecoregion and the state (Figure 7). The fact that both lakes fall below the median values for the Northern Lakes and Forests, Lakes (NLFL) region is not a surprise because that region has some of the highest quality lakes in the state; some with little or no development on them. The Bear lake FQI is slightly below the state median while the value for Munger Lake is the same as the state median. In both cases, it is the lower than the state median average conservatism value that keeps the FQI from being higher. Bear Lake has the same number of species as the median value for the state and region, but a lower average conservatism. Munger Lake has a higher number of species than the others, but a much lower average conservatism value.

Comparing the FQA of the lakes to each other indicates that although Munger has more species in it, those species are indicative of a more disturbed system because it has a lower average species conservatism value. The higher species number found in Munger Lake may be the result of the lake having a public access, a higher rate of recreational use, and its shorelands being more developed. Simply put, human use is often responsible for species introduction within aquatic systems. However, these same *anthropogenic* impacts are also responsible for the lower average species conservatism value and most importantly, raise the risk of exotic species introductions. Not surprisingly, Bear Lake has a higher average species conservatism value; which is, of course, related to its lower recreational use and shoreland development. Although Munger Lake has a slightly higher floristic quality value, its higher rate for shoreland and recreational use makes it much more susceptible to changes that could reduce this value substantially.

The dominant plant species in both Munger and Bear Lakes was muskgrass, otherwise known simply as its genus *Chara* (Figure 8). Muskgrass grows very well in hard water lakes such as Munger and Bear, so it is no surprise that it dominates the plant communities of these lakes both in terms of frequency and coverage. Other dominant species for both lakes included Illinois pondweed (*Potamogeton illinoensis*) and northern water-milfoil (*Myriophyllum sibiricum*). A complete list of species occurring within each lake can be found in Table 2.



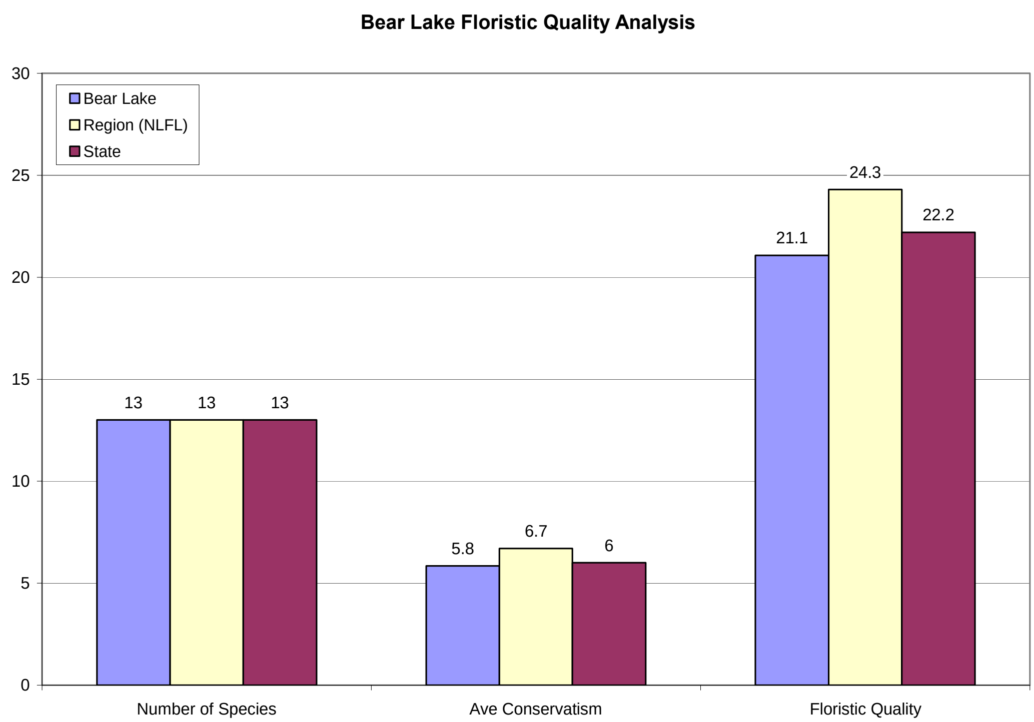
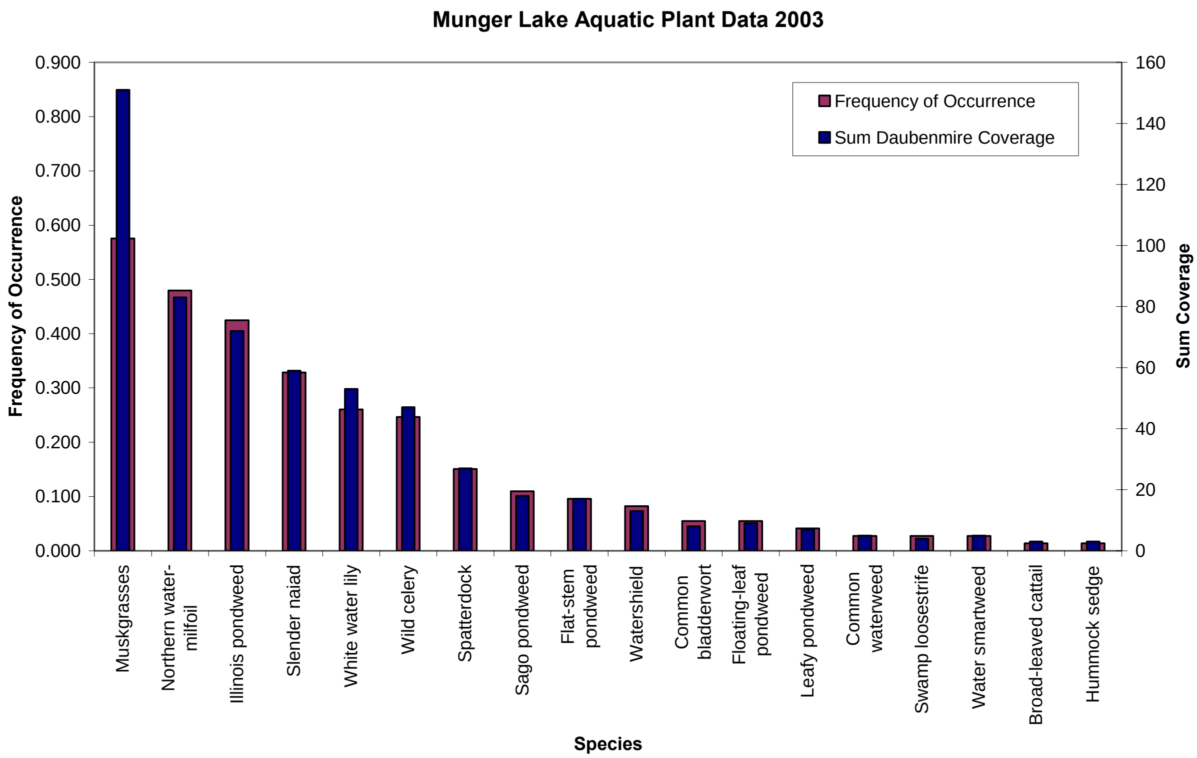


Figure 7. Floristic Quality Analysis for Munger and Bear Lakes. Data collected during July 2003.



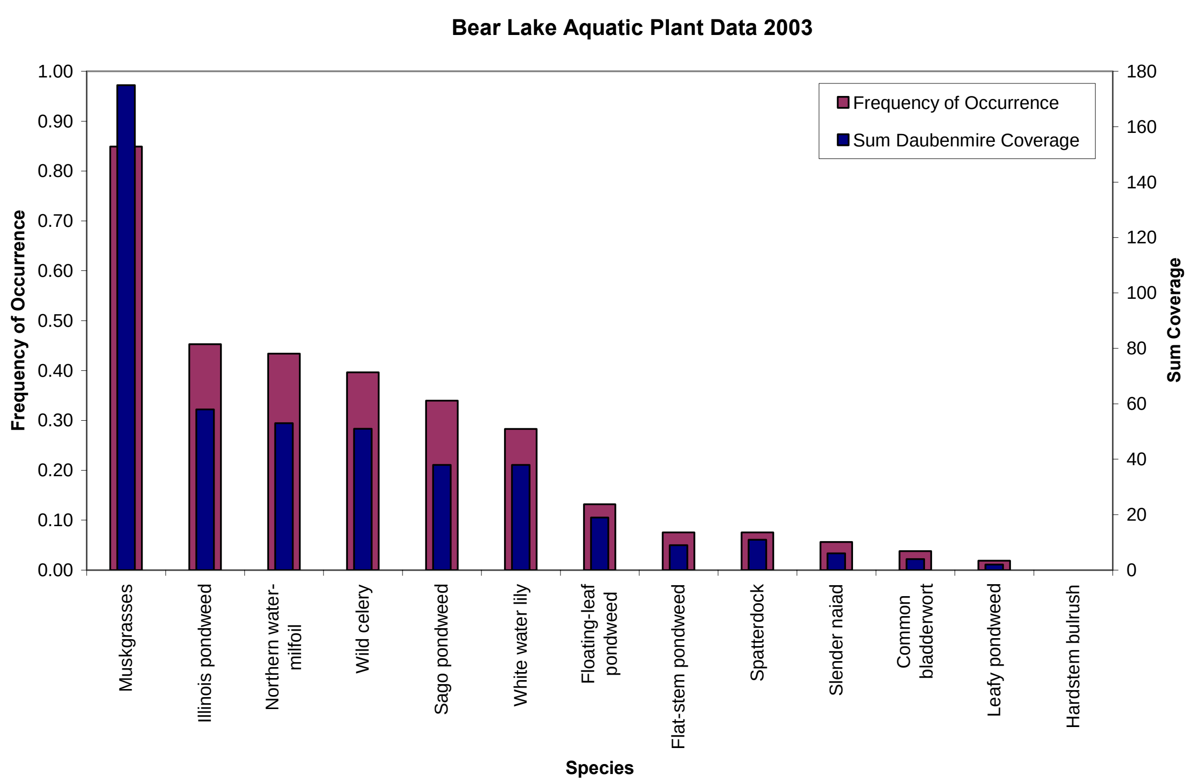


Figure 8. Frequency of occurrence and sum Daubenmire coverage values of Munger and Bear Lakes. Data collected during July 2003.

Table 1. Aquatic plant species occurring in Munger and Bear Lakes during the 2003 survey. Species are broken into community type and include coefficients of conservatism used in Floristic Quality Assessment (FQA). A detailed explanation of the FQA can be found in the Methods section.

	Scientific Name	Common Name	Coefficient of Conservatism (C)	Species Present	
				Munger	Bear
Emergent	*Decodon verticillatus*	Swamp loosestrife	5.4	✓	
	Typha latifolia	Broad-leaved cattail	1	✓	
	Carex stricta	Hummock sedge	5.4	✓	
	Schoenoplectus acutus[1]	Hardstem bulrush	5		✓
Floating-leaf	*Nymphaea odorata*	White water lily	6	✓	✓
	Nuphar variegata	Spatterdock	6	✓	✓
	Brasenia schreberi	Watershield	7	✓	
	Polygonum amphibium	Water smartweed	5	✓	
Submergent	*Chara sp.*	Muskgrasses	7	✓	✓
	Potamogeton illinoensis	Illinois pondweed	6	✓	✓
	Myriophyllum sibiricum	Northern water-milfoil	7	✓	✓
	Vallisneria americana	Wild celery	6	✓	✓
	Potamogeton pectinatus	Sago pondweed	3	✓	✓
	Potamogeton natans	Floating-leaf pondweed	5	✓	✓
	Potamogeton zosteriformis	Flat-stem pondweed	6	✓	✓
	Najas flexilis	Slender naiad	6	✓	✓
	Utricularia vulgaris	Common bladderwort	7	✓	✓
	Potamogeton foliosus	Leafy pondweed	6	✓	✓
	Elodea canadensis	Common waterweed	3	✓	

[1]Formally known as *Scirpus acutus*.

Map 2 displays the aquatic plant communities of Munger and Bear Lakes along with the dominant species within each community. Neither lake has a tremendous amount of emergent vegetation. This is especially true for Bear Lake. However, both lakes have excellent floating-leaf and submergent communities. These communities are import attributes to the well-being of the lakes and the ecosystem as a whole.

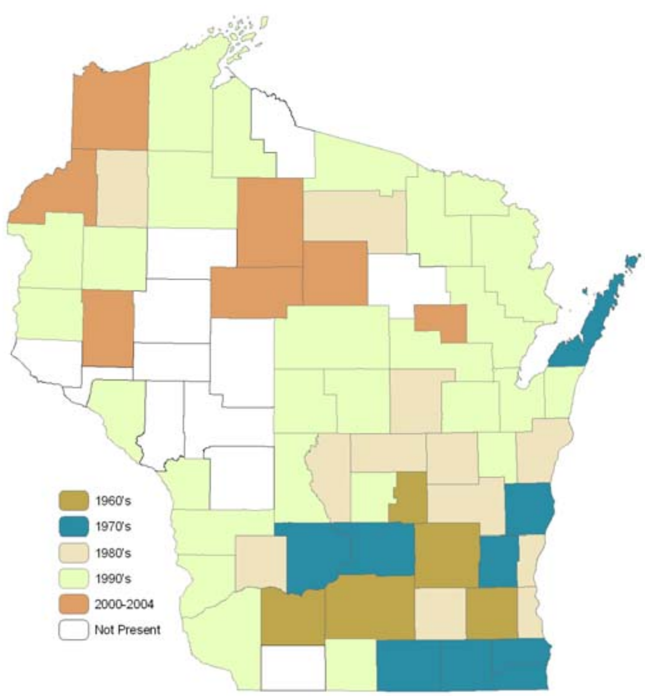


Figure 9. Eurasian water-milfoil spread in Wisconsin counties. Data from Wisconsin DNR.

Exotic Species

Eurasian water-milfoil (*Myriophyllum spicatum*) is an exotic, invasive species, native to Europe, Asia and North Africa, that has spread to most Wisconsin counties (Figure 9). 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 hampering recreational activities such as swimming, fishing, and boating.

Although the WDNR lists Munger Lake as having Eurasian water-milfoil within it, the plant was not found during the July 2003 survey. A second visit was made to the lake during late summer 2004 to verify that the colony south of the rock island was indeed the native, northern water-milfoil. Based upon leaf morphology and experience, it is believed that the colony is the native species. It is not conclusive that Eurasian water-milfoil does not exist within either lake; however, if even a small colony of 10-foot or so in diameter existed within either of the lakes, it is highly likely that it would have been found during the intensive surveys that were completed as a part of this study. Furthermore, no other exotic species were located in either lake during the study.

Watershed Analysis

The Munger and Bear Lake watersheds are approximately 841- and 297-acres respectively, which yield favorable watershed to lake area ratios of 8.7:1 and 3.8:1. In general, lakes with a ratio greater than 10:1 tend to have management problems that revolve around excessive amounts of phosphorus and/or sediments that enter the lake from its drainage basin. This is true because as the drainage area increases, so does the amount of nutrients and sediments that are delivered to the lake. This is not to say that every lake with a watershed to lake area ratio greater than 10:1 experiences problems, because the 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 infiltrate into the ground and do not produce an excessive amount of actual 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 lead to increased pollutant loading; which, in turn, can lead to nuisance algal blooms, increased sedimentation, and/or overabundant macrophyte populations.

Field-verified land use data for the Munger and Bear Lake watershed are displayed in Figure 10 and Map 3. Currently, the majority of land within the watershed of both lakes is either forested or in wetlands. As mentioned above, fully vegetated areas produce very little surface runoff; in fact, these areas allow 60-80% or greater of the precipitation that falls on them to infiltrate the ground. Having a large proportion of the watershed in these land use types does a great deal to prevent excessive phosphorus from loading to the lakes.

Modeling results of phosphorus loads to Munger and Bear Lakes based upon land cover are shown in Figure 11. According to the model, Munger Lake has approximately 92 lbs of phosphorus entering it annually. This is not a tremendous amount of phosphorus, which is one of the reasons why the water quality within the lake is considered good to very good most of the time. The same goes for Bear Lake. It has a modeled phosphorus load of about 46 lbs per year entering it from its watershed.

At this time, the biggest contributors to both of the lakes' phosphorus loads are categories that really cannot be controlled or even minimized. Forested and wetland areas, as mentioned above contribute the least amount of phosphorus per acre; therefore, converting them to anything else would only load more phosphorus to the lakes. The other big contributor for both lakes is the lake surfaces themselves. In other words, the phosphorus the enters the lakes through precipitation and atmospheric fallout. Again, even though it is a big percentage of the total phosphorus entering the lakes, it really is not that much in terms of pounds of phosphorus entering the lake. Specifically for Munger Lake, compared to the other categories, the amount of phosphorus entering from Bear Lake appears to be a great deal. However, considering the model indicates that about 46 lbs enters Bear Lake annually, the fact that it only releases about 15 lbs to Munger Lake every year is very acceptable.

Unfortunately, septic system data was not available for inclusion within the modeling; therefore, an estimate of their phosphorus loading impact on either of the lakes cannot be determined. However, examination of the Phosphorus Prediction and Uncertainty Analysis Module of the model used to determine phosphorus loads indicates that higher phosphorus concentrations would be expected for both lakes considering the estimated loads entering the lakes. This means that based upon the land uses in their watersheds, the models would expect higher measured levels of phosphorus within the lakes then were actually found during the water quality study. If the opposite were found (i.e. predicted values were much lower than measured values) two sources of phosphorus would be suspect for creating the higher actual values; 1) loads entering from septic systems and 2) internal phosphorus inputs. As discussed in the Water Quality section, the water quality analysis indicates that internal loading is negligible; therefore, the inputs from shoreland septic systems would be left. However, this is not the case; therefore, the conclusion must be, for at least the time being, that septic systems are likely having little affect on the nutrient dynamics of the lakes.

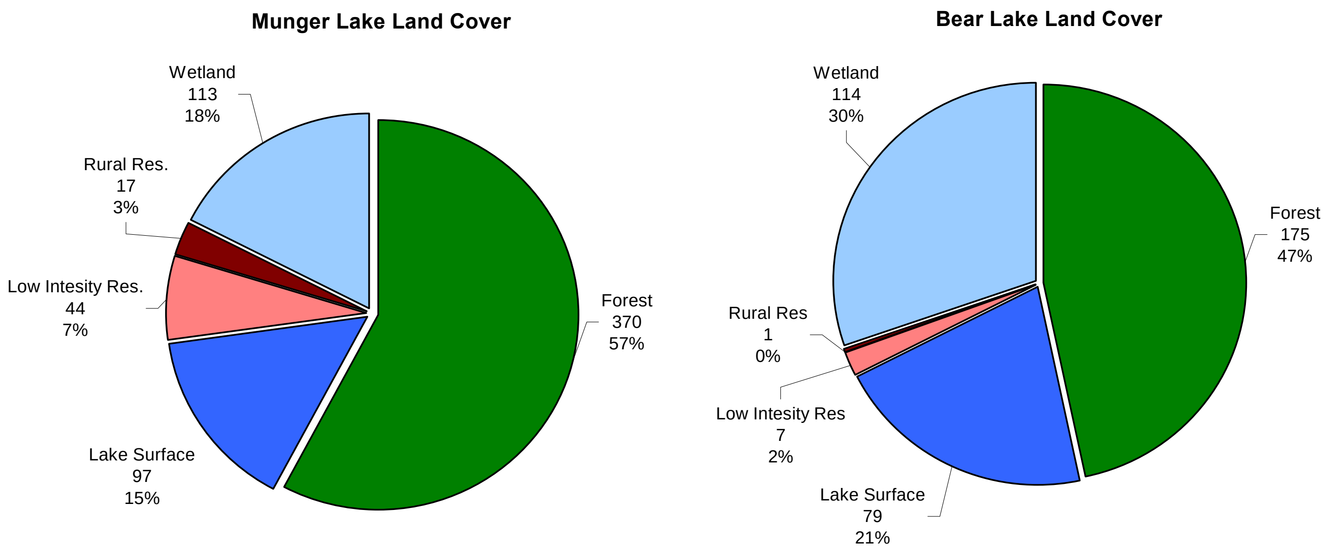


Figure 10. Land cover types and associated acreages within the Munger and Bear Lakes watershed. Percentages indicate percent of total watershed acreage.

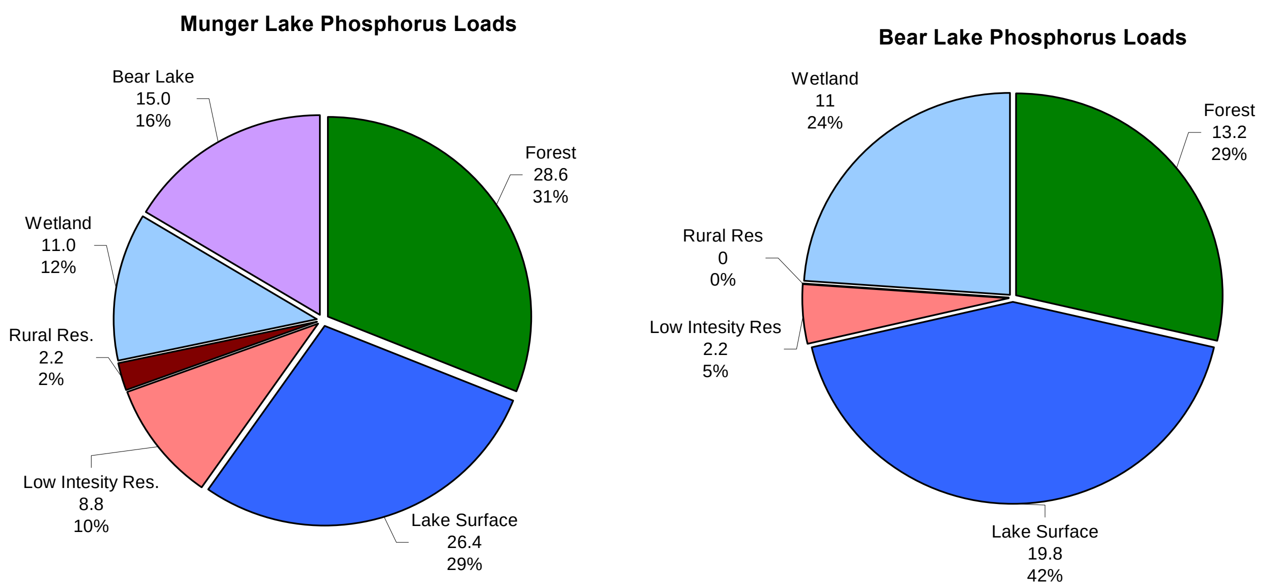


Figure 11. Phosphorus loading values based upon land cover from the Munger and Bear Lakes watershed. Annual loads in pounds. Percentages indicate percent of total load.

MANAGEMENT ALTERNATIVES

Lake management is a difficult and often controversial task to undertake because so many different types of people use our lakes for an equal variety of activities. Some people look to our lakes strictly for natural beauty, while others enjoy fishing, swimming, and recreational boating. All of these uses are important to the economic well-being of our state and local communities and can coexist if each user group takes into account the needs of the other groups and that of the lake ecosystem.

Many times lake management plans include a list of management recommendations that were created specifically for the lake in question. Although these recommendations may be appropriate for the lake, they may not be feasible for the management group to undertake. For instance, recommending that a large area of exotic plants be chemically treated may be too expensive for some lake groups to undertake even with the help of state funds, or the group may find the introduction of chemicals into their lake as unpalatable. Also, recommending that large tracts of private property be restored to the natural state may meet with great resistance because the group is not aware of the benefits of natural shorelands. Finally, many of these recommendations are not acted upon because the plan did not contain a sequence in which they should be approached nor an indication of who should implement them.

A useable lake management plan takes the needs of the stakeholders and their capacity to implement the management alternatives into account when the plan is created. In the end, these sociological factors are combined with the technical factors concerning the lake ecosystem to create a realistic action plan that will guide the group in meeting their goals. This project was designed to create such a plan.

The first step in the project was to gather information concerning Munger and Bear Lakes' water quality, their watershed, and their aquatic plant communities. These data were analyzed, modeled, and compared to other lakes in the region and state in order to provide insight to each lake's condition and to create a better and more realistic understanding of their health in the minds of its stakeholders. Then, using these data and years of lake management experience, NES ecologists created a list of management recommendations and presented them, along with a detailed description of the study results, to the MBLD Planning Committee during a four hour meeting held in July 2004. After detailed discussions at the meeting and via the phone and email, the initial recommendations were modified and added to resulting in a list of management alternatives. These alternatives were then prioritized (high, medium, or low) based upon a number of factors, including; urgency, cost, ease/difficulty of implementation, and availability of people to facilitate the tasks associated with the alternative. The prioritization is not based in anyway on the importance of the alternative or even the order the alternatives should be implemented. Rather, it is a somewhat subjective ranking that attempts to incorporate all of the factors listed above.

After the prioritization step, each of the alternatives was assigned a timeframe for implementation and a facilitator (a group, committee, or individual) that would be responsible for following through with its actual implementation. Upon the completion of this step, the prioritized alternatives became an "action plan"- an action plan that truly melds the technical and sociological components into an implementable management plan.

Focus of Management Alternatives

Fortunately, the studies did not find any major problems with either Munger or Bear Lakes. The water quality of the lakes appears to be better than other lakes in the state and better than or at least inline with other lakes in the region. Although the aquatic plant communities of the lakes are not spectacular in their species composition, they are healthy and not at nuisance levels. The watersheds that feed the lakes are largely covered with forests and wetlands, so they are loading the least amount of phosphorus to the lake possible. All in all, there are no indications that both lakes and their watersheds are not healthy at this time. Although this is great news to the lake stakeholders, it is often bad news concerning the management of the systems.

Frankly, it often takes a major health problem to get people to manage their health properly. Why fix something that isn't broken? The same goes for lake management – if there is not a major concern, like nuisance levels of native or exotic plants or pea-green water, many lake groups are not motivated to effectively manage their lakes. This is unfortunate because it is much easier to prevent problems in a lake than to deal with them after they appear. Keeping these facts in mid, the management alternatives presented below are focused on **protecting** the lakes so they remain in their current, healthy state.

Action Plan for Munger and Bear Lakes

Management Alternative: Boat Monitoring Program
Priority: High
Timeframe: Start Summer of 2005
Facilitator: Board of Directors to initiate district sub-committee
Description: Assuming that Eurasian water-milfoil truly does not exist within the system means that preventing its introduction should be a high priority of the district. The best way to do this will be to start a volunteer watercraft monitoring program at the Munger Lake public access. Training for this program is available through the Wisconsin Lake Partnership's **Clean Boats, Clean Waters: Volunteer Watercraft Inspection** training program. These are held spring through summer with the first session being held as a part of the Annual Wisconsin Lakes Convention.

Management Alternative: Volunteer Aquatic Plant Monitoring
Priority: High
Timeframe: Start Summer of 2005
Facilitator: To be determined.
Description: Locating Eurasian water-milfoil early, while the infestation is small increases the likelihood of eradication and reduces the cost of treatment. Volunteers trained in identifying Eurasian water-milfoil will complete annual boat surveys of Munger and Bear Lakes searching specifically for Eurasian water-milfoil. The first step in this process will be the training of 2-4 volunteers in basic plant identification skills. This will be accomplished through the volunteers' attendance at the workshop entitled: **Aquatic Plants: Root of a Healthy Lake Ecosystem** at the Annual Wisconsin Lakes Convention. These volunteers will then complete the informal boat surveys by motoring around the lakes looking for the plants. The survey will be completed in mid to late July when the plant should be at the surface and more easily seen.

Management Alternative: Begin Self-Help Lake Monitoring Program
Priority: High
Timeframe: Start in Summer of 2005
Facilitator: Board of Directors to enlist a volunteer from each lake.
Description: The short coming of the study associated with this management plan was the lack of historic water quality data for both lakes. The ability to examine historic data is important in all lake management activities. A member of the Board of Directors will begin the implementation of this alternative by visiting: http://dnr.wi.gov/org/water/fhp/lakes/selfhelp/shlmhowto.htm.

Management Alternative: Stakeholder education
Priority: High
Timeframe: Continuous
Facilitator: Education Committee with expert assistance as required.
Description: This action includes the education of MBLD members and other lake users concerning the importance of lake and shoreland plants in a healthy lake ecosystem, aspects of lake ecology, and other relevant topics. This action will also promote the attendance of MBLD members to the annual Wisconsin Lakes Convention in Green Bay. Expert assistance is available through the WDNR, the UW-Extension, the Nature Conservancy, the Oconto County Land and Water Conservation Department, and NES Ecological Services.

Management Alternative: Committee formation to monitor and act on watershed issues
Priority: Medium
Timeframe: To start during spring 2006
Facilitator: Board of Directors to set up committee
Description: This action would begin with the Board of Directors designating a Watershed Committee. The committee would be responsible for educating themselves on town, county and state zoning and land use regulations (including septic system rules) and will then use that knowledge to protect and enhance Munger and Bear Lakes and their watershed through the enforcement of the current laws and the promotion of additional regulations. This committee could go as far as being responsible for annual watershed surveys aimed at minimizing the effects of agricultural, construction site, and commercial/residential runoff to the lakes. If areas of concern are located, the committee would be responsible for contacting the Oconto County Land and Water Conservation Department for help. This committee may be strengthened by teaming up with similar groups from area lakes.

Management Alternative: Aquatic plant survey of Munger and Bear Lakes.
Priority: Medium
Timeframe: 2009
Facilitator: Planning Committee
Description: This would be a re-assessment of each lake's aquatic plant community as was completed for this management plan. It would be especially important to document changes in the plant community over time and for the monitoring of Eurasian water-milfoil as well as other exotic species.

Management Alternative: Shoreland restoration (buffer strips).
Priority: Low
Timeframe: Continuous
Facilitator: To Planning Committee
Description: Studies completed by the Wisconsin and Minnesota Departments of Natural Resources have shown that developed properties without a natural buffer between the lake and the developed area add significant amounts of sediment and nutrients to the lake on an annual basis. This alternative would promote the creation and maintenance of natural shoreland buffers around both lakes and the protection of natural areas that already exist. This process would be started within the stakeholder education alternative (described above). Information pertaining to the benefits and methods of shoreland restoration will be obtained from the WDNR website at: http://dnr.wi.gov/org/water/wm/dsfm/shore/restoration.htm

METHODS

Lake Water Quality Monitoring

Baseline water quality conditions were studied to assist in identifying potential water quality problems in the lakes (e.g., elevated phosphorus levels, anaerobic conditions, etc.). Water quality was monitored at the deepest point in each lake. Samples were collected with a 3-liter Van Dorn bottle at the subsurface (S) and near bottom (B), and occurred once in spring, fall, and winter and three times during summer. Samples were kept cool and preserved with acid following normal protocols. All samples were shipped to the Wisconsin State Laboratory of Hygiene for analysis. The parameters measured included:

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

In addition, during each sampling event Secchi disk transparency was recorded and a temperature, pH, conductivity, and dissolved oxygen profile was be completed using a Hydrolab DataSonde 4.

Aquatic Plant Assessments

Transect Surveys and Macrophyte Community Mapping

Quantitative aquatic vegetation surveys were conducted July 14-16, 2003 by sampling plots along 18 transects on Munger Lake and 12 on Bear Lake (Map 2). Transects started at the shoreline and extended into open water. 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 lakes using a combination of sketches and notes created on hardcopy maps and position data recorded with a Trimble GeoExplorer 3 GPS Data Collector. 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 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). Sum coverage is the total Daubenmire cover found for each plant.

Floristic Quality Assessment

A Floristic Quality Assessment (FQA) was applied to the aquatic vegetation species lists generated for each lake using the methodology of Nichols (1999). FQA is a rapid assessment metric used to assist in evaluating the floristic and natural significance of a given area. The assessment system is not intended to be a stand-alone tool, but is valuable as a complementary and corroborative method of evaluating the natural floristic quality of a lake ecosystem.

The primary concept in FQA is species conservatism. Each native species found in the lake was assigned a coefficient of conservatism (*C*) ranging from 0 to 10. The coefficient of conservatism estimates the probability that a plant is likely to occur in a landscape relatively unaltered from what is believed to be pre-settlement condition. A *C* of 0 indicates little fidelity to a natural community, and a *C* of 10 is indicative of restriction to high quality, natural areas. The FQA was applied by calculating a mean coefficient of conservatism for all species observed in the lake.

The mean *C* was then multiplied by the square root of the total number of species to yield a Floristic Quality Index (FQI). Examination of the floristic quality index within the context of statewide and regional trends was used to provide an overall evaluation of the floristic quality of Munger and Bear Lakes.

Watershed Analysis

The watershed analysis began with an accurate delineation of each lake's drainage area using U.S.G.S. topographic survey maps. 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 field verified during the fall of 2003.

The preliminary data were then corrected with the field verified data within the GIS and watershed area and acreages for each land cover were calculated. These data, along with historic and current water quality data were inputted into the Wisconsin Lake Modeling Suite (WiLMS) to determine potential phosphorus loads to the lakes.

Education

Educational components were accomplished through a "Kick-off Meeting" held in June 2003, project updates created for inclusion in the Districts's newsletter, a meeting held with the MBLD Planning Committee in July 2004 and a "Project Completion Meeting" in ? at which the final report and action plan were presented to the District. All of these materials are included in Appendix C.

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