Kusel Lake Aquatic Plant Management Plan 2002-2006

Kusel, Wilson, Round Lakes Protection and Rehabilitation District

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December 26, 2001

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Acknowledgements
Special thanks to Barb Nass, Frank Koskovich, Nancy Nelson and Tex Keenlance for providing much-needed assistance with fieldwork.

Introduction

Kusel Lake is a glacial pothole lake located in Springwater Township, Waushara County (T20N, R11E, secs. 26,27,34,35). It has a surface area of 80 acres and a maximum depth of 28 feet. The lake is predominantly upland and is fed primarily by groundwater seepage. There are no inlets or outlets, although a channel was excavated to an adjacent marsh to provide spawning habitat for fish (Figure 1). Due to the gentle terrain surrounding Kusel Lake, overland runoff is not a significant contributor of water or nutrients. Groundwater enters the lake primarily from the west, and periodically from Wilson Lake to the north (ERA, 1977). Land uses in the surrounding countryside include forestry and light agriculture. At present, the lake contains a diverse community of aquatic plants and a high quality fishery, including largemouth bass, northern pike, walleye, bluegill, black crappie, yellow perch and pumpkinseed. A county park with a public boat launch is located at the east end of the lake. The western and northern shores of the lake are heavily developed with summer cottages. One resort and one private campground with 300 plus units are also located on the lake. Thus Kusel Lake receives heavy recreational use. The interests of riparian property owners and other lake users is represented by the Kusel, Wilson, Round Inland Lakes Protection and Rehabilitation District – a lake district with taxing authority that was formed in 1974.

Within the last ten years Kusel Lake has become infested with Eurasian watermilfoil (*Myriophyllum spicatum*), an invasive exotic aquatic plant. This species formed dense beds throughout the littoral area - displacing native plants and reducing recreational and aesthetic values. Other management concerns that have arisen in recent years have been periodic algae blooms and reduced water quality. It was expected that water quality would continue to decline and that Eurasian water milfoil growth would continue to expand in Kusel Lake unless a successful management program was developed to address those issues.

Purpose of work

This report completes Phase II of a project funded in part by a Lake Management Planning Grant from the Wisconsin Department of Natural Resources. Phase I included conducting an aquatic plant survey, mapping Eurasian watermilfoil distribution and collecting data on several physical and chemical parameters in Kusel Lake. The objectives of Phase II were to utilize the information collected in Phase I to formulate a five-year aquatic plant management plan for Kusel Lake. The ultimate goal of this aquatic plant management plan is to propose a course of action for returning aquatic plant community and water quality characteristics in Kusel Lake as closely as possible to pre- Eurasian watermilfoil conditions.

Eurasian watermilfoil

An exotic species originating from Europe and Asia, Eurasian watermilfoil is now found in many areas of the U. S. Its distribution in Wisconsin is primarily in the central and southeast regions, but it is spreading northward (Borman, et.al., 1997). Due to its aggressive growth and rapid dispersal, Eurasian watermilfoil represents a substantial threat to the ecological and recreational value of Wisconsin's Lakes. Because Eurasian watermilfoil grows quickly to the water's surface and forms very dense canopies that block sunlight, it can displace nearly all native aquatic plant species. This has been attributed to significant declines in the habitat diversity of lakes. The dense canopy and surface mat formations of Eurasian watermilfoil can also form a nearly impenetrable barrier to boaters and swimmers. Eurasian watermilfoil infestation has also been linked to declines in fishery quality, invertebrate abundance and water quality (Pullman, 1993).

Management History

Studies

Several studies pertaining to aquatic plants and water quality have been conducted on Kusel Lake and neighboring Wilson and Round Lakes. *Kusel, Wilson and Round Lakes Feasibility Study Results and Management Alternatives* summarizes the results of a one-year study conducted by the Office of Inland Lake Renewal in 1975. This study included measurement of groundwater flow and nutrient transport, sediment depths, water quality, algal densities, and macrophyte species composition and abundance. The study found Kusel Lake to have exceptional water quality that was very low in nutrients. Chlorophyll a concentrations (a measure of algal density) and secchi depth reading characterized Kusel Lake as early mesotrophic. A layer of anoxic water was found to occasionally develop in the deeper portions of the lake during summer. Plant surveys described the lake as being nearly devoid of submergent vegetation.

The management recommendations given by this report were directed at maintaining Kusel Lake's excellent water quality to avoid costly management initiatives in the future, such as aquatic plant control programs. The primary management recommendation was to protect the shores on the west side of the lake from development – either through ordinances or direct land purchase – to prevent groundwater contamination through leaking sewage systems. Another recommendation was to install a hypolimnetic aeration system in the deeper portions of the lake in order to increase fish carrying capacity and production, and to maintain or improve water quality.

The *Final Report on the Kusel, Wilson and Round Lakes Study, Waushara County Wisconsin* was prepared by Environmental Resource Assessments in 1977. This report summarizes an extensive and thorough research project conducted on the three lakes. Watershed characteristics, biological surveys, limnology and water chemistry profiles, and sediment characteristics were studied (it is unclear how much data was used from the earlier study). The aquatic plant survey conducted on Kusel Lake found that submergent plants were almost completely absent. Only three species of emergent plants were found. Chemical analysis of groundwater and surface waters in this study also describe Kusel Lake as being nutrient poor and incapable of supporting significant algae or macrophyte (rooted plant) growth. Nutrient analysis of bottom sediments further characterized Kusel Lake as being incapable of supporting abundant plant growth. The lack of cottages and agricultural activity to the west of Kusel Lake – and the lack of sources for groundwater contamination – are cited as being responsible for the pristine, nutrient-poor conditions found.

Programs

From 1996 – 1998 Kusel Lake was involved in a 12-lake study called the "Wisconsin Milfoil Weevil Project". This study, conducted by the Wisconsin Cooperative Fishery Research Unit – UW Stevens Point and the Wisconsin DNR, was designed to evaluate the effectiveness of the milfoil weevil (*Euhrychiosis lecontei*) in controlling EWM. The milfoil weevil is a native species that is widely distributed throughout Wisconsin. It was also found naturally occurring in Kusel Lake. At natural densities, the milfoil weevil appeared to have no significant impact on EWM. However, studies conducted on Vermont Lakes suggest that at artificially elevated densities, the weevil could affect a decline in EWM (Lester, et.al., 1999).

In 1997 milfoil weevils were stocked into Kusel Lake in quantities calculated to bring densities to the levels prescribed for controlling EWM. Follow up monitoring conducted in 1997 and 1998, however, found no significant increase in milfoil weevil densities, and no decline in EWM density that could be attributed to milfoil weevils. Among the eleven other study lakes no significant increases in weevil density or significant declines in EWM were found either. To date, no further efforts have been directed at this management approach on Kusel Lake.

By 2000, Eurasian watermilfoil density had reached the point where some lakeshore property owners were unable to boat or swim off of their frontage. A permit was sought from the DNR to treat the milfoil with herbicides. A permit was granted to treat selected sites out to a distance of 150 feet. On June 25 Aquatic Biologists, Inc. treated 4.5 acres of milfoil using Navigate ® at a rate of 150lbs. / acre. Several post treatment investigations found that very little Eurasian watermilfoil regrowth occurred in the treatment area. The treatment was considered to be very successful.

Methods

The study entailed conducting a whole-lake aquatic plant survey, mapping the distribution of Eurasian water milfoil, and collecting limnology and water chemistry data during the 2001 season.

Two aquatic plant surveys were done on the lake – one for submergent plants and one for emergent plants. The surveys were done from June 7 –13. The submergent plant survey utilized quantifiable and reproducible methods so that future surveys can accurately assess changes to the plant community. For this survey, a series of twelve transects (labeled A through L) were laid out on the lake – radiating at 60 degree intervals from a central point in each of the two lake basins (Figure 2). Plant samples were collected at four quadrants along each transect using a tethered short-toothed garden rake. Four rake tows were made at each quadrant, for a total of 192 rake tows. All samples collected were identified to *genus* and to *species* whenever possible. Data collected included plant species composition, % frequency and relative abundance, depth, bottom composition and % disturbance.

For the emergent plant survey, twelve additional transects (labeled AB, BC, etc.) were made parallel to shore. This survey was more qualitative in nature, and documented only the presence or absence of emergent and floating-leaf plants along each transect. Percent frequency of occurrence was also calculated from this data.

The location and extent of Eurasian watermilfoil beds was identified visually and with rake tows. Milfoil beds were marked with floating buoys and their dimensions and distances from shore were measured with a laser rangefinder. Minimum and maximum depths of the beds were measured with a weighted tape. These data were used to plot the exact location of the milfoil beds onto a contour map of the lake. The map drawings were then superimposed upon an acreage grid to determine the area of the beds.

A complete water chemistry and limnology analysis was done on April 25 that included:

- Dissolved (ortho) phosphorus
- Total phosphorus
- Total Kjeldahl nitrogen
- Nitrate + nitrite as N
- Ammonia as N
- Chloride
- Chlorophyll *a*
- Color
- Secchi disc depth
- Hardness
- Suspended solids
- Total dissolved solids
- Total volatile solids
- pH
- Dissolved oxygen profile
- Temperature profile

The following limnology and water chemistry data was collected on June 7, July 9 and September 5:

- Dissolved oxygen profile
- Temperature profile
- Secchi disc depth
- Total phosphorus
- Chlorophyll *a*
- pH

Water samples were taken one foot below the surface and one foot above the lakebed at the deepest point (28 feet) for all analyses except pH and Chlorophyll *a,* which were collected at the surface only. Dissolved oxygen, temperature, secchi depth and pH were analyzed in the field. All other parameters were analyzed by the State Laboratory of Hygiene.

Results and Discussion

Plant survey

Submergents

The 2001 survey of Kusel Lake found a vastly different lake than that described from the 1975-76 surveys. The most dramatic change has been with the aquatic plant community. Twenty-five years earlier no submergent plants were found in the main lake. Three species were identified in the boat channel leading to the campground. These were alpine pondweed *(Potamogeton alpinus)*, elodea *(Elodea canadensis)* and musk grass *(Chara spp.)*. In contrast, 21 species of macrophytes were found during the submergent plant survey of 2001 (Table 1). Aquatic plants were found in each of the 12 transects.

Musk grass, Eurasian watermilfoil, variable pondweed *(P. gramineus)* and water stargrass *(Zosterella dubia)* dominated the aquatic plant community. Coontail *(Ceratophyllum demersum),* bushy pondweed *(Najas flexilis),* curly leaf pondweed *(P. crispus)* and flatstem pondweed *(P. zosteriformis)* were also abundant.

The greatest concern identified by this survey was the presence of two invasive exotic plants: Eurasian watermilfoil and curly leaf pondweed. Found in 34.9% of transects, Eurasian watermilfoil represents a serious threat to native species and the ecological health of the lake. While not as invasive as Eurasian watermilfoil, curly leaf pondweed may also reach nuisance levels. Both of these species grow rapidly during spring – giving them a competitive advantage over native plants.

Table 1. Results of the June 2001 submergent aquatic plant survey conducted on Kusel Lake.

Species common name	scientific name	Percent Frequency	Percent Composition
Musk Grass	*Chara spp.*	58.3	24.5
Eurasian Watermilfoil	*Myriophyllum spicatum*	34.9	14.6
Variable Pondweed	*Potamogeton gramineus*	27.6	11.6
Water Stargrass	*Zosterella dubia*	22.4	9.3
Coontail	*Ceratophyllum demersum*	19.8	8.3
Bushy Pondweed	*Najas flexilis*	16.1	6.8
Curly Leaf Pondweed	*Potamogeton crispus*	15.1	6.3
Flatstem Pondweed	*Potamogeton zosteriformis*	15.1	6.3
Small Pondweed	*Potamogeton pusillus*	5.2	2.2
Elodea	*Elodea canadensis*	4.7	2.0
Water Celery	*Valisneria americana*	4.2	1.7
White Water Lily	*Nymphaea odorata*	3.6	1.5
Spadderdock	*Nuphar variegata*	2.1	0.9
Watershield	*Brasenia schreberi*	1.6	0.7
Needle Rush	*Eleocharis acicularis*	1.6	0.7
Small Yellow Water Lily	*Nuphar microphyllum*	1.6	0.7
Large Leaf Pondweed	*Potamogeton amplifolius*	1.6	0.7
Bladderwort	*Utricularia vulgaris*	1.0	0.4
Filamentous Algae	*Chlorophyceae*	0.5	0.2
Northern Watermilfoil	*Myriophyllum sibericum*	0.5	0.2
Illinois Pondweed	*Potamogeton illinoensis*	0.5	0.2
Sago Pondweed	*Potamogeton pectinatus*	0.5	0.2
no plants found			10.0

Were it not for the presence of the exotic species, Kusel Lake would be characterized as having a vibrant, healthy aquatic plant community with excellent diversity. Many of the species found have significant ecological value (see Table 3.) The increased plant growth has no doubt led to dramatic increases in fish growth and carrying capacity. These plants are also important in maintaining water clarity and stabilizing bottom sediments.

Emergents

During the 1975-76 survey three species of emergent plants were identified. Beds of three-square bulrush *(Scirpus americanus)* and softstem bulrush *(S. validus)* were found in several locations around the lake. A dense bed of spadderdock or yellow water lily *(Nuphar spp.)* was found in the bay at the west end of the lake. Much like the submergent plant survey, the emergent plant survey conducted in 2001 found substantially more species. A total of 14 species of plants were found (Table 2). White water lily *(Nymphaea tuberosa)* was most widely distributed – found in 11 of the 12 transects. Hardstem bulrush *(S. acutus)*, three-square bulrush and softstem bulrush were also widely distributed – each being found in 8 transects.

It is refreshing to see an apparent increase in emergent plant growth along a lakeshore. This type of habitat is often destroyed by lakeshore property owners seeking "clean" frontage. In reality emergent and floating-leaf plants play an important role in the ecology of lakes. Emergents stabilize shorelines and capture nutrients and sediment borne on overland runoff. Emergents also provide food and nesting cover for many species of birds and mammals. Emergent plants also provide critical spawning, feeding and nursery areas for many species of fish (Table 3).

Table 2. Results of the June 2001 emergent aquatic plant survey conducted on Kusel Lake.

Species common name	scientific name	% Frequency

White Water Lily	Nymphaea tuberosa	92
Hardstem Bulrush	Scirpus acutus	67
Three-square Bulrush	Scirpus americanus	67
Softstem Bulrush	Scirpus validus	67
Spadderdock	Nuphar variegata	50
Floating-leaf Pondweed	Potamogeton natans	42
Broad-leaved Cattail	Typha latifolia	42
Creeping Spikerush	Eleocharis palustris	25
Reed Canary Grass	Phalaris arundinacea	17
Water Smartweed	Polygonum amphibium	17
Water Plantain	Alisma spp.	8
Watershield	Brasenia schreberi	8
Porcupine Sedge	Carex hystericina	8
Sedge spp.	Carex spp.	8
14		

Table 3. Description and ecological value of several aquatic plants commonly found in Kusel Lake.

Submergent Species

Musk Grass *(Chara spp.)* is a complex algae that resembles a higher plant. It is readily identified by its pungent, musk-like odor. Slender stems have whorls of toothed branches that are light green in color. The plant may often appear grayish later in the season as it becomes encrusted with calcium carbonate. Musk grass forms dense green blankets along the lakebed that stabilize sediments and contribute to good water quality. These plant beds provide important cover and feeding areas for juvenile fish. Musk grass is a favorite waterfowl food.

Variable Pondweed *(Potamogeton gramineus)* has stems that arise from spreading rhizomes. Leaves are lance-shaped with 3-7 veins. Flowers and fruit are produced on a stout stalk. Variable pondweed prefers shallow water and usually grows in association with musk grass and bushy pondweed. Tubers and fruit are favorite foods of wood ducks, Canada geese and muskrats. The extensive leafy branches provide habitat for a host of invertebrates that fish feed upon.

Water Stargrass *(Zosterella dubia)* produces long slender, ribbon-like leaves. While the plant grows at a variety of depths, the characteristic bright yellow flowers are typically produced only on shallower plants. Water stargrass forms dense tangled mats of leaves that hug the bottom. This plant does an excellent job of stabilizing sediments, and provides habitat for juvenile fish and invertebrates. Wood ducks, pintail and teal feed upon the plant.

Coontail *(Ceratophyllum demersum)*, as its name implies, produces whorls of narrow, toothed leaves on a long, trailing stem that often resembles the tail of a raccoon. This densely growing plant captures a tremendous amount of phosphorus and sediments, and is therefore highly valued for its ability to improve water quality. The plant also provides cover and foraging habitat for fish – particularly in winter when many other plants have died back. A wide variety of waterfowl feed upon the leaves and fruit.

Emergent Species

White Water Lily *(Nymphaea odorata)* develops round reddish floating pads that have a single narrow indentation. Large floating flowers have white petals with striking yellow stamens. This lily prefers calm waters and may grow in waters 6 feet deep or more. Waterfowl eat its seeds and muskrats eat the rhizomes. The shade produced by the floating leaves provides important fish cover, particularly for largemouth bass.

Bulrushes *(Scirpus spp.)* form leafless olive-colored cylindrical or triangular stems. Clusters of brown flower spikelets along these stems. Bulrushes prefer firm bottoms, and may grow above the waterline to waters as deep as 6 feet. Bulrush provides important spawning, nursery and foraging habitat for fish. Many species of birds eat the seeds. Geese and muskrats eat the stems and rhizomes.

Broad-leaved Cattail *(Typha latifolia)* has 3-5 foot long sword-like leaves, and produces a cylindrical flower spike that is dark brown when mature.
Broad-leaved cattail is the dominant plant in many wetland plant communities. It provides food and cover for a wide range of animals. Many species of marsh birds rely on it for nesting cover. It provides critical spawning habitat for several species of fish, including northern pike.

Milfoil Mapping

Figure 3 shows the distribution of Eurasian watermilfoil at the time of the survey. 13 different beds of mature milfoil were mapped. Collectively, these beds totaled 10.71 acres. Scattered milfoil growth was found in-between and adjacent to some of the beds – indicating that Eurasian watermilfoil is still expanding. The heaviest growths were found at the west end of the lake, and in the middle of the lake in the shallows between the two deep basins. Eurasian watermilfoil was found growing in as little as 1 foot of water to a maximum of 15 feet of water. The majority however, was found between the 4 and 14-foot contours.

Water Quality

Lakes can be categorized by their trophic state or "age". Oligotrophic lakes are "young" lakes. They are typically deep and clear with exposed rock bottoms and limited plant growth. Eutrophic lakes are "old" lakes. These lakes are often shallow and marsh-like; typically having heavy layers of organic silt and abundant plant growth. Mesotrophic lakes are "middle-aged" lakes, and are typically deeper than eutrophic lakes. Mesotrophic lakes may have significant plant growth, but often have areas of exposed sand, gravel or cobble bottom substrates.

A lake's trophic state is a measure of its ability to support living things. Lakes become more eutrophic with time, however trophic state is more influenced by nutrient inputs than by time. Many parameters can be used as indicators of a lake's trophic status; such as dissolved oxygen profiles, chlorophyll concentrations, secchi depths, and concentrations of plant growth- limiting nutrients such as nitrogen and phosphorus. However it is difficult to assess the *water quality* of any given lake based solely on these parameters. There are many eutrophic lakes with good water quality. Thus, the rate of change in trophic state may be better indicator of water quality.

When humans influence the trophic state of a lake the process is called *cultural eutrophication.* Cultural eutrophication typically results in an accelerated change in trophic state. A sudden influx of available nutrients may cause a rapid change in a lake's ecology. Opportunistic plants such as algae may be able to out-compete macrophytes. The resultant appearance and odor is more typically considered poor water quality.

Figure 4 shows the changes in several water quality parameters – trophic state indicators – between the 1975-76 surveys and the 2001 survey. The relevance of these parameters is discussed in the following paragraphs.

Nitrogen

After carbon, hydrogen and oxygen, nitrogen is the most abundant element in living cells. It is essential for most biochemical reactions. Nitrogen is always present in aquatic environments. Its most common form is gaseous; which is basically inert. Nitrogen is present in aquatic environments to a lesser extent in the forms of ammonia, nitrate, nitrite and urea. Of these, nitrate and ammonia are most important for plant growth. Nitrogen can limit plant growth in high phosphorus environments. The ratio of nitrogen to phosphorus found in Kusel Lake however, indicates that nitrogen is not a limiting factor.

Table 4. A comparison of averaged water quality parameters between 1975-76 and 2001 Kusel Lake surveys.

Parameter	1975-76	2001
Nitrate + Nitrite as N	110 ug/l	25 ug/l
Ammonia as N	145 ug/l	23 ug/l
Total Kjeldahl Nitrogen	215 ug/l	675 ug/l
Total Phosphorus	10 ug/l	35 ug/l
Dissolved Reactive Phosphorus	5 ug/l	1 ug/l
Calcium	34 mg/l	24 mg/l
Magnesium	13.5 mg/l	12 mg/l
Chloride	2 mg/l	2 mg/l

pH	7.35	8.25
Chlorophyll *a*	3.0 ug/l	3.5 ug/l
Secchi disc depth	8.6 feet	10.5 feet

The concentrations of nitrate, nitrite and ammonia will vary with macrophyte and algae abundance. Concentrations are lower when nutrients are tied up in living cells. The decreases in nitrate, nitrite and ammonia concentrations found in the 2001 survey then, are likely due to the increases in aquatic plant growth.

Phosphorus

Phosphorus is the most common growth-limiting element for algae. Results indicate that it is the limiting factor in plant growth in Kusel Lake. Total phosphorus is a measure of available phosphorus plus phosphorus tied up in living cells. Reactive phosphorus is the phosphorus that is available for algae growth. The decrease in reactive phosphorus between the two surveys is likely do to increases in algae growth. The large increase in total phosphorus found in 2001 is cause for concern.

Phosphates bind tightly to soil particles and generally do not move freely with groundwater. In coarse, sandy soils such as those found around Kusel Lake however, the phosphate holding capacity can be reached more quickly -allowing septic effluent to impact the groundwater entering the lake. Phosphorus may also be made more available for algae growth by disturbance of bottom sediments from boating activity.

As predicted from the results of the 1975-76 survey, development along the western shores of the lake along with increased lake usage, may have caused the recent algae blooms and increased macrophyte growth.

Chlorophyll *a*

Chlorophyll *a* is a pigment found in all plants. It is the only pigment that can convert light energy to chemical energy in photosynthesis. Chlorophyll *a* concentrations are often used to gauge algal abundance. Because algal abundance is directly related to productivity, Chlorophyll *a* concentrations are a generally good trophic state indicator.

Chlorophyll *a* concentrations increased in Kusel Lake but not markedly. It is likely that the bulk of the plant biomass in 1975 was in the form of phytoplankton. Therefore this parameter does not accurately reflect changes in Kusel Lake's productivity or trophic state.

Secchi Disc Depth

Secchi discs are used to measure water clarity. They are also used to gauge water quality and trophic state. They are one of the less reliable trophic state indicators though. In fact average secchi readings actually increased from 1975-76 in Kusel Lake.

Figure 4 shows the inverse relationships between secchi depth and total phosphorus and Chlorophyll *a* concentrations found during the 2001 study. As available phosphorus levels increase, algae growth increases; which results in higher Chlorophyll *a* concentrations. Increased algae growth equates to reduced water clarity, thus lower secchi readings.

pH

pH is the negative log of the hydrogen ion concentration. It is used to measure the acidity or alkalinity of lakes. Kusel Lake's pH increased nearly ten-fold over the last 25 years. Kusel went from being nearly neutral to a hard water lake.

Increased photosynthetic activity increases pH. Thus the increase in Kusel Lake reflects the increase in productivity.

Calcium

Calcium is necessary for the metabolic processes of all living things. All vertebrates, mollusks and many invertebrates require large quantities of calcium carbonate as skeletal strengthening material.

Calcium carbonate is precipitated in hard water lakes and forms layers of marl in bottom sediments. The decrease in Kusel Lake's calcium concentrations reflects the increases in pH.

Magnesium

All living cells require magnesium for respiration. The element plays an important role in the photosynthesis reaction. It is often present in sufficient quantities in aquatic ecosystems not to be a limiting factor in plant growth. It does not appear to have been a limiting factor in Kusel Lake either.

Chloride

While chloride ions are essential for plant photosynthesis, free chlorine is highly toxic to living cells. Chlorine kills by oxidation of cell membranes, but the process quickly converts it to harmless chloride ions. Thus chloride concentration is used to identify chlorinated waste discharges in lakes. Fortunately this parameter has remained low in Kusel Lake.

Dissolved Oxygen

Oxygen concentration is one of the greatest limiting factors in aquatic ecosystems. Because water is capable of holding relatively low levels of oxygen relative to air, oxygen is easily depleted by respiration and decomposition unless continually replenished. Atmospheric diffusion and photosynthesis are the main sources of dissolved oxygen. However, photosynthesized oxygen concentrations vary considerably. In fact, very productive lakes may experience periodic anoxic conditions.

Dissolved oxygen profiles are good trophic state indicators. Oligotrophic lakes show little variation from saturation at all depths. Mesotrophic lakes typically develop anoxic conditions in deeper waters. The oxycline gradually rises in the water column until thermal inversion replenishes oxygen in the depths. This oxygen deficit in the hypolimnion is due to productivity in the epilimnion. In eutrophic lakes this oxycline may reach the surface, causing fish kills.

Reports from the earlier lake study describe Kusel Lake as forming aperiodic oxyclines – indicating that the lake formed dissolved oxygen profiles typical of early stage mesotrophic lakes. Figure 5 shows oxygen profiles from the 2001 study. Throughout the season the oxycline rises steadily. By September insufficient oxygen existed below 16 feet deep to support fish life. This is a profile typical of mid- to late-stage mesotrophic lakes.

Conclusions

Based on the results of this study, two main areas of management concern have been identified for Kusel Lake: 1) the presence of two exotic aquatic plants – Eurasian watermilfoil and curly leaf pondweed, and 2) accelerated eutrophication caused by nutrient enrichment.

Eurasian watermilfoil and curly leaf pondweed threaten Wisconsin Lakes because they aggressively out-compete native plants. In time, monotypic stands of these species may develop. In ecological terms this may result in reduced species diversity, reduce water quality and poorer quality fisheries. From the standpoint lakeshore property owners and other lake users, the aesthetic and recreational value of the lake is diminished. Some of these things have already been experienced in Kusel Lake by the increase in Eurasian watermilfoil growth. Left unchecked, these conditions are likely to worsen.

The accelerated eutrophication of Kusel Lake has had several significant short-term benefits, notably a dramatic improvement in the fishery and an increase in macrophyte growth, which has had the effect of helping to maintain water quality in spite of increased human use. If this cultural eutrophication is not slowed or abated, the trend will be toward increased algae growth, decreased water clarity, decreased macrophyte growth, a shift in the fishery to species more tolerant of warm, turbid waters, and an increased incidence of winter and summer fish kills.

Management Considerations

Eurasian Watermilfoil

Several methods are commonly employed for large-scale control of Eurasian watermilfoil – with widely varying success. Boat-mounted mechanical weed harvesters have often been employed to control Eurasian watermilfoil. This method is usually used in lakes that have historically used harvesters, and in situations where lake management units have done insufficient planning to receive permits for herbicide use. Mechanical harvest is not a recommended control method for Eurasian watermilfoil, however. Eurasian watermilfoil can reproduce by fragmentation (Borman, et.al. 1997), and the free-floating plant matter left from cutting operations can accelerate dispersal of the plant. Mechanical harvest does offer several distinct advantages, though. Harvested plant matter can be removed from the lake system, eliminating the possibility of low dissolved oxygen due to bacterial decomposition. The possibility of algae blooms due to nutrient release is also greatly reduced. There are no water use restrictions following mechanical harvest either. A disadvantage of mechanical weed harvest is that it is not species selective. While cutting does not typically kill plants, there is little evidence to suggest that cutting can induce a shift back to native species. In the process of removing plants, weed harvesters also kill substantial numbers of fish, reptiles, amphibians and invertebrates (Shardt, 1999). Perhaps the greatest drawback of a mechanical harvest program is the cost. Cost / benefit analyses conducted by the Florida Department of Environmental Protection found that mechanical harvest of nuisance weeds cost over 40 times as much as some herbicide treatments to achieve the same level of control (Shardt, 1999). Given these considerations, employing a mechanical weed harvester would be a poor choice for Kusel Lake.

There has been some research into the use of biological vectors, such as insects, to control Eurasian watermilfoil. Two insect species have been associated with Eurasian watermilfoil decline, the milfoil weevil (*Euhrychiosis lecontei*) and a chironimid, *Crycotopus myriophylli* (Lester, et.al., 1999). Plantings of the milfoil weevil have been most commonly tried in Wisconsin lakes. To date, no documented successes have occurred in Wisconsin Lakes, though. Because of this, and because milfoil weevils have already proven unsuccessful in Kusel Lake, this method should not be given further consideration.

Herbicides have been the most successful tools for controlling Eurasian watermilfoil. Of the herbicides most commonly used, 2,4D (*Navigate*®, *Aquakleen*®), has shown the most promise. The main concerns with using herbicides in lakes are human health and safety, and environmental impacts. 2,4 D is an organic herbicide that biodegrades very quickly in aquatic environments. Numerous studies conducted over the last 50 years have found that 2,4D does not cause cancer or birth defects, does not bioaccumulate or persist in the environment, and does not affect fish or wildlife (see www.24d.org). studies recently completed on two other Waushara County Lakes, Gilbert and Wilson, found no significant negative impacts to any native species following large-scale 2,4D treatments. In fact most native species showed increases in percent frequency. Control of Eurasian watermilfoil in these lakes was also excellent – 94.5% in Wilson and 100% in Gilbert. Based on these considerations, 2,4D treatments are the most realistic choice for long-term control of Eurasian watermilfoil in Kusel Lake.

Curly Leaf Pondweed

While curly leaf pondweed is a major nuisance in many Wisconsin lakes, it commonly exists in Waushara County lakes at sub-nuisance levels. Because of the relatively high % frequency of this plant found in Kusel Lake, curly leaf pondweed warrants continued monitoring. If monotypic stands of the plant develop, control efforts should be undertaken.

Water Quality

There are no simple solutions for dealing with the cultural eutrophication that has occurred in Kusel Lake. In order to maintain desirable water quality characteristics, nutrient inputs must be managed. Increased residential development in the watershed may necessitate construction of a sewage treatment facility to reduce nutrient loading in groundwater. Installation of a hypolimnetic aeration system, as recommended in *Kusel, Wilson and Round Lakes Feasibility Study Results and Management Alternatives,* may also be effective in managing in-lake nutrient budgets and maintaining water quality. Protection of undeveloped shorelines through land acquisition programs may also be essential to the long-term health of the lake.

Recommendations

Dealing with Eurasian watermilfoil is the most pressing concern. A permit should be sought to conduct large-scale 2,4D treatments in the spring of 2002. This treatment effort should target all Eurasian watermilfoil in the lake. Follow-up treatment should be made as needed later in the season. The goal of this treatment should be to reduce Eurasian watermilfoil frequency by 90% or more by 2003. Periodic retreatments should be made as needed through 2006 to maintain Eurasian watermilfoil at or below target levels.

Aquatic plant surveys should be done annually from 2003 – 2006. These surveys should duplicate the methods used in the 2001 survey. The effectiveness of the Eurasian watermilfoil control program can then be evaluated so that management approaches can fine-tuned to meet goals. The status of other species, such as curly leaf pondweed, can also be monitored to ensure that they do not reach nuisance levels.

A more extensive analysis of water chemistry parameters, including groundwater analysis, should be scheduled for 2003. This should create a better understanding of Kusel Lake's nutrient budgets, and allow for informed management decision-making in this area.

In 2006 the Kusel Lake Management Plan should be revised to direct management of the lake over the next five years.

The Lake District should again seek funding from the DNR's Lake Planning Grant Program to conduct future lake studies.

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Appendix

Appendix 1. Submergent aquatic plant survey data from the 2001 Kusel Lake survey.

Species	Plant samples collected by transect												Total	Percent Frequency
	A	B	C	D	E	F	G	H	I	J	K	L		
Musk Grass	5	3	11	9	14	11	16	6	13	6	11	7	**112**	58.3
Eurasian Watemilfoil	14	11	2			9	3	8	3	2	5	10	**67**	34.9
Variable Pondweed	3	5	3	9	7		5	6	6		6	3	**53**	27.6
Water Stargrass	4	5	4	1	3	10	4		4	2	2	4	**43**	22.4
Coontail	9	5			1	10	1	2	2	1	2	5	**38**	19.8
Bushy Pondweed		1		4	1	6	2	4	6		5	2	**31**	16.1
Curly Leaf Pondweed	3					5	3	6	3	1	3	5	**29**	15.1
Flatstem Pondweed	3	2			1	5	1	8	5		1	3	**29**	15.1
Small Pondweed		2		2	1	2	1		1		1		**10**	5.2
Elodea				1		6						2	**9**	4.7
Water Celery								1	4		3		**8**	4.2
White Water Lily						6		1					**7**	3.6
Spadderdock						4							**4**	2.1
Watershield						3							**3**	1.6
Needle Rush							1	1			1		**3**	1.6
Small Yellow Water Lily						2				1			**3**	1.6
Large Leaf Pondweed						1			2				**3**	1.6
Bladderwort		1				1							**2**	1.0
Filamentous Algae									1				**1**	0.5
Northern Watermilfoil	1												**1**	0.5
Illinois Pondweed						1							**1**	0.5
Sago Pondweed						1							**1**	0.5
no plants found		1	4	4						10		3	**22**	4.6
TOTAL													**480**	

Appendix 2. Emergent aquatic plant data from the 2001 Kusel Lake survey.

Species		**Transect**												
common name	**scientific name**	**A-B**	**B-C**	**C-G**	**G-H**	**H-I**	**I-J**	**J-K**	**K-L**	**L-D**	**D-E**	**E-F**	**E-A**	**% Freq.**
white water lily	Nymphaea tuberosa	x	x	x	x	x	x	x	x		x	x	x	92
hardstem bulrsuh	Scirpus acutus	x		x	x	x	x	x				x	x	67
three-square rush	Scirpus americanus	x	x		x	x	x			x		x	x	67
softstem bulrush	Scirpus validus			x		x	x	x		x	x	x	x	67
spadderdock	Nuphar variegata				x	x			x	x		x	x	50
floating-leaf pondweed	Potamogeton natans					x	x	x			x		x	42
broad-leaved cattail	Typha latifolia	x				x				x		x	x	42
creeping Spikerush	Eleocharis palustris	x			x								x	25
Reed Canary Grass	Phalaris arundinacea				x				x					17
Water Smartweed	Polygonum amphibium	x							x					17
Water Plantain	Alisma spp.	x												8
Watershield	Brasenia schreberi												x	8
Porcupine Sedge	Carex hystericina	x												8
Sedge spp.	Carex spp.												x	8
14		8	2	3	6	7	5	4	4	4	3	6	10	

Appendix 3. Submergent plant survey transect descriptors.

	Depths (ft.)	Bottom Substrates (%)		% Disturbed*	% No Plants**
QUAD 1	ave = 2.2 min = 1.0 max = 3.0	marl muck sand-muck sand gravel rock unknown	0 17 25 50 0 8 0	67	23
QUAD 2	ave = 5.9 min = 2.0 max = 14.0	marl muck sand-muck sand gravel rock unknown	0 58 8 25 8 0 0	25	8
QUAD 3	ave = 8.2 min = 5.0 max = 15.0	marl muck sand-muck sand gravel rock unknown	8 42 17 17 0 0 17	17	2
QUAD 4	ave = 15.7 min = 12.0 max = 18.0	marl muck sand-muck sand gravel rock unknown	58 0 0 0 0 0 42	0	2
AVERAGE OF ALL	ave = 8.0 min = 1.0 max = 18.0	marl muck sand-muck sand gravel rock unknown	2 44 13 24 2 2 15	27	12

* Percentage of quadrants showing evidence of human disturbance such as raking, prop scars, etc.

** Percentage of rake hauls at each quadrant where no plants were collected.

Appendix 4. Kusel Lake water chemistry analysis results.

Collection Date: 4-25-01 - Spring Turnover
Collection point: 1 FOOT ABOVE LAKE BED, DEEPEST POINT OF LAKE

parameter tested	result	unit	comment
Calcium, Total	24	mg/l	
Chloride	2.1	mg/l	
Chlorophyll A, uncorrected	-	ug/l	laboratory accident, no test done
Color, True	10	SU	
Hardness (as CaCO3)	110	mg/l	
Magnesium	12	mg/l	
Ammonia	15	ug/l	
Nitrate + Nitrite	17	ug/l	
Kjeldahl Nitrogen, Total	400	ug/l	
Phosphorus, Total	12	ug/l	
Phosphorus, Dissolved Reactive	2	ug/l	
Total Dissolved Solids	122	mg/l	
Total Solids	130	mg/l	
Total Volatile Solids	44	mg/l	
Suspended Solids	<2	mg/l	low sample volume
pH	8		
Dissolved Oxygen	13.1	mg/l	
Secchi Depth	12	ft	

Collection Date: 4-25-01 - Spring Turnover
Collection point: 1 FOOT ABOVE LAKE BED, DEEPEST POINT OF LAKE

parameter tested	result	unit	comment
Calcium, Total	24	mg/l	
Chloride	2	mg/l	
Color, True	10	SU	
Hardness (as CaCO3)	110	mg/l	
Magnesium	12	mg/l	
Ammonia	31	ug/l	
Nitrate + Nitrite	32	ug/l	
Kjeldahl Nitrogen, Total	950	ug/l	
Phosphorus, Total	91	ug/l	
Phosphorus, Dissolved Reactive	ND	ug/l	LOD = 2
Total Dissolved Solids	320	mg/l	
Total Solids	156	mg/l	
Total Volatile Solids	60	mg/l	
Suspended Solids	22	mg/l	
Dissolved Oxygen	6.8	mg/l	

Collection Date: 06-07-01
Collection point: 1 FOOT BELOW SURFACE, DEEPEST POINT OF LAKE

parameter tested	result	unit	comment
Chlorophyll A, Uncorrected	3.2	ug/l	
Phosphorus, Total	10	ug/l	
pH	8		
Dissolved Oxygen	9.4	mg/l	
Secchi depth	13	ft	

Collection Date: 06-07-01
Collection point: 1 FOOT ABOVE LAKE BED, DEEPEST POINT OF LAKE

parameter tested	result	unit	comment
Phosphorus, Total	27	ug/l	
Dissolved Oxygen	0.1	mg/l	

Collection Date: 07-09-01
Collection point: 1 FOOT BELOW SURFACE, DEEPEST POINT OF LAKE

parameter tested	result	unit	comment
Chlorophyll A, Uncorrected	3	ug/l	
Phosphorus, Total	12	ug/l	
pH	8.5		
Dissolved Oxygen	7.9	mg/l	
Secchi depth	9.5	ft	

Collection Date: 07-09-01
Collection point: 1 FOOT ABOVE LAKE BED, DEEPEST POINT OF LAKE

parameter tested	result	unit	comment
Phosphorus, Total	37	ug/l	
Dissolved Oxygen	0.1	mg/l	

Collection Date:09-05-01
Collection point: 1 FOOT BELOW SURFACE, DEEPEST POINT OF LAKE

parameter tested	result	unit	comment
Chlorophyll A, Uncorrected	4.4	ug/l	
Phosphorus, Total	16	ug/l	
pH	8.5		
Dissolved Oxygen	8.6	mg/l	
Secchi depth	7.5	ft	

Collection Date: 09-05-01
Collection point: 1 FOOT ABOVE LAKE BED, DEEPEST POINT OF LAKE

parameter tested	result	unit	comment
Phosphorus, Total	77	ug/l	
Dissolved Oxygen	0.2	mg/l	