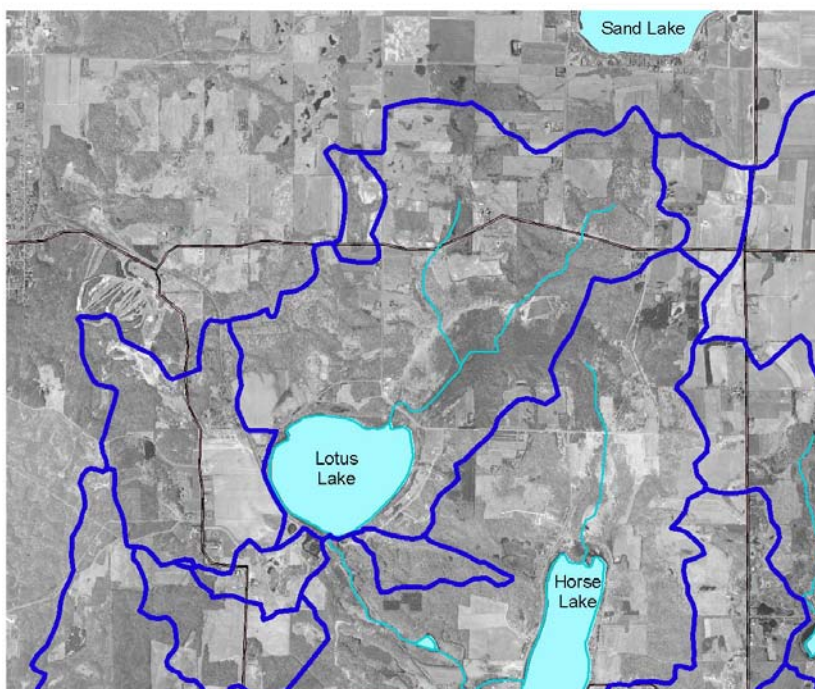


Lotus Lake Watershed



**Lotus Lake Water
Quality &
Biological
Assessment
LPL-973-05**

**Lotus Lake
Education &
Riparian Survey
Project
LPL-977-05**

This report is a summary of the water quality in Lotus Lake during the season of 2005. Data was collected by Polk County Land and Water Resources Department staff and lake volunteers. This report characterizes the current status of the lake (physical, chemical, and biological), models the phosphorus loading to the lake, summarizes Lotus Lake residents' perceptions, and offers recommendations for future management.

Physical Characteristics of Lotus Lake Watershed

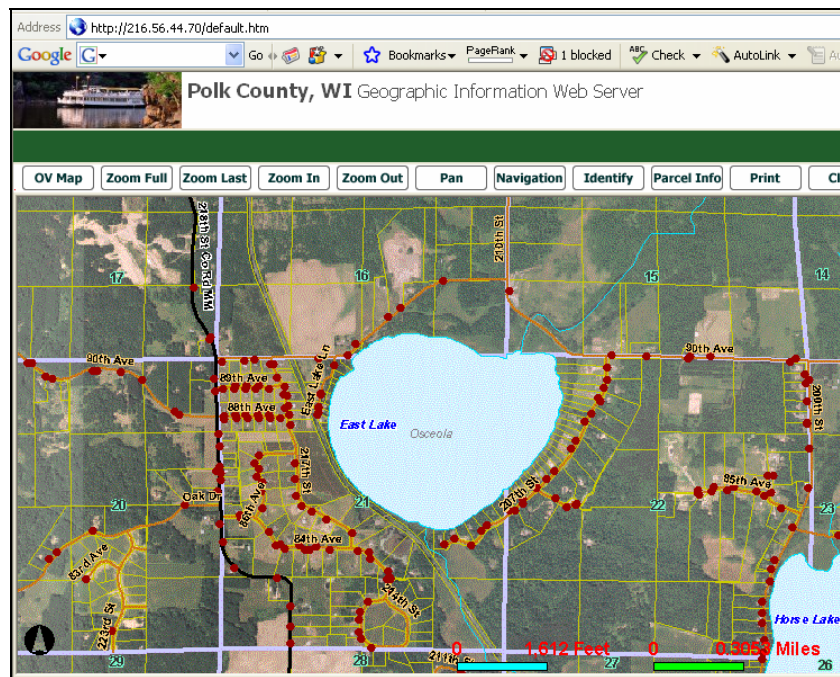
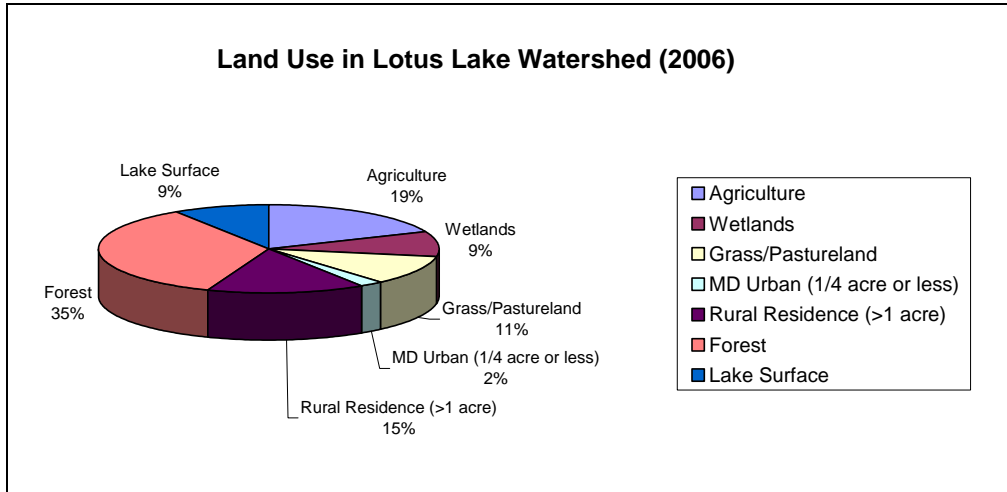
Lotus Lake is a shallow lake (15 feet maximum depth) near Dresser, Wisconsin. The lake has many characteristics of a marshland, but has 246 acres of open water. Upstream of Lotus Lake is a productive wetland through which Horse Creek flows and enters in the northeast corner of the lake. This wetland is home to many waterfowl, reptiles, tag alders, and wetland plants and shrubs. Lotus Lake is a eutrophic lake and experiences algal blooms during the summer months. The lake is part of the Horse Creek Watershed, a State Priority Watershed, and the larger Saint Croix River Basin. Horse Creek leaves Lotus Lake from the south and eventually flows to Cedar Lake and the Apple River.

Watershed and Lakeshore Land Use

It was noted in 1961 (Surface Water Resources) that 4 cottages surrounded Lotus Lake (then called East Lake). Waterfowl and muskrats were common in the six acres of marsh wetlands adjoining the lake. A parcel count around Lotus Lake in 2002 revealed 49 parcels. Today there are many riparian homes, Lotus Lake Estates, and subdivisions in

the watershed. Waterfowl do frequent the lake, but a local hunter noted it was no longer a prime location for duck hunting.

The Lotus Lake watershed is approximately 2712 acres. The majority of the land is forested (954 acres). Agriculture is the second largest land use at 504 acres. Rural residences comprise 403 acres, grass and pasture land encompass 298 acres, wetlands occur on 248 acres, and medium density urban development exists on 58 acres. The remainder of the watershed is lake surface.



Water Profiles

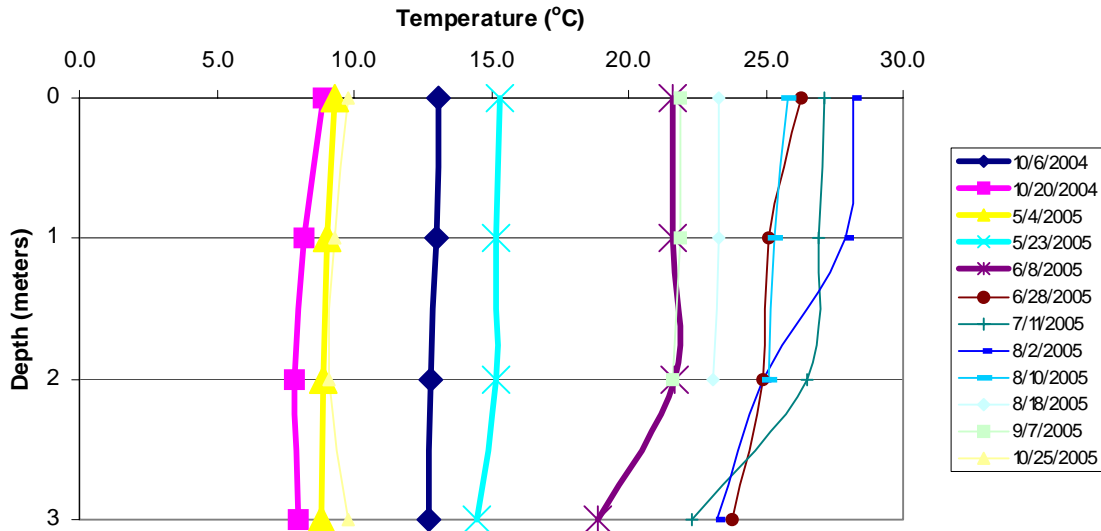
The temperature and dissolved oxygen were measured every two weeks in May and June and monthly from July to October. Secchi depth was also measured at this time. A YSI 85 instrument was lowered into the water at 1-meter depth intervals and the temperature, dissolved oxygen, conductivity, specific conductance, and salinity were recorded. See Appendix A for all data.

The temperature of the vertical water column is important to determine the amount of mixing and stratification that occurs in Lotus Lake. The amount of mixing is influenced by other factors like lake depth, size and shape, climate, topography, and vegetation. Together, mixing determines the pattern of nutrient cycling in the lake and the availability of nutrients to biological organisms.

The amount of dissolved oxygen in the lake water is important for the survival of aquatic organisms. Water with dissolved oxygen concentrations below 2 mg/L is not able to support life. Low oxygen concentrations will also affect the types of fish and invertebrates that can inhabit the area.

Looking first at the temperature profiles of Lotus Lake, one can see that the temperature on a given day is nearly uniform throughout the lake. This means that the lake is well mixed and has not stratified, which is expected of a shallow lake. Water temperature as well as nutrient concentration will be relatively even throughout the whole water column because of mixing. In May, the water temperature started at approximately 9° Celsius and warmed to 28° Celsius by August. On August 2, there is some degree of stratification starting to occur. The sun warms the upper surface water, and the lower water does not heat as fast. This creates differences in density in the water and helps the layers to separate. In deeper lakes (25 feet or more), this stratification is more succinct and will cause the oxygen in the lower layer (hypolimnion) to be depleted. It also traps nutrients at the bottom of the lake during stratification as the water is not turning the nutrients to the surface, which are later brought up during turnover.

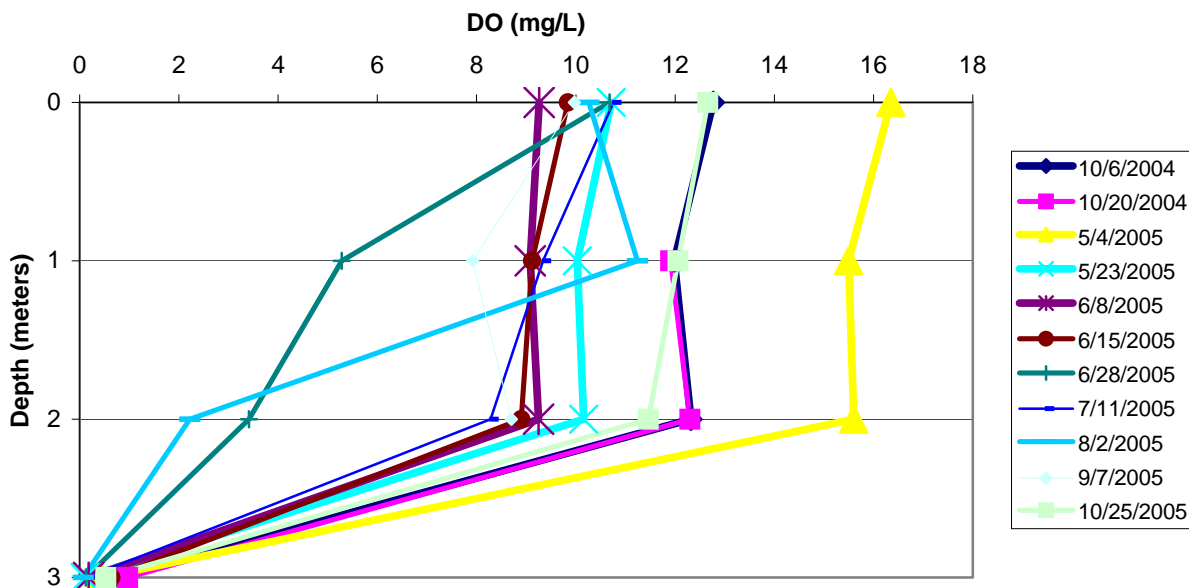
Temperature Profile for Lotus Lake



The oxygen profiles of Lotus Lake are typical of a northern shallow lake. Oxygen is brought into the lake from the atmosphere by wind and water movement. Fish, aquatic organisms, and bacteria that decay matter use oxygen while photosynthesizing plants and algae give off oxygen. The very bottom of the lake (at 3 meters depth) is mostly devoid of oxygen as the organic matter that settles to the bottom decomposes. Dissolved oxygen concentrations below 2 mg/L are considered anoxic and do not support large aquatic life.

Field notes for June 28, 2005, indicate a rain event occurred the previous day, and the water was greenish brown. August 2, 2005, was a hot, humid day (in the 90's). The dissolved oxygen curve on August 2 shows evidence of a slight algal bloom where the algae are giving off DO at 1 meter, and then DO decreases with depth as organic matter settles to decompose. The four profiles with the highest oxygen concentrations (above 12 mg/L at the surface) were measured in early spring or late fall during the turnover sampling events.

Dissolved Oxygen Profile for Lotus Lake



Water clarity is a measure of the light penetration into the water. Light penetration is important for plant growth and therefore the invertebrates and fish that use plants. Water clarity is affected by things *dissolved* in the water (minerals and natural acids) and things that are *suspended* in the water (such as algae or silt). Water clarity changes over the course of a growing season as more algae grow as the water warms. You expect to see the best water clarity in early spring, fall, and winter when biological activity is at its lowest.

Water clarity is measured by using a Secchi disk, an 8-inch round disk with alternating quadrants of white and black. The disk is lowered into the water on a calibrated rope, and when the colors cannot be differentiated, that depth is called the Secchi depth. This is a relatively cheap, accurate measurement of water clarity that can be compared over time.

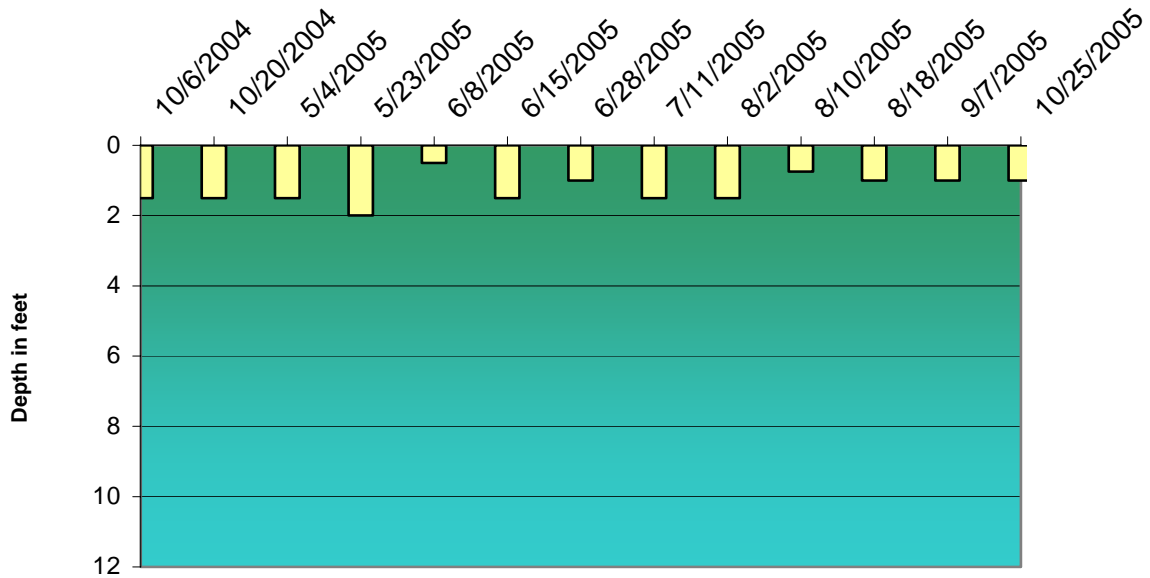


Water Clarity	Secchi Depth (ft)
Very poor	3
Poor	5
Fair	7
Good	10
Very good	20
Excellent	32

The Secchi depth ranged from 0.5 feet to a maximum of 2 feet over the summer (see table below). The average Secchi depth on Lotus Lake was 1.25 feet. The water clarity index (above) indicates Lotus Lake has very poor water clarity and suggests many particles are

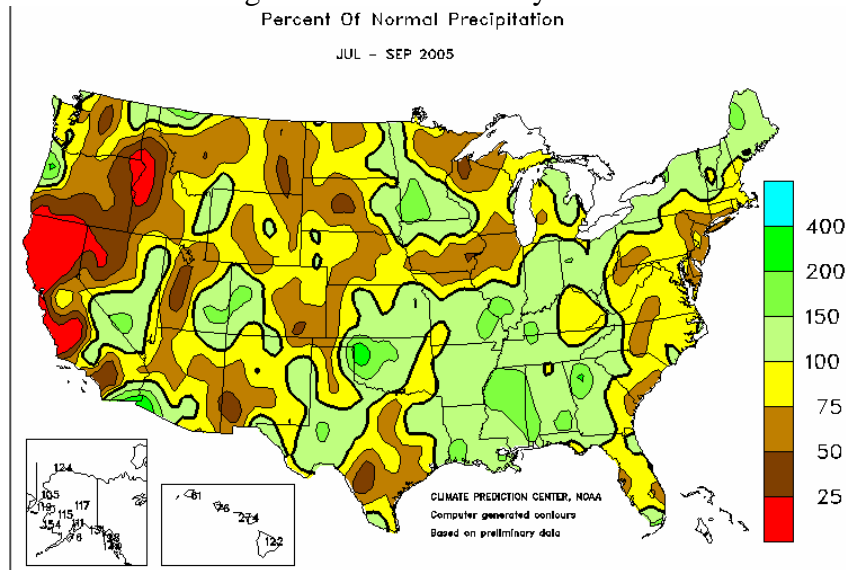
suspended or dissolved in the lake. Chlorophyll *a* (a measure of the amount of algae) and total suspended solids, two chemical tests, will be discussed in upcoming sections, which may affect water clarity.

Secchi Depth on Lotus Lake



Lake Level

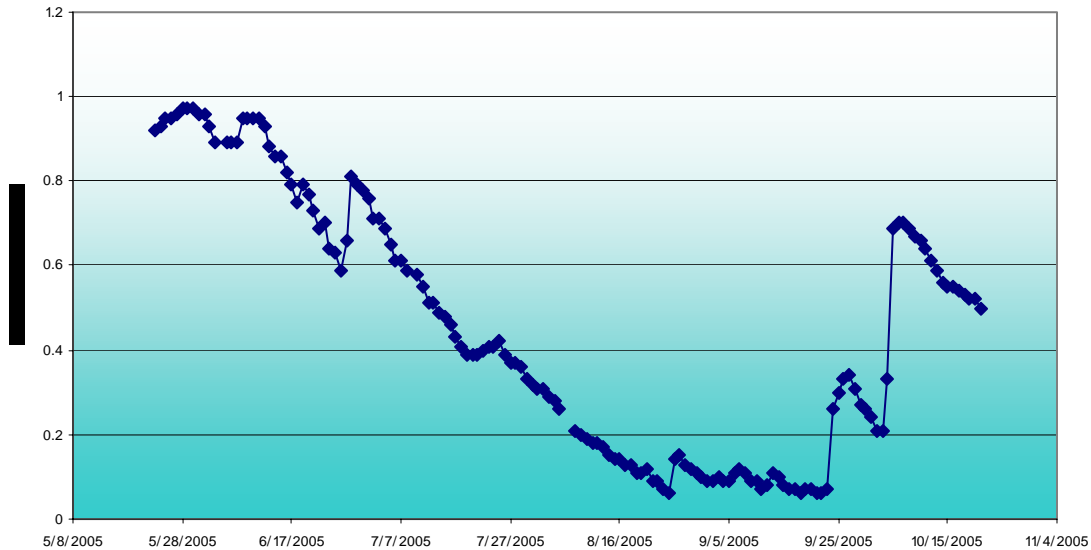
2005 was a dry year. Mid summer was very dry with record downpours in September. According to the National Oceanic & Atmospheric Administration (NOAA), precipitation in the area during late summer was only 75% of normal.



http://www.cpc.noaa.gov/products/analysis_monitoring/regional_monitoring/3-month-archive.shtml

The water level fluctuation of Lotus Lake is closely related to the amount of precipitation received. From the beginning of the season to the lowest point, Lotus Lake dropped 0.86 feet in water level. The lake was recharged 0.6 feet with late rains. The lake level is significant for plant growth, invertebrate and fish habitat, and nutrient cycling as well as docking and launching.

Lotus Lake Level 2005



Chemical Measures of Water Quality in Lotus Lake

Water chemistry samples were collected once a month from May to September of 2005. The samples were sent to the Water and Environmental Analysis Lab in Stevens Point to be analyzed. In addition, a spring and two fall turnover samples were collected and analyzed for additional chemical parameters. Appendix B contains all of the water quality data.

Phosphorus

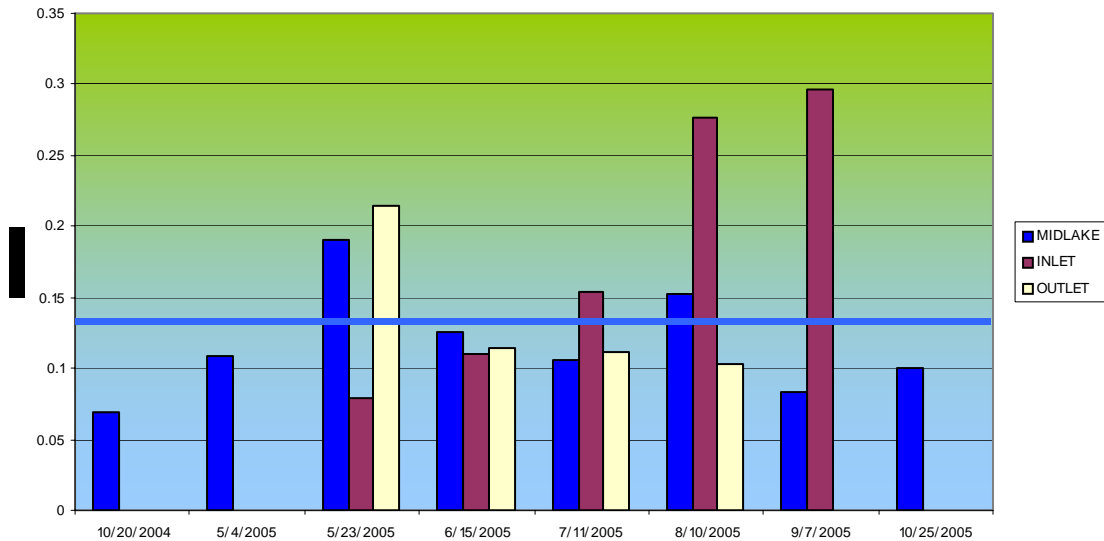
In more than 80% of Wisconsin's lakes, phosphorus is considered the limiting nutrient of lake growth. This means that the phosphorus concentration will determine the amount of plant and algae growth that occurs in the lake (Shaw et al. 2000). Phosphorus is present in a variety of forms, but typically evaluated as either soluble reactive phosphorus (also known as SRP, orthophosphate or PO_4^{3-}) or total phosphorus (TP). SRP is dissolved phosphorus in the water column that is immediately available to plants and algae. For this reason, SRP is usually present in low concentrations (about 5% of TP, Wetzel, 2001) and recycled quickly. Total phosphorus is a measure of the dissolved phosphorus *plus* organic and inorganic particulate phosphorus suspended in the water. TP is often used as a measure of lake phosphorus because it is more representative of the total quantity of phosphorus.

According to Shaw et al., (2000) local sources of phosphorus can be largely enhanced by human activities. These activities include soil erosion, non-Wisconsin purchased detergents, septic systems, runoff from lawns, gardens and agricultural fields and/or barnyards, construction site runoff, and development. Dishwasher detergents contain phosphorus, whereas laundry detergents purchased in Wisconsin do not. Regional sources of phosphorus may include animal wastes along with runoff from farmlands.

Lotus Lake had a summer growing season mean SRP concentration of 21 ppb. Spring turnover SRP concentrations of 10 ppb (Shaw, 2002) have been known to develop nuisance algal blooms. With a spring turnover SRP concentration of 17 ppb, there is enough phosphorus to fuel algal blooms early in the year on Lotus Lake.

The average summer TP concentration in Lotus Lake was 131 ppb. This is considered a hypereutrophic lake. The TP range of the summer samples was from 83 ppb to 191 ppb.

Total Phosphorus Concentrations in Lotus Lake



The average TP concentration flowing into Lotus Lake from the inlet was 183 ppb. Horse Creek from the north originates through a wetland. Wetland communities are very productive and have a lot of organic material and biological production. Channelized wetlands are said to retain only 5% of their nutrients, while the rest seems to be released to Lotus Lake. Lotus Lake retains some of the nutrients (settling of matter to the lake bottom) and the outlet had an average TP concentration of 136 ppb.

	Average Summer SRP	Average Summer TP
Inlet	122 ppb	183 ppb
Mid Lake	21 ppb	131 ppb
Outlet	18 ppb	136 ppb
Ave Turnover (3 samples)	15 ppb SRP	93 ppb TP

Nitrogen

Nitrogen is another important nutrient in lakes for plant and algae growth. In Wisconsin, nitrogen does not occur naturally in most soil minerals, but is a major component of organic matter (Shaw et al., 2000). Sources of nitrogen within the watershed include rainfall (up to 0.5 mg/L), domestic and agricultural fertilizer, lawn and garden clippings, and animal wastes on agricultural land. The amount of nitrogen in lake water usually can be related to local land use such as septic systems or lawn and garden fertilizer used on lakeshore property.

Nitrate and ammonium are two forms of nitrogen that are readily available to plants and can easily reach groundwater and surface water. The forms of nitrogen that were analyzed for Lotus Lake were NH_4^+ (ammonium), $\text{NO}_2^- + \text{NO}_3^-$ (nitrite + nitrate), and Total Kjeldahl Nitrogen (TKN), which is organic nitrogen plus ammonium. Both forms of inorganic nitrogen ($\text{NO}_2^- + \text{NO}_3^-$ and NH_4^+) are used by aquatic plants and algae and are very soluble, which means they are readily leached to groundwater. These forms can be transformed to organic nitrogen, and from organic nitrogen back to inorganic forms through the nitrogen cycle. Nitrogen also exists as a gas, and some algae species are able to obtain nitrogen from the atmosphere. These nitrogen concentrations are relatively low and do not drive algal blooms. As a reference, the drinking water standard for nitrate is 10 mg/L, which we are well below. Ammonium and TKN were also low, raising no flags. Nitrogen parameters were not analyzed on the inlet or outlet samples.

Lotus Lake

Summer Average	Inorganic		Organic
	$\text{NO}_2^- + \text{NO}_3^-$	NH_4^+	TKN
Mid Lake	0.084 mg/L	0.124 mg/L	2.31 mg/L

Nitrogen to Phosphorus Ratio

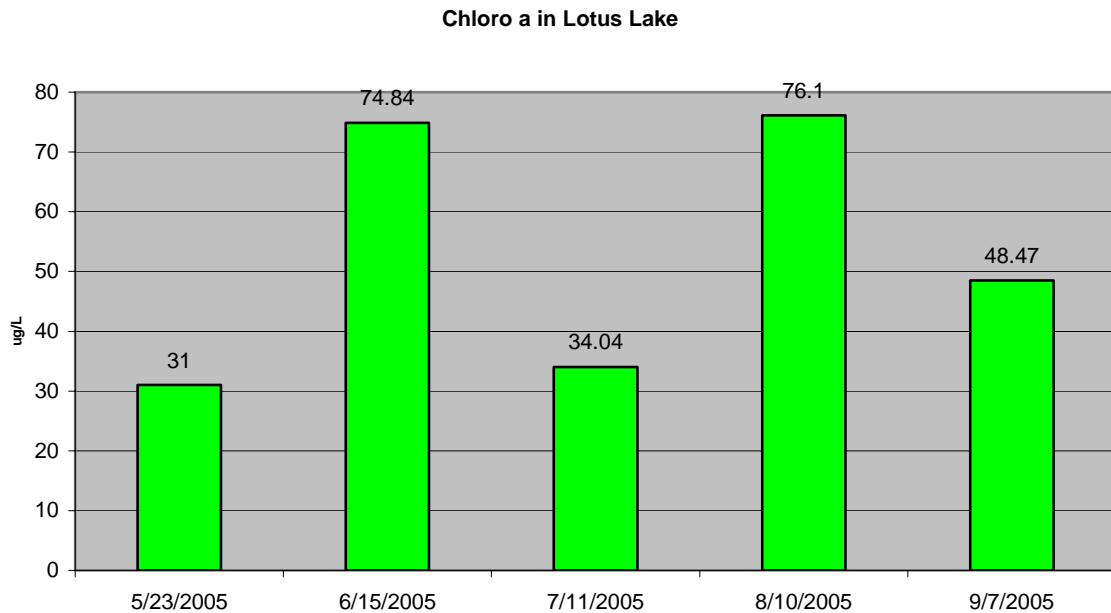
A plant's need for nutrients varies depending on the species and nutrient. Typically, plants and algae need about 10-15 times the amount of nitrogen as they do phosphorus. By comparing the total nitrogen content of the water to the total phosphorus concentration, a lake manager can see if the lake is nitrogen or phosphorus limited, relatively speaking. Lotus Lake has a TN:TP ratio of 22:1. This means there is 22 more times the amount of nitrogen than phosphorus, and the lake is limited by phosphorus input. Any addition of phosphorus will spur plant or algae growth. Best management practices should be implemented within the watershed to limit phosphorus loading to the lake to maintain a healthy ecosystem.

Chlorophyll *a*

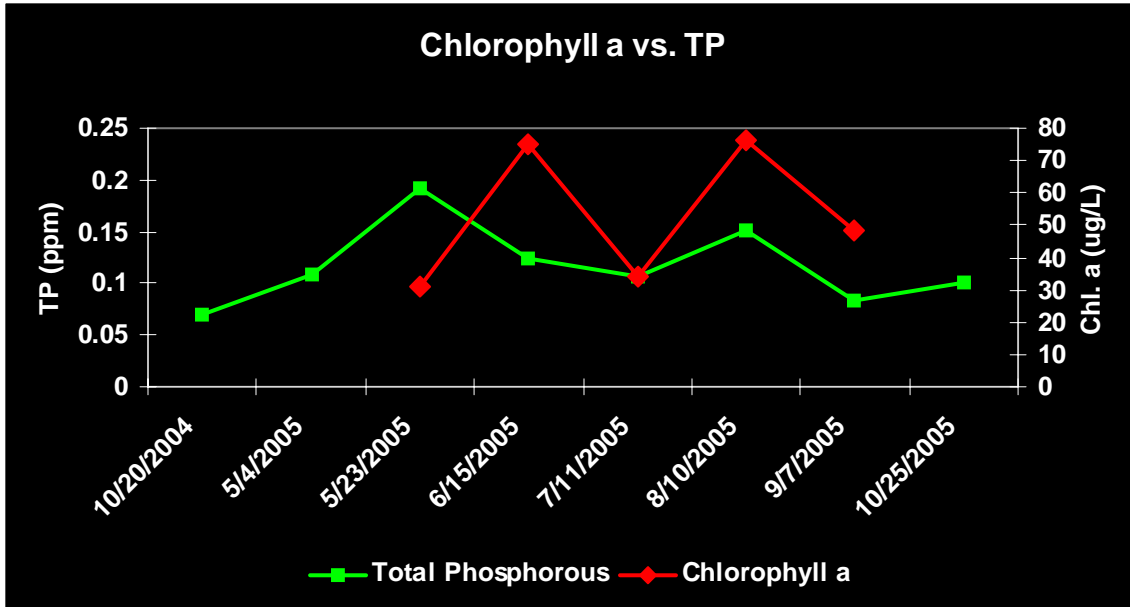
All plants and algae contain a green pigment called chlorophyll *a* which is necessary for photosynthesis. The amount of chlorophyll *a* in a sample of lake water is a measure of the amount of algae in the water column. This measure is not a direct correlation, but

gives the best account of algal biomass to date. Lillie and Mason (1983) assert that a chlorophyll *a* concentration of 10 ug/L is an indication of an algae bloom or potential for a bloom development.

Chlorophyll *a* samples were collected mid lake during the growing season. The concentration averaged 52.9 ug/L. This is a high value and classifies Lotus Lake as eutrophic according to the trophic classification by Lillie and Mason (ibid). The range of chlorophyll *a* concentrations for shallow mixed lakes in Wisconsin is usually between 15 and 30 ug/L. Generally data is collected and averaged for a 5-year baseline before manipulation of a system is planned.

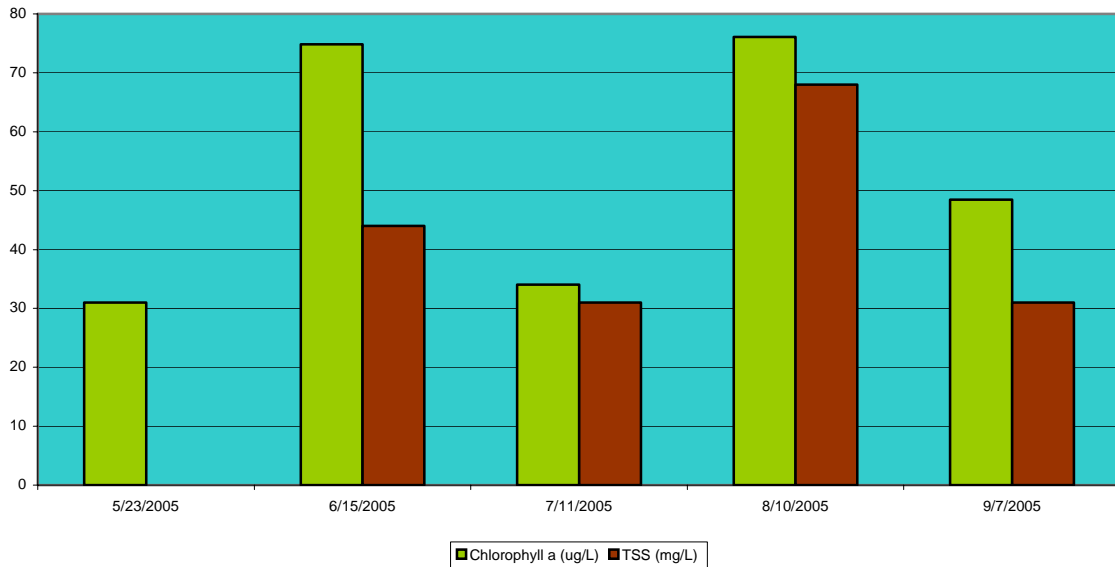


The algae in Lotus Lake also affects the total phosphorus concentration, and we see a relationship between chlorophyll *a* and the phosphorus concentration. The following chart shows a delayed response in chlorophyll *a* concentration following an increase in total phosphorus in the lake.



Chlorophyll *a* is also related to the amount of total suspended solids in the water column. Total suspended solids are a measure of the particulate matter in a water sample, such as algae or sediments. The R^2 value between chlorophyll *a* and TSS is 0.86 meaning the two parameters are correlated; much of the total suspended solids in Lotus Lake is algae.

Lotus Lake 2005



TROPHIC STATUS INDEX (TSI)

A frequently used index for a waterbody is the Trophic State Index by Carlson (1977), which measures the biological response for trophic state classification. Trophic state is understood to be the biological response to forcing factors such as nutrient additions, but the effect of nutrients can be modified by factors such as season, grazing, mixing depth, etc. Three variables, chlorophyll pigment, Secchi depth, and total phosphorus, are used independently to estimate algal biomass. This data is relatively easy to obtain and it allows comparison of variables for several lakes on the same scale.

The equations for arriving at the trophic state index are:

$$\text{TSI (CHL)} = 9.81 * \ln (\text{CHL}) + 30.6$$

$$\text{TSI (SD)} = 60 - 14.41 * \ln (\text{SD})$$

$$\text{TSI (TP)} = 14.42 * \ln (\text{TP}) + 4.15$$

The calculations for each index are:

$$\text{TSI (CHL)} = 70$$

$$\text{TSI (SD)} = 75$$

$$\text{TSI (TP)} = 73$$

TSI	General Description
<30	Oligotrophic; clear water, high dissolved oxygen throughout the year throughout the lake
30-40	Oligotrophic; clear water, possible periods of oxygen depletion in the lower depths of the lake
40-50	Mesotrophic; moderately clear water, increasing change of anoxia near the bottom of the lake in summer, fully acceptable for all recreation/aesthetic uses
50-60	Mildly eutrophic; decreased water clarity, anoxic near the bottom, may have macrophyte problem; warm-water fisheries only.
60-70	Eutrophic; blue-green algae dominance, scums possible, prolific aquatic plant growth. Full body recreation may be decreased
70-80	Hypereutrophic; heavy algal blooms possible throughout the summer, dense algae and macrophytes
>80	Algal scums, summer fish kills, few aquatic plants due to algal shading, rough fish dominate.

Lotus TSI Ratings

Based on the different results for each index variable, one can compare the results to make a few more relationships. In the case of Lotus Lake, TSI (CHL) < TSI (TP) < TSI (SD). Some factors that could be influencing the lake are non-algal particulates that affect light attenuation [because TSI (CHL) < TSI (SD)]. However, the TSI's are relatively the same indicating algae is the largest factor that affects light penetration (Carlson, 1996).

Chemistry from Turnover Samples

In spring and fall when the lake temperature is uniform throughout, a lake turnover sample is collected. Data collected during spring and fall overturn represent a lake's most uniform water quality conditions and are most valuable for comparing year-to-year changes. Because there is little biological activity in early spring and late fall, nutrient concentrations show what minerals remain in the water. During the turnover period, samples are analyzed for additional components, which gives us supplemental information about the lake.

Alkalinity, Calcium, and Total Hardness

Some of the dissolved minerals in the lake water are calcium and carbonate. A lake's hardness and alkalinity are affected by the type of minerals in the soils and bedrock in the watershed and by how much the lake water comes into contact with these minerals. If a lake receives most of its water from groundwater that flows through an aquifer containing calcite (CaCO_3 , a.k.a. limestone) and dolomite (CaMgCO_3), hardness and alkalinity will be high. The two measurements are usually related because of their source. Total hardness is a measure of calcium, magnesium, sodium, and sulfur. Alkalinity is a measure of the amount of inorganic carbon (CO_2 , CO_3 , and HCO_3) in the system, which is the lake's buffering system against acid rain. The carbonate system is affected by photosynthesis, respiration, and contact with the atmosphere, affects basic biological productivity, and regulates the solubility of many toxic chemicals.

The average alkalinity measured in Lotus Lake during turnover samples was 75 ppm as CaCO_3 . The amount of carbon in the system is able to resist changes in pH, and the lake is not sensitive to acid rain. The average total hardness was 85 mg/L as CaCO_3 . This classifies the lake as moderately hard. The calcium hardness of Lotus Lake was 62 mg/L as CaCO_3 , which makes up over half of the lake's hardness. Excess calcium in the system may react with carbonate to precipitate and form a white floc on plant leaves and sediments.

The pH of the lake during turnover samples averaged 8.39. During the spring 2005 event, the pH was one standard unit higher at 8.99 versus 7.78 and 7.89 in fall of 2004 and 2005 respectively. This change in pH is most likely brought on by an increase in the amount of algae in spring. The algae utilize carbon dioxide, which creates more basic conditions. As such, the alkalinity and calcium concentrations in the lake are lowered because of precipitation of calcium carbonate, driven by the increase in pH.

Phosphorus concentrations in the lake during turnover reveal naturally high concentrations. The SRP was 15.3 ppb and TP averaged 93 ppm. These levels are slightly lower than during the summertime, but enough to stimulate algal blooms. Nitrogen concentrations were also lower in the lake during turnover than in the growing season.

Chloride, Sulfate, Sodium, and Potassium

Additional parameters measured during the turnover samples were chloride, sulfate, sodium, potassium, turbidity, and color. Chloride is a biologically non-reactive element that occurs in the environment because of human impact. Sources include septic systems, animal wastes, agricultural fertilizers, and road salts. Increases in chloride can mean that one or more of these sources are affecting the lake. Naturally occurring chloride concentrations in this part of Wisconsin range between 3-10 mg/L. Average lake concentrations were found to be 6.7 mg/L. If an increase in chloride is found over time, it may be an indicator of human influences and the sources should be investigated to prevent further pollution.

The sulfate concentration in Lotus Lake was 5.8 mg/L. Generally sulfate concentrations in this part of Wisconsin are under 10 mg/L. Sources of sulfate include minerals found in the watershed and acid rain carried from industrial output. Sulfate can also be more present in lakes that are depleted of oxygen. Sulfate in the water column is reduced to hydrogen sulfide (smells like rotten eggs) and is toxic to aquatic organisms.

Natural levels of sodium and potassium ions in soil and water are very low, and their presence may indicate lake pollution caused by human activities. Sodium is often associated with chloride. It finds its way into lakes from road salt, fertilizers, and human and animal waste. Potassium is the key component of commonly-used potash fertilizer and is abundant in animal waste. Soils retain sodium and potassium to a greater degree than chloride or nitrate; therefore they are not as useful as environmental indicators. Increasing sodium and potassium values over time can mean there are long-term effects caused by pollution. Although not normally toxic themselves, these compounds strongly indicate possible contamination from more damaging compounds. The sodium and potassium concentrations found in Lotus Lake were relatively low at 3.0 mg/L and 1.8 mg/L, respectively.

Turbidity and Color

Turbidity is another measure of water clarity that is caused by particles of matter rather than dissolved organic compounds. Sources of turbidity in a lake include silt or clay soils present in runoff, suspended animals, and suspended plants and algae. Higher turbidity levels are often associated with higher levels of disease-causing microorganisms such as viruses, parasites and some bacteria. The average turbidity in Lotus Lake was 8.7 NTU, which is low.

Color of lake water can also affect water clarity because of dissolved organic compounds. Sources of color commonly originate from the decomposition of naturally occurring organic matter. The average color of Lotus Lake was 53.7 CU. According to Shaw et al, this water color is considered Medium (40-100 units). However, there was a difference in color between the samples, with the fall 2005 turnover sample being much higher. This is most likely due to the influence of the organic decomposition coming from the upstream wetland during the fall months.

Date of Sample	Turbidity (NTU)	Color (CU)
10/20/04	6.5	33.0
5/23/05	9.7	38.0
10/25/05	10	90.4
Average	8.7	53.7

As stated in previous sections, plant decomposition occurs most rapidly under oxygenated conditions. So when more oxygen is present, more decomposition will take place. There are two possible reasons the decomposition rate may have increased in Lotus Lake in 2005. 2005 was considered a dry year and the lake level was down even to

the point of not discharging through the outflow. More organic matter could have been retained in the lake for which to decompose. Also, the draw down exposed more of the lakebed and sediment to the atmosphere, giving it oxygenated conditions to break down. Thus Lotus Lake has more color as a result of the dissolved organic compounds.

The presence of additional oxygen in the water could lead to increased decomposition of organic matter, affecting the lake color. The criteria established by the Environmental Protection Agency for color in lake water is that “increased color (in combination with turbidity) should not reduce the depth of the compensation point for photosynthetic activity by more than 10 percent from the seasonally established norm for aquatic life.” While this does not give an exact value for limits of color in Lotus Lake, the EPA document further explains the reason/nature for these criteria. “The effects of color in water on aquatic life principally are to reduce light penetration and thereby generally reduce photosynthesis by phytoplankton and to restrict the zone for aquatic vascular plant growth.” If color in Lotus Lake continues to rise, it will negatively impact the aquatic plants. Future monitoring of color will determine if the fall of 2005 measure warrants cause for concern.

Lead

Lead is a toxic metal that can affect the central nervous system and other organs if too much is consumed. The Wisconsin “action level” for lead concentration in potable water is set at 15 µg/L (or 15 ppb). This action level is set for public drinking water supplies and community water systems. It does not apply to surface waters such as lakes or rivers, however, we are using the information here as a basis for comparison. The lead concentration was tested in Lotus Lake and was 2.4 ppb. Lead tends to remain insoluble, meaning it prefers to be in a solid state rather than as a liquid. Lead is more likely to be found in the lake sediments than in the liquid water column.

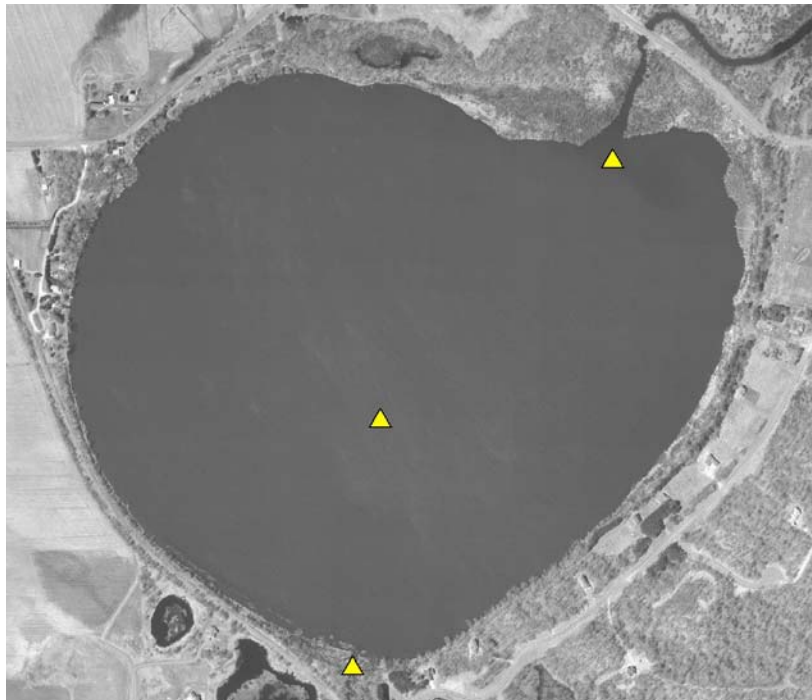
Other lakes in the state were queried for lead concentrations. Generally low levels of lead were found unless the site was known to be contaminated. The background level is typically lower than 2 µg/L. Three homeowner wells were tested around Lotus Lake in 2002. The faucets were run for at least 10 minutes to clear the water lines of plumbing influence. The range of results of lead in these samples was below detection limits to 6.1 ppb (Ruetz, 2006). Sources of lead to the environment include lead-based paint, lead shot from firing ranges, contaminated food (lead in the air or lead-soldered food containers), drinking water in homes where there is corrosion of plumbing systems, lead-based gasoline (from the 1970’s), and lead fishing tackle (sinkers and jigs).

In this area of the state, problems with lead have been less associated with human implications and more with problems for upland birds. Lead sinkers or lead shot can be mistaken for food or grit and consumed by waterfowl and wildlife. In many studies, water birds and birds of prey cause of death was caused a fourth of the time (25%) from lead poisoning. Lead particles can also be carried from land to surface water by stormwater runoff.

Lake Sediments and Lead

Lake sediments are an important component of lake studies. The sediments are both a source of nutrients to the lake water and also a place for nutrients to settle out of the water column, depending on the chemistry and time of year. The sediments react with the lake water, especially in an unstratified lake, to replenish the lake with nutrients from decomposing organic matter. The lake bottom is also a store for nutrients and other elements that enter the lake and settle to the bottom. These accumulated sediments give a record of watershed and biological activity to see what may be affecting the lake.

Three sediment samples were collected from Lotus Lake with a Ponar dredge. The top 3 inches of lake sediment were gathered and stored in a Ziplock bag. The samples were frozen and transported to the testing lab. The sample locations are illustrated in the following aerial photograph, and the results are summarized in the following table.



Lotus Lake Sediment Samples
 August 10, 2005
 ppm=mg/kg

Location	Lab Number	Description	TN %	TN (ppm)	TP (ppm)	TK (ppm)	S (ppm)	Pb (ppm)	Moisture (%)	Dry Matter (%)
Inlet	6193	taken from boat. Some plant material in sample. Sediment was organic debris about 1/4 inch or less and fines. Brown and runny. About 1 foot deep in water, but muck about 5 feet or more.	0.7	1045	480	305	520	129	85.1	14.9
Mid Lake	6194	very runny, fine, brownish green, no plant material noticeable, finely decomposed	1.3	1445	610	185	400	37	88.9	11.1
Outlet	6195	Very dry at site. Very sandy with marshy vegetation. Taken about 150 feet from lake, upstream of little dam at outlet.	0.1	565	775	70	1015	1	43.5	56.5

The flow pattern of the lake and creek has some influence on the content of lake sediments. Typically we expect to see the highest elemental values at the deep hole, which accumulates the most sediment, organic matter and plant fragments from settling. Lotus Lake, a drainage lake, has an incoming creek which creates a delta at the inlet as the water slows down in the lake entrance. Nutrients that are associated with sediments will be elevated with the higher solid content.

The inlet and mid lake samples were fairly similar in composition. Total nitrogen was highest at the deep hole (mid lake sample) as organic material (dead plants, algae, invertebrates, and vertebrates) washes to the lowest point. Total phosphorus was also higher at the mid lake site than the inlet site. The outlet sample was quite different in composition because of the bottom substrate at the site. It was much sandier and “terrestrial” with less lake accumulation, indicated in the higher percentage of dry matter in the sediments. The two upper samples (inlet and mid lake) show more lake influence with a higher percent moisture in the sediments from the organic material collected at each site.

Potassium (K) and sulfur (S), minor components of plant makeup, were higher at the inlet than the mid lake sample. This is most likely because of the sediment settling pattern, but could indicate a source of nutrients other than plant decomposition. The sulfur content is higher than the phosphorus content at two of the samples. Further investigation of upstream land use reveals both a shooting range and a gravel pit. The sulfur could be from gunpowder influence or it is also notable that Lotus Lake is located near railroad tracks. Charcoal used to fuel the trains was high in sulfur content. Black powder, or gunpowder, is made by mixing elemental sulfur, charcoal, and saltpeter (potassium nitrate) in the ratio of 75:15:10 saltpeter:sulfur:charcoal.

A lead plume is also evident in the sediments originating upstream. Lead travels as a solid and is most concentrated at the source of contamination. The inlet had a concentration of 129 ppm, 37 ppm at the midlake site, and 1 ppm lead at the outlet. The sediment samples collected in 2005 by the Land and Water Resources Department staff were all below the probable effect concentration (PEC) (please see the following table). This does not mean lead-contaminated sediment will not drift in the future. Boat disturbance, which causes bottom sediments to resuspend and move in the water column, may move the lead into other places of the lake. Historical information on Lotus Lake shows lead sediment samples in the upstream reaches (in the wetland) and on Osceola Rod and Gun Club property ranging between 15 and 18,100 mg/kg.

Sediment Quality Guidelines to protect benthic macroinvertebrate communities have three levels.

TEC	None or low probable effect	36 mg/kg lead
MEC	Some probability of effect to benthic organisms	83 mg/kg lead
PEC	Probable effect of impact to benthic organisms high	130 mg/kg lead

Sediment samples were taken and tested for lead concentration at two other sites in Polk County. Upstream of the Woodley Dam on the Apple River (sample date 12/14/04) the lead was 937 mg/kg. This was from an 8-foot sediment core which was homogenized and analyzed. Following the Osceola Dam blow out in 2002, sediment samples were analyzed with an average lead concentration of 15 mg/kg. The surface water on Osceola Creek at that time was less than 1 ppm lead. Other lead sediment testing on Polk County lakes **by the DNR** (personal communication with Philip Richard, Hydrogeologist, 2005) in previous years was:

Lake	Lead concentration (mg/kg)
Balsam	66
Bone	77
Butternut	54
Deer	58
Lotus (2003)	43

Lead and Fish Tissue

Because lead is known to be in the lake system, fish samples were collected to determine if lead was present in fish tissue. Six specimen were collected at the same time the fish electroshocking was performed. We intended to collect game fish that are consumed, but none were caught during the survey. As a worst case scenario, carp, which are bottom feeders and root in the lake sediment, were collected for analysis. The fish were measured and filleted, and only the meat or consumable portion of the fish was tested.

The EPA health advisory set for waterfowl is 0.25 ppm (ppm=mg/kg). None of the samples reached the 0.25 ppm threshold.

Lotus Lake Fish Tissue Results

Date Sampled: 9/28/05

Sample #	Lead GFAA (mg/kg)	Length of Fish (inches)	Sex
1	<0.09	16.5	F
2	<0.09	19.6	M
3	<0.09	18.2	F
4	0.16	18	F
5	0.23	16.8	F
6	<0.09	15.6	F

Biological Measures of Water Quality in Lotus Lake

Limnology is the study of freshwater communities. The study includes chemical parameters, physical features, and biological structure. Just as a plant needs chemical elements (nutrients) to grow, the plant also changes the chemical environment (plants are used in clean up plans to abate pollution.) This biological/chemical interdependence also exists between biology and the physical environment (a floating leaf plant shades the water and can affect the temperature) and chemical and physical parameters (dissolved organic matter can change the color of lake water). Six biological characteristics of Lotus Lake were assayed: algae, zooplankton, aquatic macroinvertebrates, aquatic vegetation, terrestrial vegetation, and fisheries.

Algae

Two types of testing were completed on Lotus Lake for algae. Chlorophyll *a* samples were collected and analyzed, as described in the Chemical Measures section. Chlorophyll *a* is universal to all plants and algae, but certain flora also contain accessory pigments for photosynthesis. Cyanobacteria also utilize chlorophyll *d*. Universal statements about algal communities and quality based on chlorophyll *a* samples are difficult to make.

For these reasons, algae composition samples were examined to determine the species of algae present. Great variability exists between lakes in quantity and assemblages of algae. The species composition of Lotus Lake is described below. Relative concentrations of algal classes show the dominance over the summer season. Any species of concern can also be identified if present.

Algae Composition

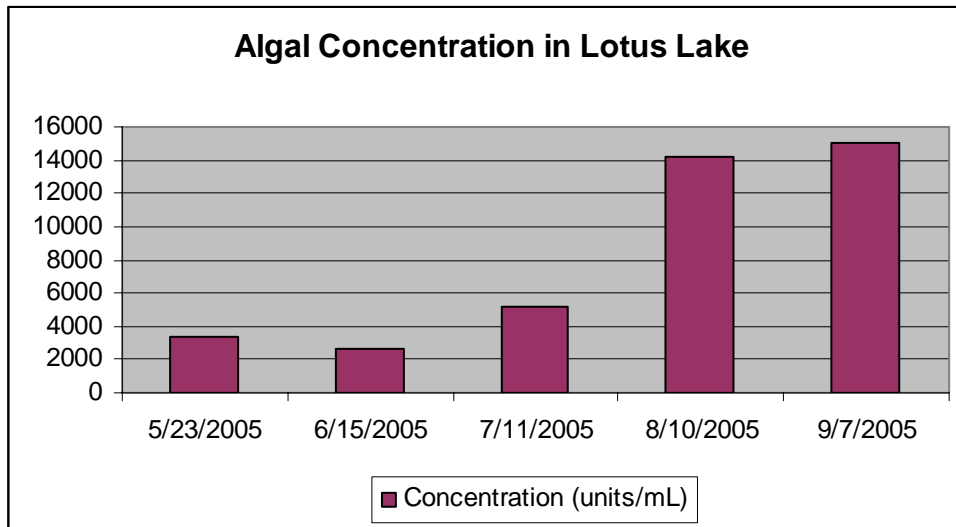
Algae are an important component of a lake's food web. Algae, also called phytoplankton, are microscopic plants that convert sunlight and nutrients into biomass, which may or may not be consumable. They are the primary producer in the aquatic ecosystem and their identification and enumeration is important because they respond quickly to changes in water chemistry. Because of their short life cycle, changes in water quality are often reflected by changes in the algal community within a few days or weeks. Determination of the numbers and types of algae present in a water body is useful in environmental monitoring programs and impairment assessments. Correct identification of target species is critical when determining a management strategy.

Algal morphologies can be unicellular, planktonic, colonial, pseudo filamentous, filamentous, or take other forms. Algae are classified or divided by a combination of their characteristics including photosynthetic pigments (like chlorophyll *a*), starch-like reserve products, cell covering, and other aspects of cellular organization.

The types of algae in a lake will change over the course of a year. Typically there is less biological activity in winter and spring because of ice cover and cold temperatures. As

the lake warms up and gains access to more sunlight, algae communities begin to grow. Algae can live on bottom sediments and substrate, in the water column, and on growing plants and leaves. The genus and species that are found are in response to the climate, nutrients, carbon dioxide, grazers, and other factors in the lake (Wehr and Sheath, 2003). When high nutrients are available, blue green algae often becomes predominant.

The concentration of algae in the water column was measured in units/ml. As described, algae morphologies can be unicellular or colonial, depending on the type of algae. The concentration analysis measured the algae in the natural units that they take. This measurement does not describe biomass in the lake. Biomass is the weight of all living material in a unit area at a given instant in time. This is a measure of the amount of production in the lake by phytoplankton. The following graph is shown for comparison of algae units throughout the season, but is not indicative of the biomass in Lotus Lake, just the number of algal units per milliliter of water.



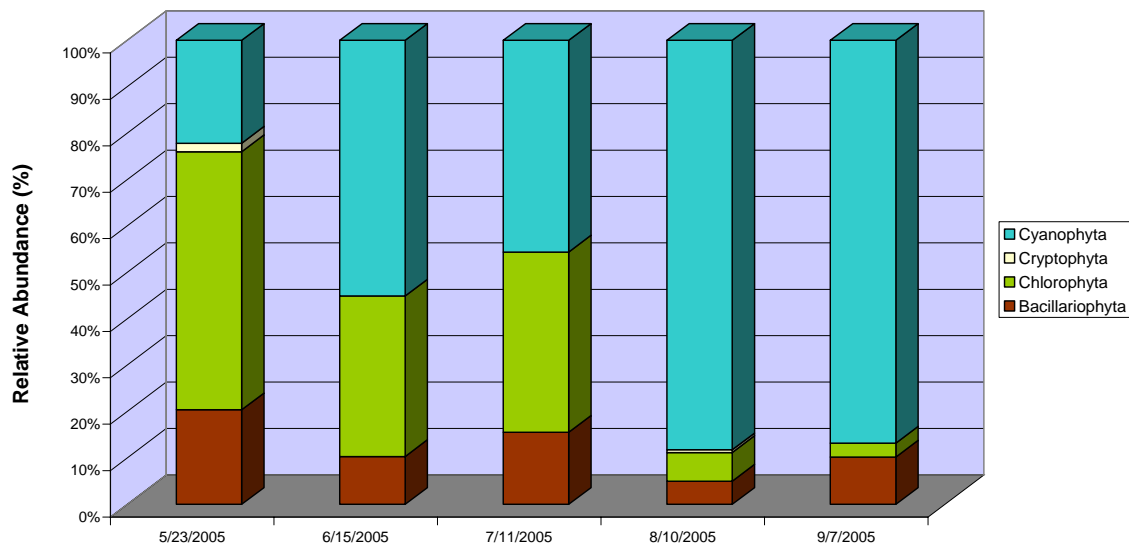
There are 12 classes of algae found in typical lakes of Wisconsin. We found 4 classes in Lotus Lake:

Algal Class	Common Name	Characteristics
Chlorophyta	Green Algae	Have a true starch and provide high nutritional value to consumers. Can be filamentous and intermingle with macrophytes.
Bacillariophyta	Diatoms	Have a siliceous frustule that makes up the external covering. Sensitive to chloride, pH, color, and total phosphorus (TP) in water. As TP increases, see a decrease in diatoms. Generally larger in size. Tend to be highly present in spring and late spring. Can be benthic or planktonic.
Cryptophyta	Cryptomonads	Have a true starch. Planktonic.

Cyanophyta	Blue Green Algae	Prevail in nutrient-rich standing waters. Blooms can be toxic to zooplankton, fish, livestock, and humans. Can be unicellular, colonial, planktonic, or filamentous. Can live on almost any substrate. More prevalent in late to mid-summer.
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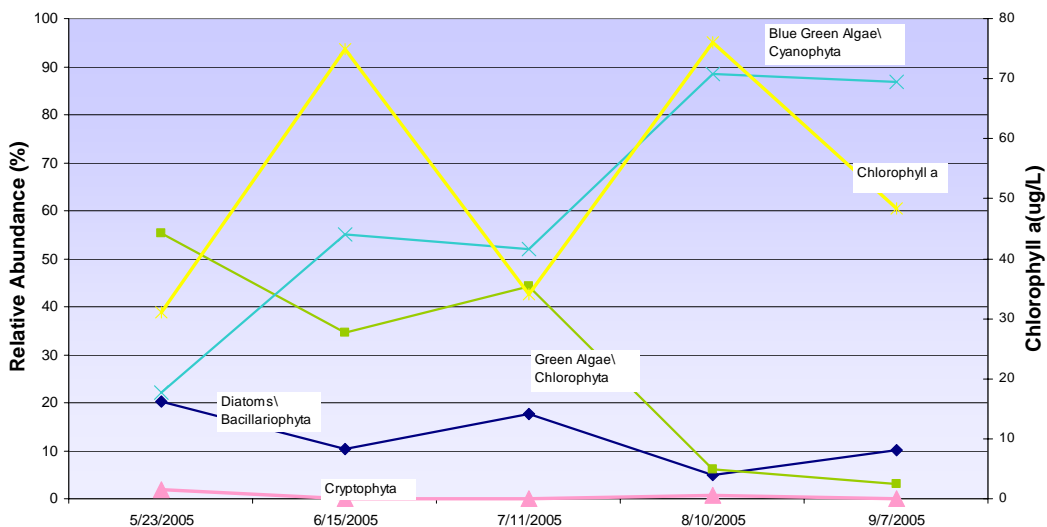
Green algae were the dominant algae class in Lotus Lake in May. Blue green algae became the dominant algae class by June, making up at least 52% of the relative abundance for the remaining months. Green algae were present throughout the summer, but in decreasing abundance. Cryptophyta were not largely represented with a maximum of 1.8%. Bacillariophyta ranged from 5%-20.3% abundance in the algae population.

Algal Composition in Lotus Lake 2005



Blue greens do not supply high quality food for zooplankton or fish. Certain blue greens are capable of producing toxins. These toxins inhibit plant growth by alleopathic organic compounds and enable blue greens to proliferate. The toxins are said to be produced only from certain species when their concentration exceeds 100,000 cells/ml (World Health Standard). The toxins also affect zooplankton, fish, dogs, livestock, and humans.

Algal Composition in Lotus Lake 2005



This second graph of algal composition is the same information as the previous graph, but shows each algal class individually. Chlorophyll a is also shown.

In Lotus Lake, there were four blue-green species capable of producing a toxin. The species concentration was measured in units/ml, which is the natural form they take, versus cells/ml. One unit of algae may have between 20-200 cells. It is important to know the cells/ml in order to know when to analyze for toxins.

Because of the unknown blue-green biomass, it is recommended that further testing be conducted on Lotus Lake. Algae should be analyzed in cells/ml. It is recommended to have five years of baseline data to rule out anomalies such as runoff and seasonal variation. Water samples should also be collected and analyzed specifically for blue green toxins when algae concentrations surpass 100,000 cells/ml.

In addition to high blue green algae concentrations, another species of concern was found in Lotus Lake. *Cylindrospermopsis raciborskii* was identified, which is an exotic blue green algae species not typically found in Wisconsin. The algae most likely arrived on the feet or feathers of waterfowl. “Cylindro” is also capable of producing toxins, although has not yet been known to do so in Wisconsin. See the DNR website for more information on blue green algae <http://dnr.wi.gov/org/land/parks/safety/bluegreenalgae.html> or contact the Department of Health and Family Services at (608) 266-7480.

Under accelerated nutrients (be it cultural eutrophication or seasonal differences), lakes try to keep them selves in some sort of balance with regard to nutrients and diversity. “Lakes reorder their internal states to the new environmental conditions. The biological standing stocks usually increase (Biomass) at higher nutrient levels. Species structure may be the key to achieve ecosystems capacity of resilience. Species respond to nutrient

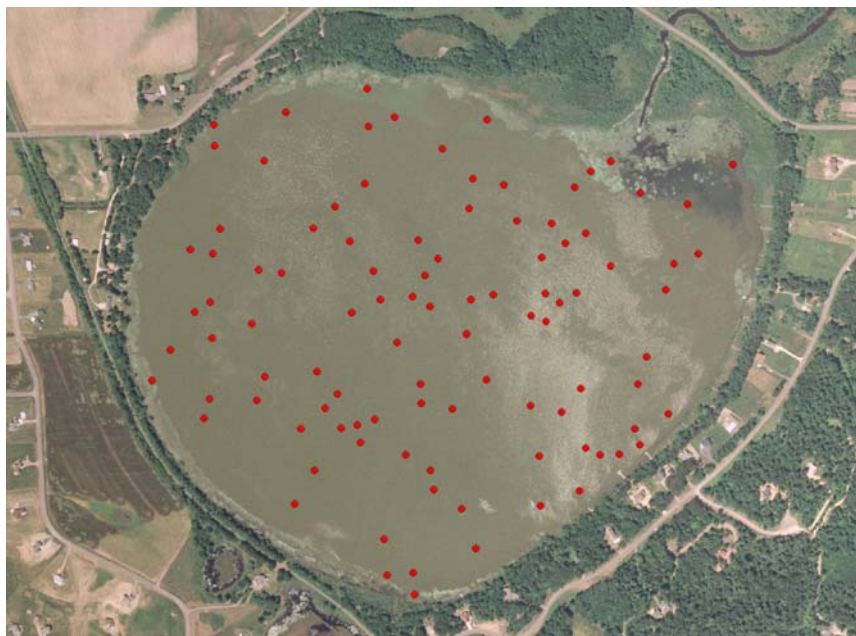
and light conditions. Community structure change is an ecosystemic resilience response to a change in the lake nutrient environment.” (Quiros, 2000)

Watershed management and best management practices to limit phosphorus fertilization of the lake are considered a water treatment recommendation for toxin limitation. With reduced nutrients, the algal community will respond by changing the class of algae, which will have cascading effects on the rest of the lake ecosystem. Residents and neighbors of Lotus Lake should find out how they can reduce the amount of nutrients originating from their property.

Aquatic Macrophytes

Aquatic macrophytes are to lakes what trees are to forests. The plants serve as food and habitat for waterfowl, small mammals, herptiles, aquatic bugs, algae, fish, and zooplankton. They also take up nutrients from lake sediments and the water column, hold lake sediments in place, and reduce erosion from wind and waves. They are an essential part of a lake ecosystem and water quality. The type and amount of plants are very telling of a lake ecosystem, particularly of shallow lakes.

Two aquatic macrophyte surveys were conducted on June 27th and August 18th, 2005. One hundred (100) random sampling points in the lake were generated in ArcView. The points were downloaded and located with a GPS unit to sample during the field surveys for a point intercept sampling method. Of the 100 sample points, only 13 sites had vegetation in June and only 14 in August.



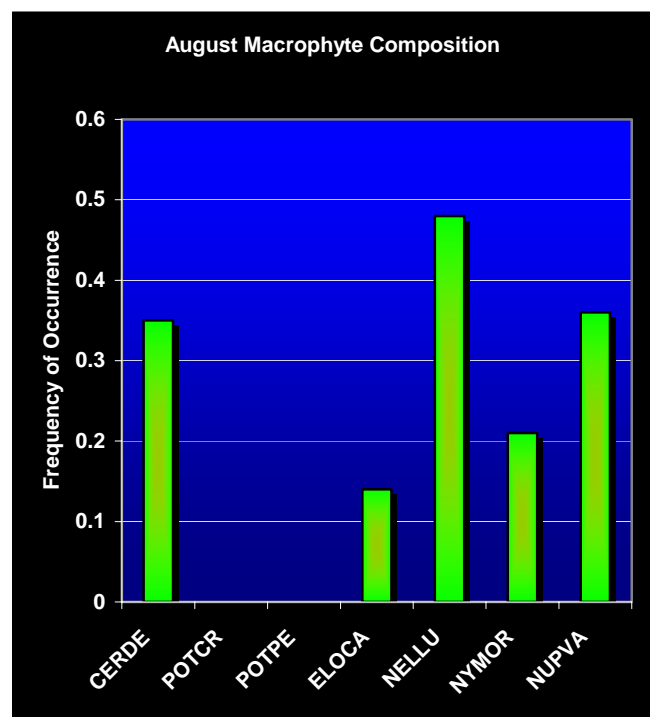
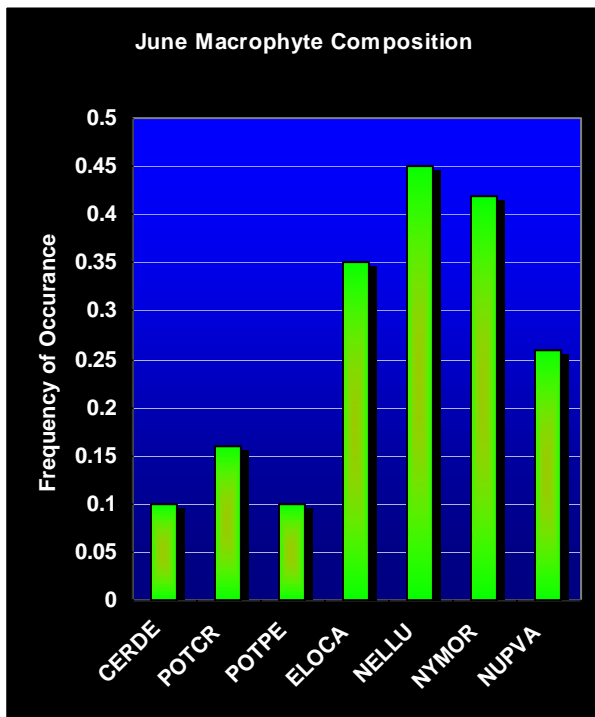
Macrophyte collection sites on Lotus Lake

The Jessen and Lound rake method was used to sample the macrophytes. This method uses a rake with a handle in an area 1-meter square (1 m²). The rake is drawn in a figure eight and inverted and brought to the surface to assess the sample.

Each plant on the rake head was identified to species and the approximate density of each species determined (e.g. *Potamogeton zosteriformis*, density of 4). This can be used to determine species composition or dominance of a species at a site or certain water depth. The results were then evaluated using three different indices or metrics, the Floristic Quality, Shannon-Wiener Diversity Index, and the Frequency of Occurrence for each species.

The Frequency of Occurrence (FO) is defined as the number of sites that the species occurred divided by the total number of sites in the lake with vegetation. FO is expressed as a percent. The FO shows that *Nelumbo lutea* (American Lotus) was the dominant species on Lotus Lake, occurring at 45% of the sites with vegetation in June and at 48% of the sites with vegetation in August. Other floating leaf species such as *Nyphea ordata* (White water lily) and *Nuphar Variiegata* (Yellow water lily) were also present. *Elodea canadensis* (Common water weed) was the most common submerged species in June, while *Ceratophyllum demersum* (Coontail) was the most abundant submerged species in August.

These floating leaf plant species do not offer much protection in the water for fish foraging, hide outs, or macroinvertebrate habitat. The leaf is on or above water and does not have structure (leaves) in the water for attachment. Lotus Lake likely does not have an adequate aquatic plant community to provide enough habitat to support a sport fishery.



Species Frequency of Occurrence in June and August 2005. CERDE = *Ceratophyllum demersum*, POTCR = *Potamogeton crispus*, POTPE = *Potamogeton pectinatus*, ELOCA = *Elodea canadensis*, NELLU = *Nelumbo lutea*, NYPOR = *Nymphaea ordata*, NUPVA = *Nuphar variegata*.

The Shannon-Wiener Diversity Index was also calculated for the macrophytes in the lake. The Shannon-Wiener Index is a measure of order within a particular system. With this number we can then specify the degree of diversity. For example, a site with only one species has an H value of 0, the higher the number, the more diverse a lake. Because the total number of individual plants was not determined in this survey, the density of the species was substituted for the total number. It was thought that the density of the species would accurately represent the population of each individual species.

The Shannon-Wiener diversity index for Lotus Lake was calculated to be 1.69 in June and 1.47 in August. The actual diversity rating is probably slightly higher than calculated as other species, such as *Myriophyllum sibiricum* (Northern water-milfoil) were observed but not collected. Additional monitoring would improve diversity indices and our understanding of the aquatic plant community. This diversity index is low probably because of the shallow rooting depth of plants. Plants were only found to grow at a maximum depth of 5 feet. At sites deeper than 5 feet, plants were not found most likely due to reduced light conditions because of poor water clarity.



2005 littoral zone coverage in Lotus Lake

The Floristic Quality Index was determined to assess the quality of the macrophyte community in Lotus Lake. The Floristic Quality Index evaluates the closeness of the flora in an area to that of an undisturbed condition. It can be used to identify natural areas, compare the quality of different sites or locations within a single lake, monitor long-term floristic trends, and monitor habitat restoration efforts. This is an important assessment in Wisconsin because of the demand by the Department of Natural Resources (DNR), local governments, and riparian landowners to consider the integrity of lake plant communities for planning, zoning, sensitive area designation, and aquatic plant management decisions (Nichols, 1999).

Using the equation $I = \bar{C}\sqrt{N}$ (where I is the floristic quality, \bar{C} is the average coefficient of conservation (obtainable from <http://www.botany.wisc.edu/wisflora/FloristicR.asp>) and \sqrt{N} is the square root of the number of species), the floristic quality of Lotus Lake was determined to be 10.95. The average for this area of the state (North Central Hardwood Forest) is 17 to 24.4 with a median of 20.9. Lotus Lake appears to have a very disturbed macrophyte community.

Turbidity and the subsequent lack of light penetration is the main factor affecting the growth of aquatic macrophytes in Lotus Lake. Therefore many resources should be put into reducing turbidity on the lake through reducing nutrients and limiting sediment resuspension. Because there is a systematic relationship between the macrophyte abundance and the transparency of a lake, there should be a gradual decline in pelagic chlorophyll *a* concentrations with an increase in aquatic plant life.

It has long been observed that water tends to be less turbid if there is aquatic vegetation present. Indeed, many studies have shown that vegetation enhances water clarity, but the most spectacular are the observations of whole lakes that switch between a clear vegetated state and a turbid state with little vegetation. This phenomenon is called Alternative State Equilibrium.

Zooplankton

Zooplankton are microscopic animals that are an essential part of the lake food chain. Zooplankton can be herbivores (eating algae and bacteria) or carnivores (eating other zooplankton). Fish and macroinvertebrates feed on zooplankton. Zooplankton population can have a profound effect on the water clarity of a lake because of its grazing given the type of algae in a lake (green, blue green, etc.). Blue green algae are undigestable by zooplankton and rarely consumed. Since they are not part of the food web, their population can increase unchecked by the food chain. Many species of zooplankton are mobile, controlling their buoyancy to move up or down in the water column, or being able to move by propulsion or oaring. They take refuge in aquatic plants from predation by fish species and other invertebrates.

Inclusion of zooplankton community analysis can help provide a more thorough understanding of water quality. In some lakes, the relative abundance of zooplankton species or types can be an indicator of water quality. Some species are limited by

physicochemical variables such as oxygen, temperature, or salinity. Zooplankton are also affected by competition between species, predation by other species, and food availability.

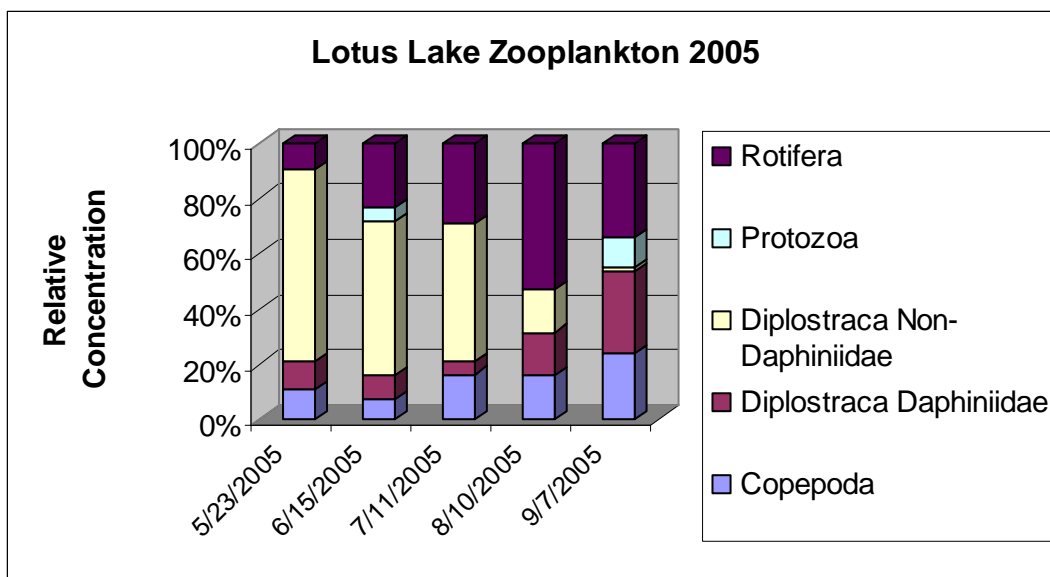
Continuous, long-term monitoring of zooplankton community structure can be useful in detecting patterns and changes in species composition that may be related to changes in water quality. A routine monitoring program also helps to separate the ordinary effects of seasonal changes in the zooplankton community from changes caused by other factors. The species composition in a particular water body usually remains somewhat stable over time, and the sudden appearance of new species or disappearance of existing species could indicate a change in water quality due to toxic substances, eutrophication, or imbalance between piscivorous (fish-eating) and planktivorous (plankton-eating) fish.

Rotifers are a phylum of zooplankton that eats relatively small particles. They typically do not reduce algae blooms because they eat bacteria and small algae.

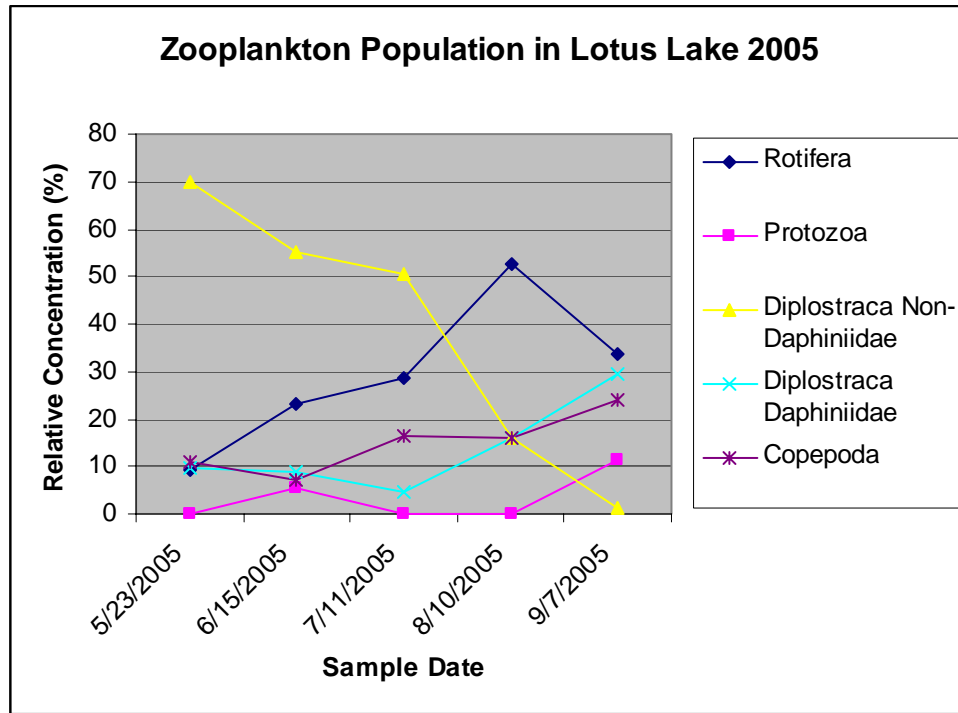
Protozoa are also a phylum of zooplankton that help control bacteria biomass. Species within this phylum are mobile and can be herbivores or consumers, but directly affect algae very little.

Diplostraca is an order of zooplankton which includes Daphniidae and non-Daphniidae families. **Daphnids** are waterfleas that are very influential on water clarity because they consume mostly green algae. Big water fleas are desirable. When blue green algae becomes the dominant algae, daphnids tend to decrease in size and number in a lake. **Non-daphnids** such as Bosima and Chydorus genuses are mostly benthic (live on the lake bottom) and do not affect water column clarity. When filamentous algae is present, Chydorus will perch on it.

Copepoda are common predators, eating daphnia and other zooplankton.



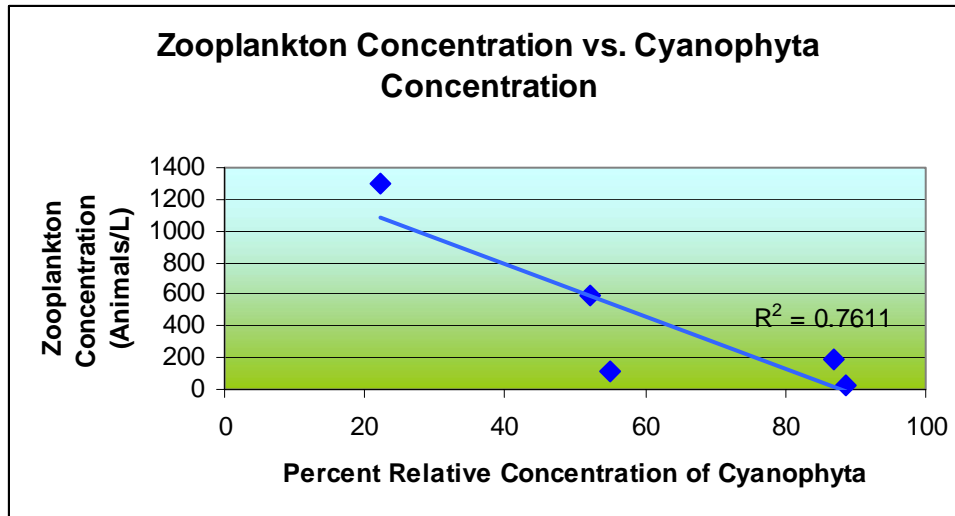
Diplostraca non-daphniidae made up the majority of zooplankton concentration early in the season. Rotifers predominate late in the season. Daphnids relative concentration ranges from 4% to 30% over the 2005 summer.



This second graph of zooplankton composition is the same information as the previous graph, but shows each zooplankton type individually.

Sample Date	Total Zoo Sample Conc (animals/L)	Cyanophyta Relative % Conc
5/23/05	1301	21.1
6/15/05	110	55.1
7/11/05	589	52
8/10/05	26	88.5
9/7/05	192	86.8

The total zooplankton sample concentration varied widely per sampling date. There seems to be an outside influence affecting the zooplankton population. Macrophyte density did not vary greatly throughout the summer season. The sampling dates when zooplankton concentrations were high, the percent of cyanophyta (blue green algae) was relatively low. As the percent of cyanophyta increased, the concentration of zooplankton greatly decreased. This inverse relationship seems to be tightly correlated ($R^2 = .76$). Further research into the fish predation and other factors will be necessary to determine the decline of zooplankton population.

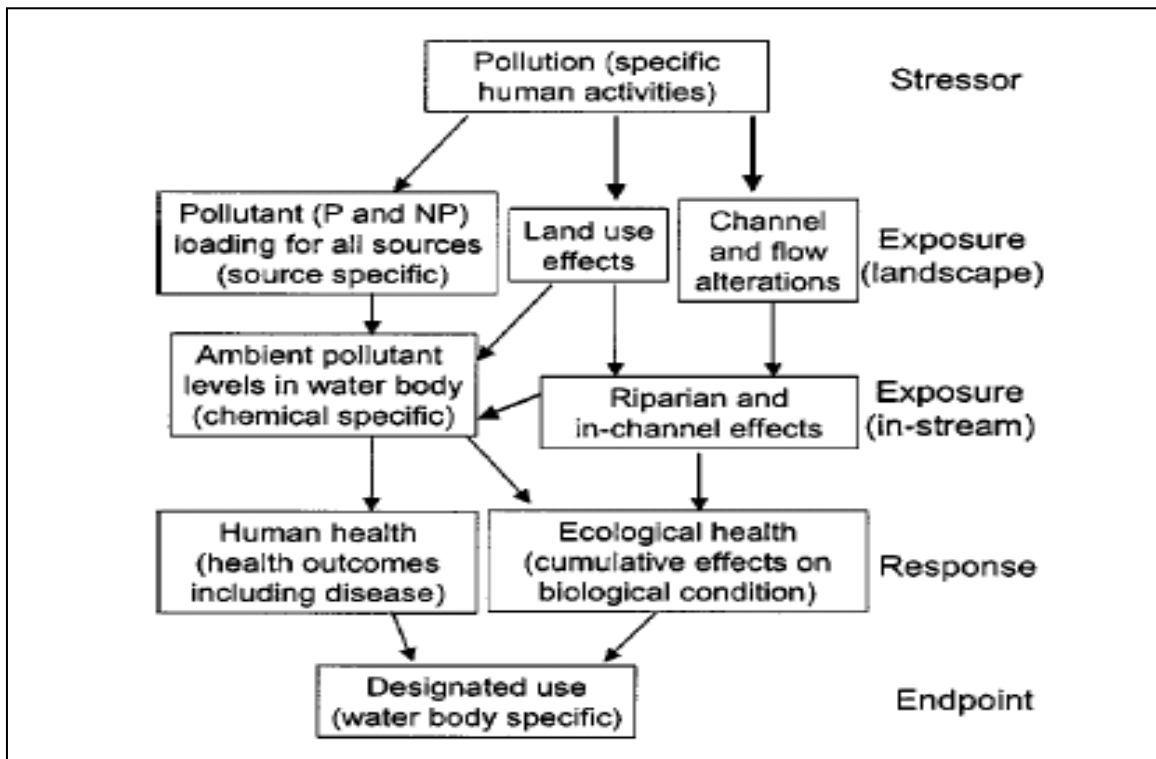


Macroinvertebrates

Benthic macroinvertebrate samples were taken on May 24 and October 28, 2005. The objective of this lake bottom-bug collection was to assess how riparian land use affects the functional feeding ecology of benthic macroinvertebrates and hence the entire food web of the lake. (Please see Appendix C for a description of macroinvertebrate feeding ecology and its significance.)

The near shore invertebrate community illustrates the connection between land and water, reflecting the complexity of aquatic systems. Current research has greatly increased our knowledge of lake organisms and how they respond to eutrophication (degradation of water quality by accelerated nutrients). Along with exotic species, eutrophication is the greatest environmental hazard in many inland lakes. If we can associate communities of organisms with nutrient concentrations and land uses, an IBI-type index can be used to set management goals based on nutrients and also evaluate the progress of restoration and management using benthic macroinvertebrates.

This type of approach can be used to develop IBI's (index of biotic integrity) that reflect lake classification and current land use conditions and associate them with designated uses and nutrient criteria to set realistic restoration goals. The figure below demonstrates how the ecology, not chemical endpoints, shows cumulative effects of human activities by changes in land use. The changes and ecological response then designate water use.



Biologic response to stressors Source: Karr and Yoder 2004

Methods

Six study sites were chosen based on terrestrial vegetation and adjacent land use (below). Site one was classified as “Old Field”; it was likely grazed by cattle in the past, but is recovering to a more native community. Site two was classified as “Lawn”. This was at one of the older cabins on the lake with a long established turf grass cover. For the most part, there is no native vegetation and has severe potential for erosion. Site three was in the wetland margins of the “Rail Road Bed” along the southwestern side of the lake. Emergent aquatic vegetation was present at this site, but there is potential to see long term effects of disturbance from the rail road and more recent ATV use.



Invertebrate sampling points on Lotus Lake

Site four was a “Forested” site with coarse woody habitat present and probably indicative of the habitat that surrounded the whole lake before the riparian area was inhabited. Site five was sampled near a “Floating Sedge Meadow” which is a critical environment of the lake margin. Site six was sampled adjacent to the DNR “Parkland” on the North side of the lake. This site was impacted by purple loosestrife, but for the most part has a native plant community with large basalt boulders present for periphyton (filamentous algae) growth, which is an important food for different invertebrates groups.

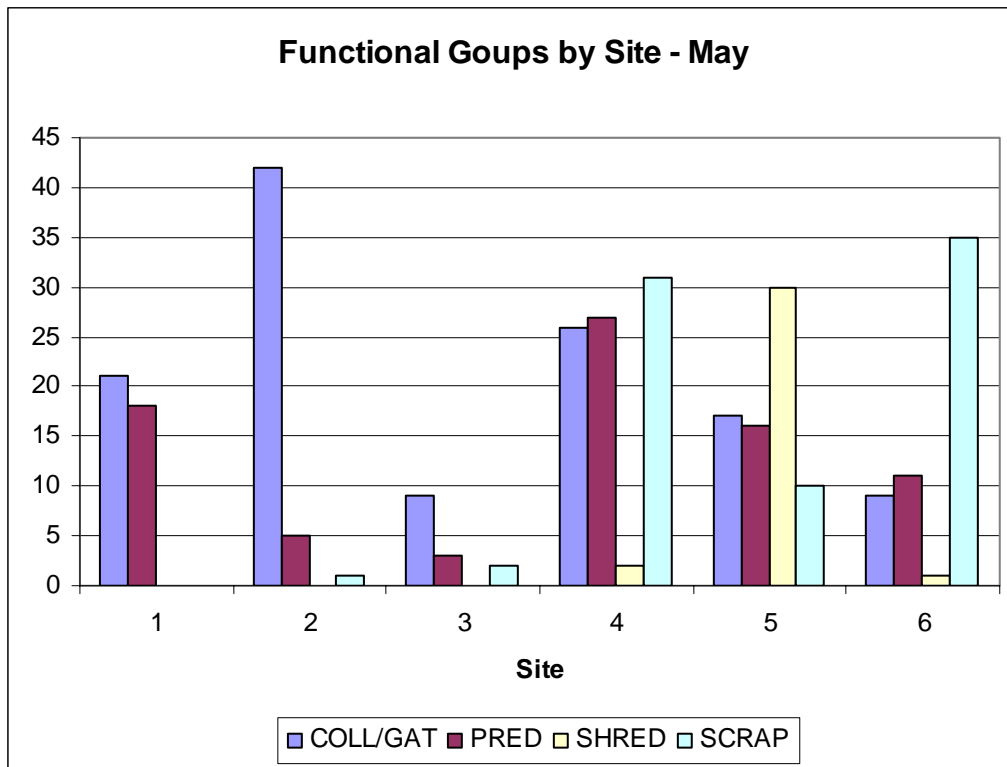
Benthic invertebrates were sampled using an aquatic D-frame kick-net as suggested in Merritt and Cummins (1996). Triplicate samples were taken in the field and preserved in 95% ethanol for identification at the lab. Samples were sorted under a dissecting microscope at 20-40x magnification and identified under a compound scope when necessary at up 400x (below).



Sorting station and view of sorting tray through scope

Statistical Analysis

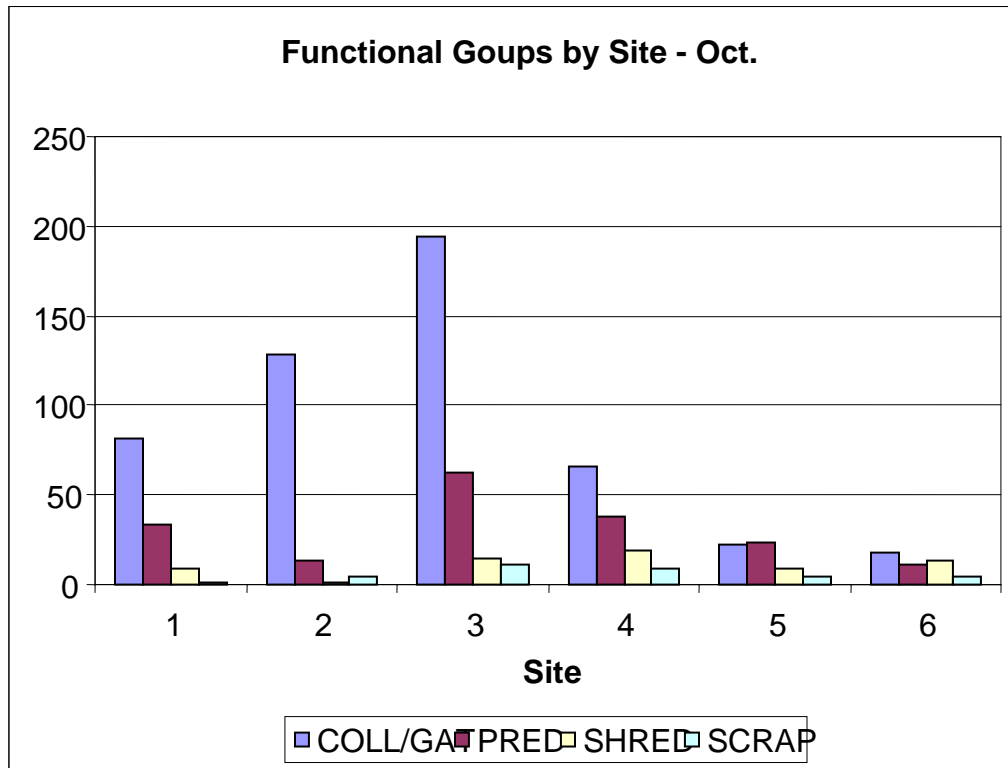
All six sites were used for analysis. The triplicate samples were analyzed separately, and small differences between sites were observed in processing. For each site, the abundance of functional feeding groups was summed and graphed, and a one-way ANOVA (analysis of variance) was run.



Abundance of Functional Feeding Groups in May 2005 Sampling

In May there was a significant difference between the number of shredder macroinvertebrates and the number of collector gatherers. In October there was a significant difference between collector gatherers and predators, scrapers and shredders (for a description on functional feeding groups, see the discussion below and

Appendix C). No shredders were found at impacted sites (sites 1-3) in May and very few shredders were found in October.



Abundance of Functional Feeding Groups in October 2005 Sampling

The vast number of collector gatherers present in October is likely related to seasonal variability and vegetation die back in the wetland margins of sampling sites two and three. There was not a statistical significance between sites in May or October. However, in both sampling periods, neither shredders nor scrapers appear unless there is a native riparian environment. The shredders present at sample sites one and two (field and lawn) in October were amphipods; this group can also act as collectors and gatherers, which is likely the case.

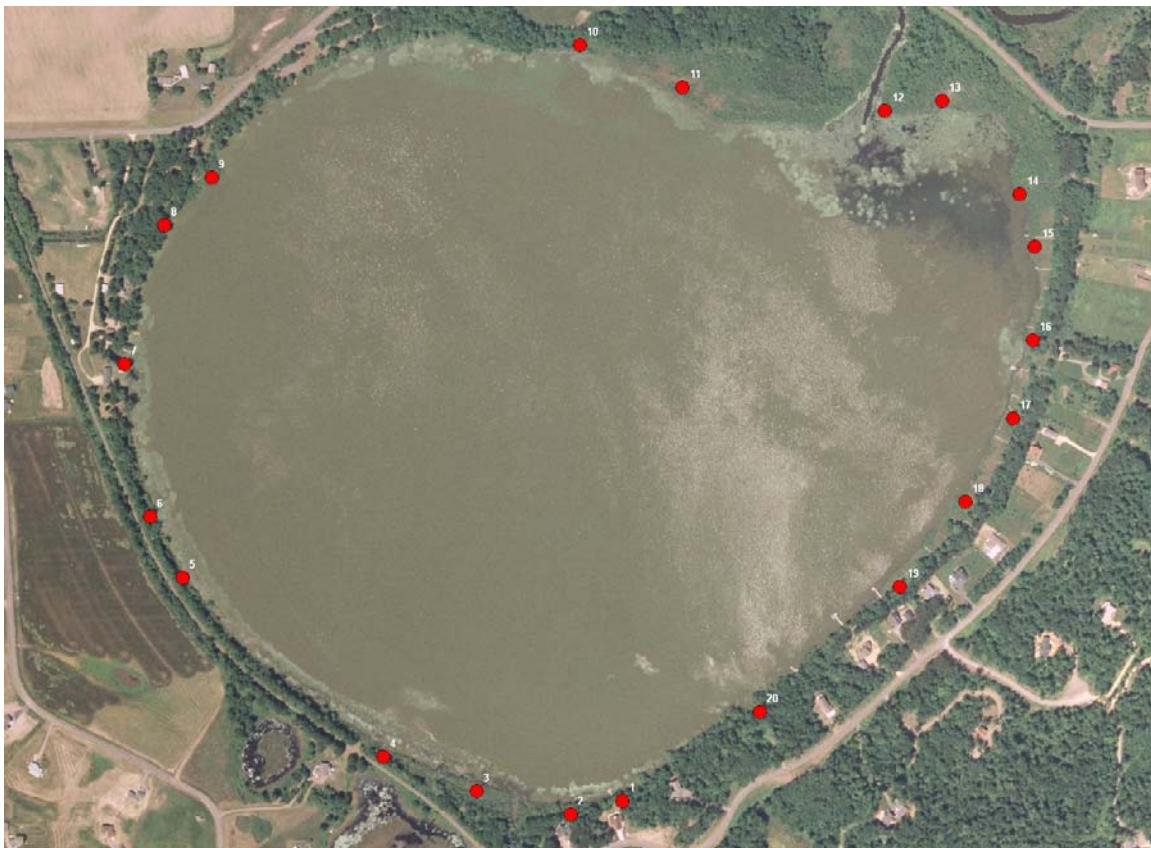
Discussion

The samples show how essential a native riparian community is for the entire lake food web. Shredders and scrapers are fundamental in the cycling of nutrients in a lake and the breakdown of external inputs. The shredders and scrapers use nutrients immediately, and the nutrients are not available in the water column. Leaves from trees are easily colonized by diatoms and bacteria which aids in invertebrate digestion of these material whereas grass is not colonized. In order to improve the efficiency of nutrient uptake, any unnatural shorelines should be reforested and the near shore zone should remain relatively undisturbed to prevent nutrients from being available in the water column. Aquatic macrophytes (submergent and emergent) should be left intact as habitat for macroinvertebrates.

Seasonal and annual variability occurs in nature's cycles. The variability could be overcome by taking a 5-10 year sample. This is possible by using recent death assemblages of chironomidae (midge) head capsules. These head capsules are left intact on the lake bed and can be identified by their mouth parts, which will also tell the functional feeding group of each invertebrate. This head capsule technique is used for paleolimnological studies, which relate benthic macroinvertebrates to nutrient content in lake sediments.

Terrestrial Vegetation

The riparian zone of a lake is ecologically and hydrologically significant. On Lotus Lake, the community is an incredible transition from floating sedge meadow to lowland second growth forest. The lake edge attracts numerous critters both on land and in the water. The shoreline vegetation is also important to reduce overland flow, which can bring in nutrients from the watershed. Buffers of native grasses and other forbs staked beside lake inlets reduce initial sediment loads of 5,000 ppm by as much as 50% depending on slope, velocity, plant species, particle size, and water body (Karr and Schlosser, 1978).



Vegetation transect sites on Lotus Lake

The object of the terrestrial vegetation survey was to assess riparian zone health. The vegetation survey was carried out on Lotus Lake on August 30th, 2005. Twenty sampling

points were established around the lake. Meter squared points were assessed for ground cover, and all trees and shrubs within a thirty-foot radius were identified.

The approximate density of each species found was determined by estimating the coverage within the meter square for ground cover. The sampling method used was the U. S. Army Corps of Engineers standard method for wetland delineation, which can determine species composition or dominance of a species at a site or certain community. The results were then evaluated using the Shannon-Wiener Diversity Index.

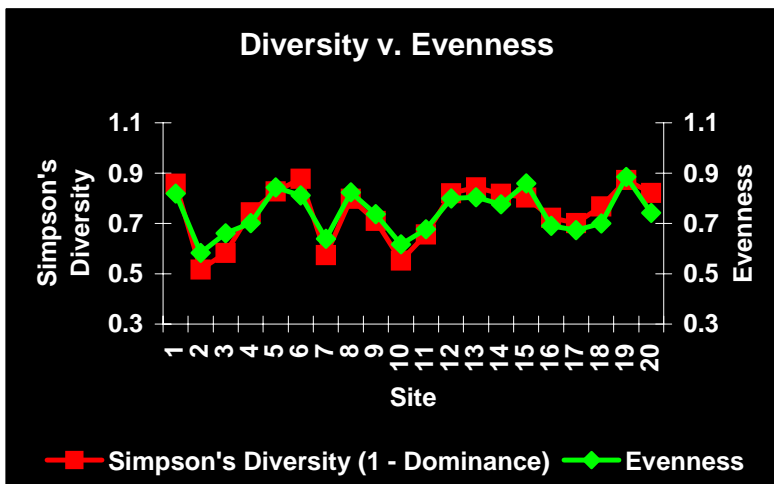
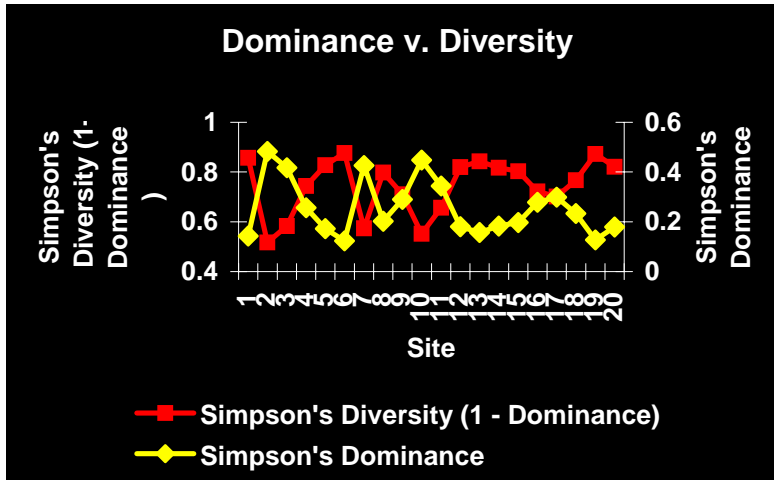
Species diversity is the number of species in a community; the greater the number, the greater the diversity of species. Using the Shannon-Wiener Diversity Index, a site with only one species has an H value of 0; the higher the number, the more diverse an area. Because the total number of individuals was not determined in this survey, the density of the species was substituted for the total number. It was thought that the density of the species would accurately represent the population of each individual species.

The Shannon-Wiener diversity index for Lotus Lake's riparian area was calculated to be 1.7 on average with the highest rating at a 2.2. As the watershed has recent human impact and is dominated by many differing and changing land uses, this is to be expected. The actual diversity rating is probably slightly higher than calculated as other species were observed in passing but were not collected within the meter-square. Additional monitoring would improve diversity indices and our understanding of the riparian community.

The riparian area of Lotus Lake is an integral part of the ecosystem. Although the diversity rating is low, there is a rich complex of many different ecosystems in a small geographic area. Likely, the low diversity rating comes from the dominance of Speckled Alder (*Alnus incana*) in the floating wetland communities around the Lake. To assess this, a Simpson's Diversity Rating was compared to the Simpson's Dominance Rating and the evenness of the different sites.

Evenness is a measure of the relative abundance of the different species of an area. This can be defined as $J = H/H_{\max}$ where H = Shannon-Weiner Diversity of the site and H_{\max} = H maximum or what H would be if all species had the same number of individuals. H_{\max} is calculated as $H_{\max} = \ln S$ where $\ln S$ is the natural log of the number of species.

Simpson's Dominance is much like the Shannon-Weiner Diversity Index. Simpson's Dominance measures the probability that two individuals randomly selected will belong to the same species. This is calculated as $C = \sum_{i=1}^s (p_i)^2$ where C = Simpson's Dominance, s = the total number of species, and p_i = the proportion of individuals that belong to the i th species; this is calculated as n_i/N where n_i = the number of individuals in species p_i , and N = the total number of individuals. Simpson's Diversity is simply calculated as $1 - C$.



These calculations and graphs show that as a species', such as speckled alder, dominance increases, the diversity rating of a site decreases. Conversely, the diversity rating and evenness calculation follow almost exactly.

Although floating communities tend to be naturally low in diversity, these concepts are extremely important to keep in mind. The plant community of Lotus Lake's watershed is most likely an invaluable part of the lake's ecosystem, particularly to birds, small mammals, and herptiles.

Purple loosestrife (*Lythrum salicaria*) dotted the lake perimeter and reached a density of 85% on the north end. This invasive plant is starting to spread across the lake, and in doing so, it will displace many native species, making the diversity even lower and driving away the wildlife that remains. An aggressive control strategy should be employed to diminish this threat. Despite its beauty, *L. salicaria* has little, if any, use to native wildlife and will displace the native species that are present.

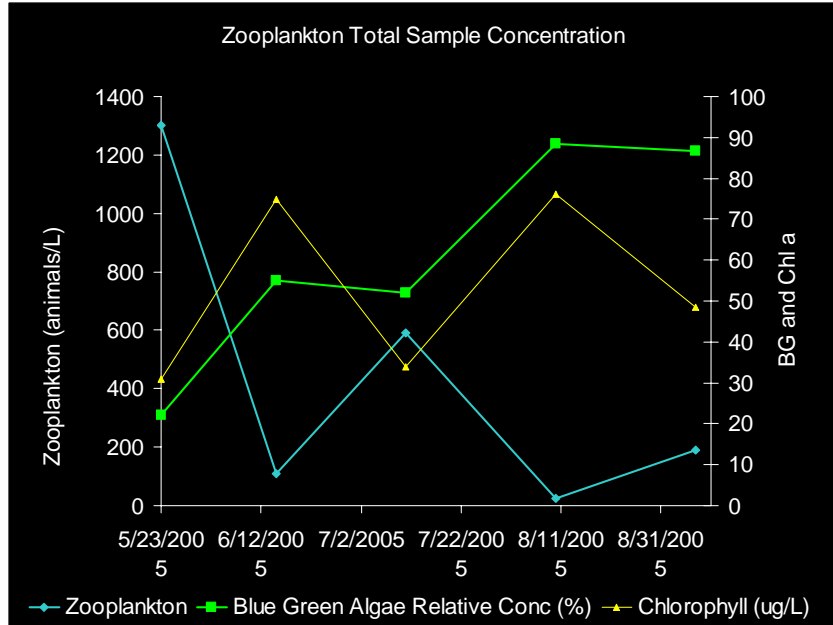
In order to maintain the amount of biological integrity that remains around Lotus Lake, an aggressive purple loosestrife management plan should be employed. Along with this, riparian-owners have a responsibility to maintain and enhance the biological integrity of their shoreline. This will improve the wildlife habitat in the near shore area and eventually improve the water quality of Lotus Lake. Riparian community needs to be protected and enhanced through activities such as shoreline restoration and leaving coarse woody debris at the water's edge. The watershed plant community should continue to be monitored to ensure a healthy ecosystem and gauge the effectiveness of management techniques. A major disturbance to the natural community of Lotus Lake could be detrimental to its ecosystem and the surface and groundwater quality of Lotus Lake.

Biological Summary

Suspension of lake sediments can contribute up to 20-30 times the internal phosphorus loading of an undisturbed lake. Because a lack of vegetation increases the turbidity of a water body, there are shifts in the fish, invertebrate, and zooplankton communities. For example, turbidity decreases the efficiency of visual hunters such as perch and pike. However, the lack of vegetation as a refuge for young fish is probably one of the main factors involved in the change in the fish community.

For the same reason, there tend to be large numbers and much more diverse communities of invertebrates in stands of aquatic vegetation. These stands offer refuge from predation by fish and provide lurking sites for many invertebrate predators such as odonates and Chaoboridae. Food availability is much higher for invertebrates in stands of vegetation. Although very few invertebrates consume a significant amount of intact aquatic macrophytes, decomposing macrophytes provides a high quality detritus that is eaten by many invertebrates. The periphyton layer that covers macrophytes is probably the most important food source for invertebrates in vegetated areas.

For zooplankton, submerged aquatic vegetation provides an important retreat against fish and invertebrate predation. During the day zooplankton leave the open water and aggregate in or near submerged plant beds. Large homogeneous fields of floating leaf aquatic vegetation (such as the lotus and water lilies) are not as effective as a daytime refuge for zooplankton as a diverse community with many plant architecture types and submerged hide aways. The raised level of turbidity due to algae (particularly cyanobacteria) can also cause toxins to be released into the water and make the algae unpalatable to most zooplankton.



Zooplankton vs. cyanobacteria in Lotus Lake. Note the drop in zooplankton population as cyanobacteria rises.

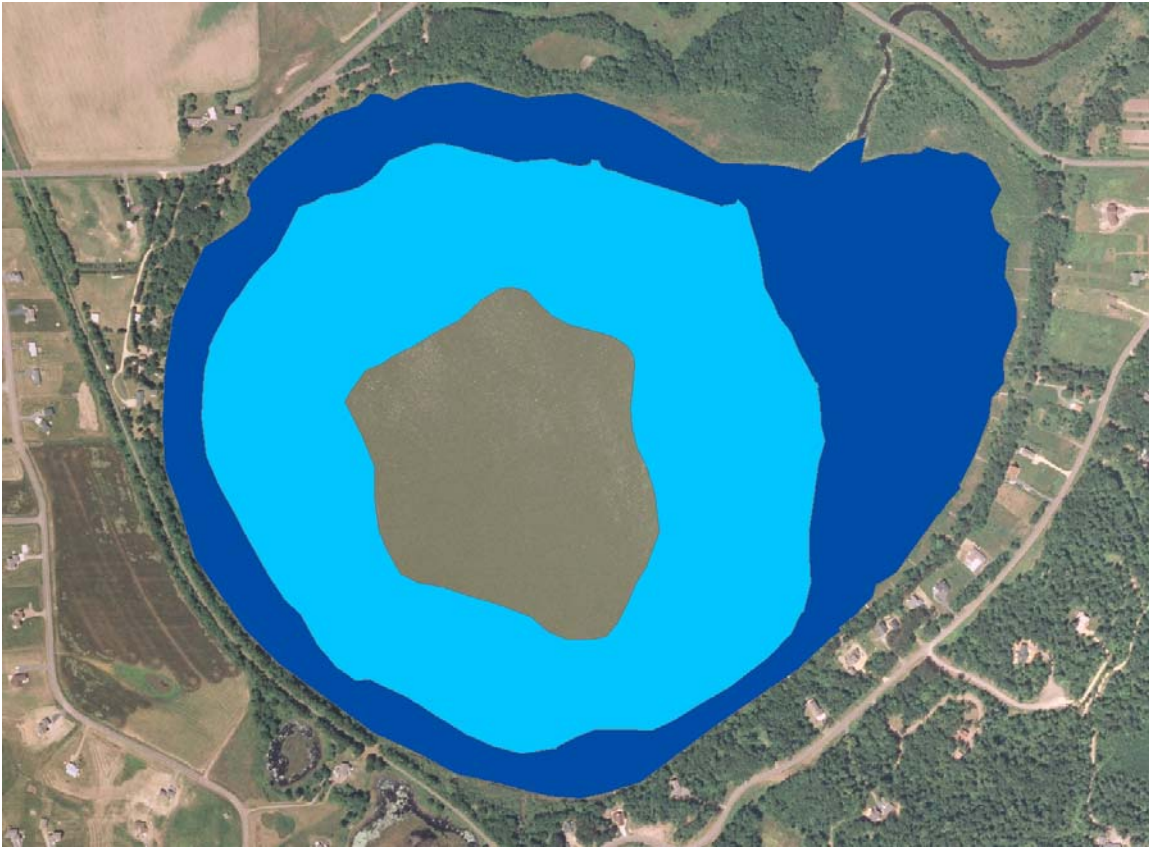
One way to reduce suspended sediments is to limit the amount of motorized activity on the lake. Because the maximum depth of Lotus Lake is 15 feet, any motorized activity will have an impact on benthic substrate. Residents and citizens using Lotus Lake should be educated on the no-wake laws in riparian areas and the effect of motorized traffic on water quality along with the importance of aquatic plants.

A second way to control the suspended sediment and increase light penetration would be to control carp. This can be done in a variety of ways, but the most prudent would be to hire a professional company to make the removal. It is likely that carp are a major influence on the whole biology of the lake by uprooting plants and increasing turbidity.

In order for Lotus Lake to become a biologically healthy lake, the aquatic macrophyte community must be enhanced to include more submerged species, and the coverage must be expanded to at least the 5-foot rooting depth. Increasing the submerged plant community should lead to clearer water. It is imperative that the aquatic plant community is enhanced for Lotus Lake to overcome the algae dominated, turbid state that it is in. Being able to attain some plant growth into the 10-foot range is highly unlikely for Lotus Lake, but none-the-less would increase visibility and the health of the lake.

In reviewing the Biological Section of this report, it is obvious how all components are interrelated and dependant on each other. In order to improve the fisheries, food and habitat need to be available. Therefore, aquatic plants and bugs must be enhanced. To improve bug efficiency, the type of material entering the lake from the riparian zone should be coarse organic matter to maintain a shredder population. These shredders cycle nutrients, which help keep the lake water clearer (from algae.) The biological circle crosses back and forth, interacting at each trophic link. Humans also cross the cycle by

manipulating links. BMPs are designed to lessen human impact on our natural resources and allow the biological cycle to remain in balance. Our management of individual properties can be a wildlife haven or an ecological desert.



Dark blue indicates the 5-foot region of Lotus Lake, while light blue indicates 10.

A more aggressive approach to increasing aquatic macrophyte diversity and submerged plant density may be to propagate species such as *Vallisneria americana* and possibly *Myriophyllum sp.* This would require DNR approval and may not be possible as long as carp are in the system.

Fish Survey

Lotus Lake's fishery was sampled by electro shocking by the Wisconsin DNR on September 28, 2005, with Heath Benike, lead biologist. A formal report was not drafted, but e-mail correspondence with Heath has supplied the following strategy:

An aeration system has been in operation since the winter of 2004. This system was installed to prevent frequent fish winterkills from occurring. Dissolved oxygen monitoring during both winters suggest the aeration has been very effective and no fish winterkills have occurred. In addition, dissolved oxygen readings were well above 4 ppm throughout most of the winter. We start seeing fish kills occurring when dissolved oxygen reading fall below 2ppm for extended periods of time.

Adult bluegill and largemouth bass were stocked in 2004, 2005 and 2006. In addition, northern pike fingerlings were and will be stocked in 2005, 2006 and 2007. Black Crappie, yellow perch and carp appear to be also present naturally after the most recent winterkill. The goal of the stocking is to develop an adult population of desirable fish that should be able reproduce naturally without needing to stock the lake in the future.

At this time, our survey from 2005 indicated that bluegill and black crappie reproduction was present in 2005. This indicates that the fishery is starting to respond to the stocking of adult fish that has occurred. I would suspect over time that a respectable panfishery should establish but it usually takes bluegill 7-8 year to grow to a desirable size (7-8 inches). That being said it will probably be close to 2011 before a real fishable population of bluegill is present in the lake. On a more positive side, the black crappie population has some adult fish present in the lake and is and will provide fishing for adult fish at this time and into the future.

A low density largemouth bass population has been created with the recent stocking. We did not document any natural reproduction, but I suspect that the bass population will start taking hold soon. There is no reason that the bass population can not reproduce in Lotus Lake it make just take a few years for the population to really take hold.

Northern pike stocking has just began and the fish are small at this time, its really hard to determine if the stocking has been successful, but there is adequate spawning habitat available so I am optimistic we can develop a natural reproducing northern pike population in the future.

Carp are still the dominant fish in the lake, however I am optimistic that over time if the other fish start increasing in abundance we can reduce the existing niche for carp with more desirable fish species. This has two potential benefits. The first benefit is that we can create a desirable recreational fishery for anglers and secondly we can possibly improve water quality by reducing the density of the Carp population. Carp are known to create turbidity and dislodge aquatic vegetation. Reducing their presence should only help minimize any water quality concerns.

I plan to follow up with another survey in 2008 to see how the fish community is responding. HB

Aerators

A sudden appearance of dead fish in a lake or pond causes considerable concern and alarm for most people. Most fish kills, however, result from natural events, although people can influence their frequency and severity. Fish kills usually result from too little oxygen in the water. While some result from spills or illegal discharges of toxic substances, most kills occur when oxygen dissolved in the water drops to levels insufficient for fish survival.

For a dissolved oxygen or DO related fish kill to occur, a combination of environmental conditions must occur simultaneously. Weather patterns, water temperature, depth and quality, amount and type of plant growth, fish community structure, along with the presence of viruses and bacteria, are all factors that are necessary to trigger a fish kill. Lakes and ponds located in residential areas are particularly vulnerable to DO-related fish kills. Developed areas create runoff that contains high amounts of nutrients from septic tanks and street and yard drainage that enters water bodies and causes water quality problems. High levels of nutrients from fertilizers applied to lawns, golf courses and farms cause aquatic plants to thrive.

Most times, fish can tolerate temporary lags in DO levels. Fish kills occur only when several contributory factors occur simultaneously. Prolonged cloudy weather, drought conditions, overcrowded fish populations, excessive algal or other plant growths and high water temperatures are the most common factors that combine to cause fish kills. A typical scenario occurs when fish are observed at the water surface appearing to gasp for breath. Fish usually continue to die from viral or bacterial infections for 3-4 days.

A few dead fish floating on the surface of a pond or lake is not necessarily cause for alarm. Expect some fish to die of old age, injury, winter starvation, diseases, parasites, predation, toxic algae, severe weather, water pollution, or even post-spawning stress in the springtime. However, when large numbers of fish of all sizes are found dead and dying over a long period of time, it is necessary to investigate and determine the cause.

In order to prevent fish suffocation in fertile ponds:

- Do not overfertilize ponds.
- Do not overstock fish.
- Do not feed ducks or sportfish.
- Fence livestock from the pond and upstream waters.
- Prevent manure and animal waste runoff into the pond.
- Use herbicides only in the Spring and Fall, if necessary.
- Treat only one-third of the pond surface each time with herbicide.
- Install emergency surface aerators or pump-sprays.

Very few kills result in total loss of the population. Remaining fish can usually reproduce and quickly restore the population. Occasionally, undesirable species will tolerate low DO and dominate the population. Many people incorrectly assume that these “trash fish” have out competed sport fishes; however, this is actually a situation where hardy “trash fish” species have thrived in a situation of poor water quality that other species find intolerable.

People can only prevent fish kills by maintaining good water quality.

Phosphorus Modeling

The Wisconsin Lake Modeling Suite (WiLMS) developed by the DNR was used to model current land use conditions, a forested watershed condition, and projected-development conditions for Lotus Lake. The model outcome predicts the likely phosphorous concentration in Lotus Lake, which is the limiting nutrient for algal growth in most Wisconsin lakes.

The following table summarizes annual external source loading estimates based on the Nurnberg model for estimating gross internal loading. The model that appeared to be the “best fit” for Loveless Lake was the Vollenweider Shallow Lake Model (1982). The Vollenweider model predicts a spring turnover and growing season average. The model also calculates an estimated phosphorous concentration in the water column (mg/m^3).

Watershed Condition	Total P Loading (lbs)	Water Column Concentration (P in mg/m³ or µg/l)
Present	398 - 2112	30 - 128
Forested	148 – 616	12 - 43
Developed	538 – 2005*	39 - 123*

Table 1

*The developed versus present condition of the watershed shows a likely increase of total phosphorus loading due to changes in land use. The upper limits of the developed watershed must be assumed to further affect the water column phosphorus concentration because of paved surfaces and impervious areas. Imperviousness increases the volume of runoff and erosion (aka phosphorus loading) to a lake. Overall, highly developed condition degrades the water quality more than the present condition on Lotus Lake.

The model indicates that if the Lotus Lake watershed were forested, the lake phosphorus concentration would be between 12-43 µg/l. This is in comparison to present conditions predicting 30-128 µg/l and observed concentration today of 119 µg/l.

The projected development condition bodes grim for Lotus Lake. The projected development condition assumes that all crop, grassland, and rural residential land (47% of the Lotus Lake watershed) will be converted into medium density residential (~1 house per 2 acres). Although it may be unlikely that all the existing open land will be converted to such a land use, it is not unreasonable to assume that at least 40% of the developable open land and crop land will eventually be converted. Under the current zoning law it is possible for such a conversion to occur. The in-lake phosphorus concentration is predicted to be 39-123 µg/l which will maintain current water quality conditions or bring more algal blooms. Consequently, more algal blooms would increase internal loading due to reduced oxygen at the water/sediment interface as plant matter decays.

Therefore, an overall in-lake phosphorus concentration of 43 µg/l is a potential management goal. This number is the in-lake phosphorus concentration of a forested watershed. Such a level would increase water clarity and ensure a quality lake for generations. However, restoring the watershed to a forested condition and reducing the in-lake phosphorus concentration is an unlikely scenario based on environmental and economic restraints. It is heartening to know that limiting nutrient inputs to the lake will likely result in improvements. Such reductions may be possible through the implementation of best management practices (BMPs), shoreline restoration, wetland restoration, or some combination of these management options.

A 66% reduction of phosphorous loading from external sources would significantly affect total phosphorous concentrations in Lotus Lake. Such a reduction would classify the lake as mesotrophic. A perceived improvement in water clarity would be noticeable as the lake chemistry and biology shift towards a balanced ecosystem. A reduction of phosphorus loading is possible with new advances in bioretention and other stormwater management practices. Future studies should model the effectiveness of such BMPs.

Phosphorus may be further reduced within the water column by limiting horsepower and/or setting speed limits. Such activity disturbs lake sediment, suspending them and makes nutrients available to plants and algae. Controlling the population of carp (*Cyprinus carpio*) would also help tremendously in curbing the effects of internal loading. *Cyprinus carpio* is an introduced species to this area and forages in the lake sediment for aquatic invertebrates. In doing so, it turns up lake sediments and increases bioturbation. The association should work closely with DNR fisheries biologists to develop a carp control strategy above all other fisheries management techniques.

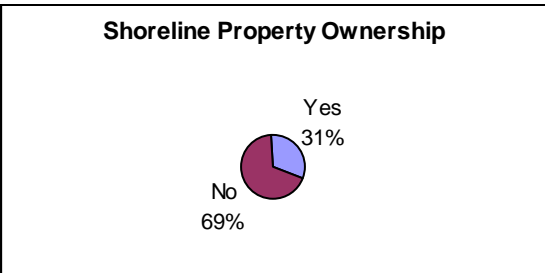
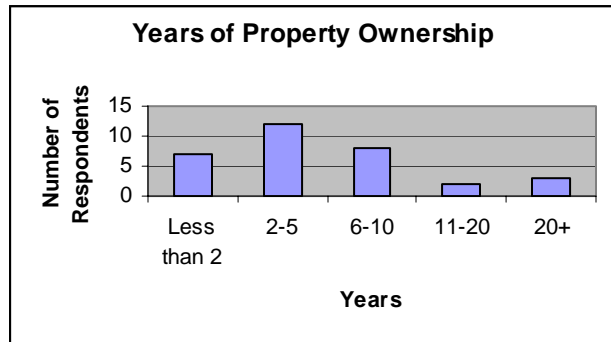
The empirical models in WiLMS estimate that internal loading makes up approximately 31% of the total phosphorous in the water column. However, this model does not take into account the presence of an exotic species such as *Cyprinus carpio* in the lake.

Although 43 µg/l is a management goal to improve water quality, paleolimnological techniques are necessary to set realistic nutrient criteria goals. Paleolimnological cores allow us to determine past in-lake phosphorus concentrations by diatom-inferred phosphorous reconstructions. This is the only way to know past phosphorus concentrations before settlement in the watershed. From this, we can set realistic, attainable goals for water quality in Lotus Lake.

Public Survey

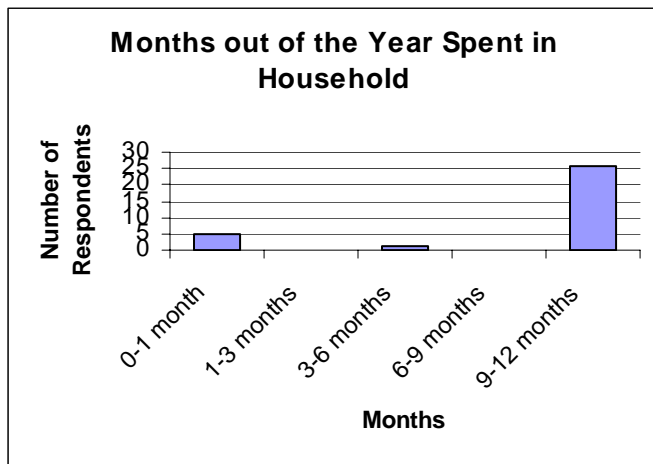
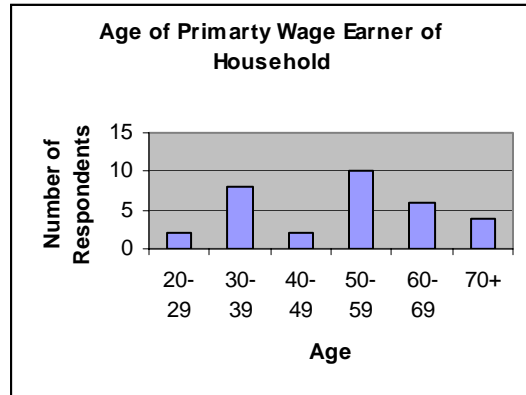
The survey results were compiled to summarize landowner’s objectives, goals, and concerns about Lotus Lake and its surrounding resources. Of the surveys sent out, 32 were received and the results are summarized below. The survey questionnaire is featured in Appendix D.

Of the 32 surveys received, 12 (38%) have owned property between 2-5 years on or near Lotus Lake.



Twenty-two of the respondents did not own shoreline on Lotus Lake.

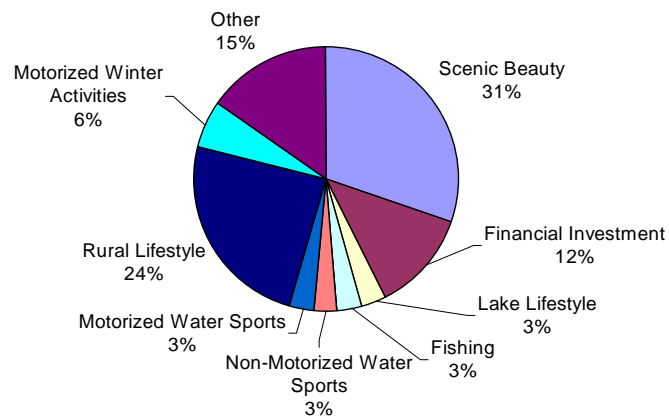
There is a diverse age group of landowners in the Lotus Lake Watershed. The largest age group represented in the survey was 50-59yrs (10) followed by 30-39yrs (8).



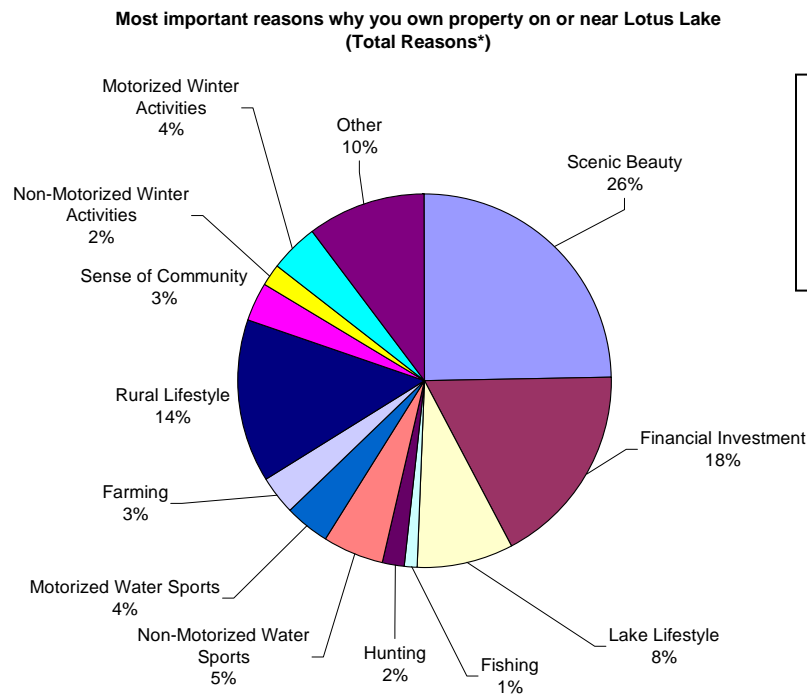
Almost 100% of the respondents live on their property year-round, the remaining few appear to use it as a summer or vacation home.

Most important reason you own property on or near Lotus Lake. (Top Ranked Reason*)

Property owners near Lotus Lake indicated scenic beauty as the number one reason for being near the Lake followed by rural lifestyle.



**Respondents were asked to rank their top 3 reasons for living around Lotus Lake, the chart denoted as the "Top Ranked" reason was the number one concern, while the chart denoted as "Total Reasons" was the total off all reasons listed for owning property.*



Scenic beauty and financial investment are the top two reasons indicated for owning property on or near Lotus Lake.

A Maine study compared lakeshore properties varying only in terms of lake water quality, with all other features controlled. This study concluded that good water quality added as much as \$200 per frontage foot to the value of the property (Michael et al. 1996). Another study conducted by Mississippi Headwaters Board and Bemidji State University (Krysal, et al., 2003) concluded that for a one foot increase in Secchi depth on a lake, property values increased up to \$400 per lake frontage foot. Visit [http://www.uwsp.edu/CNR/uwexlakes/lakeleaders/Sept2006/Lake Economics.pdf](http://www.uwsp.edu/CNR/uwexlakes/lakeleaders/Sept2006/Lake_Economics.pdf) for more information on lakeshore economics and the cost of lakefront property. The following management recommendations should be observed to protect residents' lake beauty and financial investment on Lotus Lake properties.

Education Component

The members of Lotus Lake Association strived to understand their lake. The Association welcomed the LWRD staff and the Polk County Health Department Environmental Scientist to their meetings. Members also attended PCALR meetings, Clean Boats/Clean Water training and initiated CB/CW at their landing. Members contacted the LWRD office often for updates and were eager to help with the grant. Members wanted to learn what they could execute to achieve better water quality. The Lotus Lake Association is also interested in obtaining more information about Lotus Lake to gain a better understanding of the lake ecosystem. They are in support of another lake study grant and are willing to provide more hours of volunteer service.

Several meetings and workshops were held to explain the role of each study component. Lotus Lake Association members, lake residents, Osceola Rod and Gun Club members,

and the public were invited to attend. Grant updates were shared with the lake association and sent to property owners.

Management Recommendations

The aquatic plant community of any shallow lake is an invaluable part of the lake's ecosystem, particularly to invertebrates and fish. In order to protect these lakes, the aquatic plant community needs to be protected and/or enhanced. Aquatic plant communities should continuously to be monitored to ensure a healthy ecosystem and gauge the effectiveness of management techniques. A major disturbance to the macrophyte community of Lotus Lake could be detrimental to its ecosystem. Enhancement would enrich the water quality and fisheries.

Consider if an aerator is necessary for Lotus Lake. The constant stirring of a shallow lake could be affecting turbidity, color, and macrophyte growth. Shallow lakes are accustomed to fish kills; with an inlet and outlet creek, the fishery will recover quickly. Adequate habitat and food is a more important factor to improve the sport fishery.

Watershed residents should limit the amount of impervious surfaces on their property to allow for water infiltration and reduce runoff. Raingardens and native vegetation are also beneficial to reduce stormwater runoff and for wildlife habitat.

Any new construction in the watershed shall have proper erosion control measures in place. Sediment loading from construction sites is a major polluter to our waterways. ***Properly installed*** silt fences, erosion control blankets and other BMPs are required under the Uniform Dwelling Code and Stormwater and Erosion Control Ordinance.

Riparian vegetation, aquatic plants, and coarse woody debris (fallen trees and logs) should be left where it stands to preserve the water quality of Lotus Lake.

Recreational boating should be moderated on shallow lakes. Non-motorized sports will have less impact on water quality and turbidity than PWC and motorized boats. At a minimum, slow-no-wake speeds should be implemented and the 100-foot from shore law upheld.

Agricultural and other best management practices should be utilized in the watershed, including education, to reduce phosphorus and other pollution reaching surface waters.

Work with Osceola Rod and Gun Club to try to implement voluntarily use of lead-free shot over the upstream wetland.

Residents should continue their relationship with the Polk County Association of Lakes and Rivers, Wisconsin Association of Lakes, and the Lakes Partnership. An informed citizenry will be the best advocate for the lake. Newsletters and conferences will be valuable educational material for Lotus Lake residents.

Continued monitoring of Lotus Lakes' biological community and water quality is important for establishing a baseline. Citizens should become familiar with the Self Help program and Adopt a Stream to initiate citizen monitoring in the near future. New residents should be alerted of local Zoning laws to prevent misunderstandings and violations.

No phosphorus fertilizers shall be applied in shoreland areas of Polk County.

Septic systems should regularly be maintained and checked on to prevent pollution from entering the lake.

Area residents and fisherman should inspect boating and fishing equipment to prevent the introduction of an invasive specie into Lotus Lake. Unused fishing bait should be disposed of in the trash. Tackle and sinkers should be lead free. Aquatic plants should be removed from the trailer and axles before and after launching.

Purple loosestrife should be observed and removed from the shoreline area. A volunteer monitor on the lake should raise *Galerucella* beetles in order to control its spread. Purple loosestrife is an immediate concern which threatens to invade the native community in Lotus Lake Park.

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Appendix A

Profile Data

Appendix B

Water Quality Data

Appendix C

Functional Feeding Groups

Appendix D

Sociological Survey Questionnaire