Wild Goose Lake
Polk County, Wisconsin
Water Quality & Biological Assessment, LPL –1224-08

Wild Goose Lake 2008

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Introduction

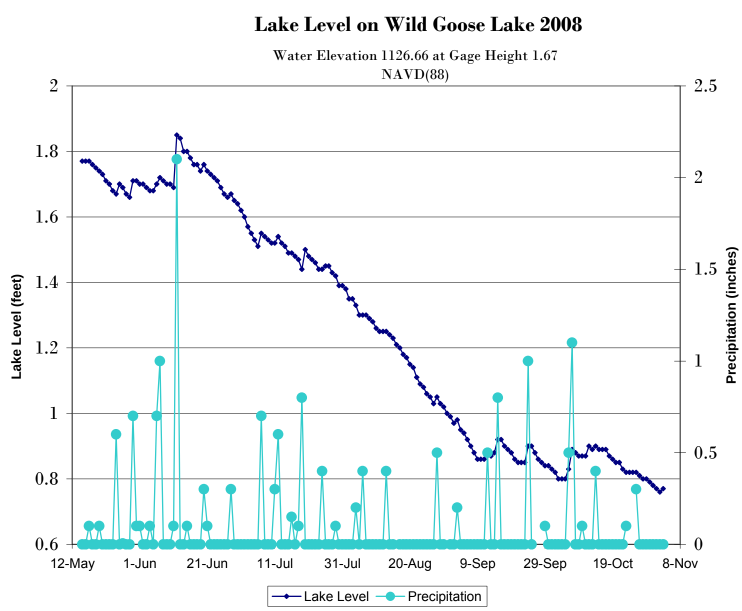
The study on Wild Goose Lake was performed by the Polk County Land and Water Resources Department with assistance from the Wild Goose Lake Association and financial assistance from a Department of Natural Resources Lake Planning Grant (LPL-1224-08). The samples were collected during the growing season of 2008. This report characterizes the current physical, biological, and chemical status of Wild Goose Lake.

Physical Setting and Properties

Wild Goose Lake is a 182 acre lake located in Balsam Lake Township. The maximum depth is 12 feet, and there are 2 bays connected to the large basin. A hardwoods bog set in a bay to the northwest of the lake drains into the lake via an intermittent stream. Only 37% of the shoreline is developed with residential cabins right now.

The watershed drainage area 0f Wild Goose Lake is 998.7 acres with a myriad of rural land uses. Inputs to the lake stretch back as far as 1.5 mile away near Balsam Lake. Wild Goose Lake is connected to East Lake via a road culvert. The flow of water tends to be into East Lake. East Lake is surrounded by agricultural fields and pasture land, and most likely benefits from the higher quality water of Wild Goose Lake.

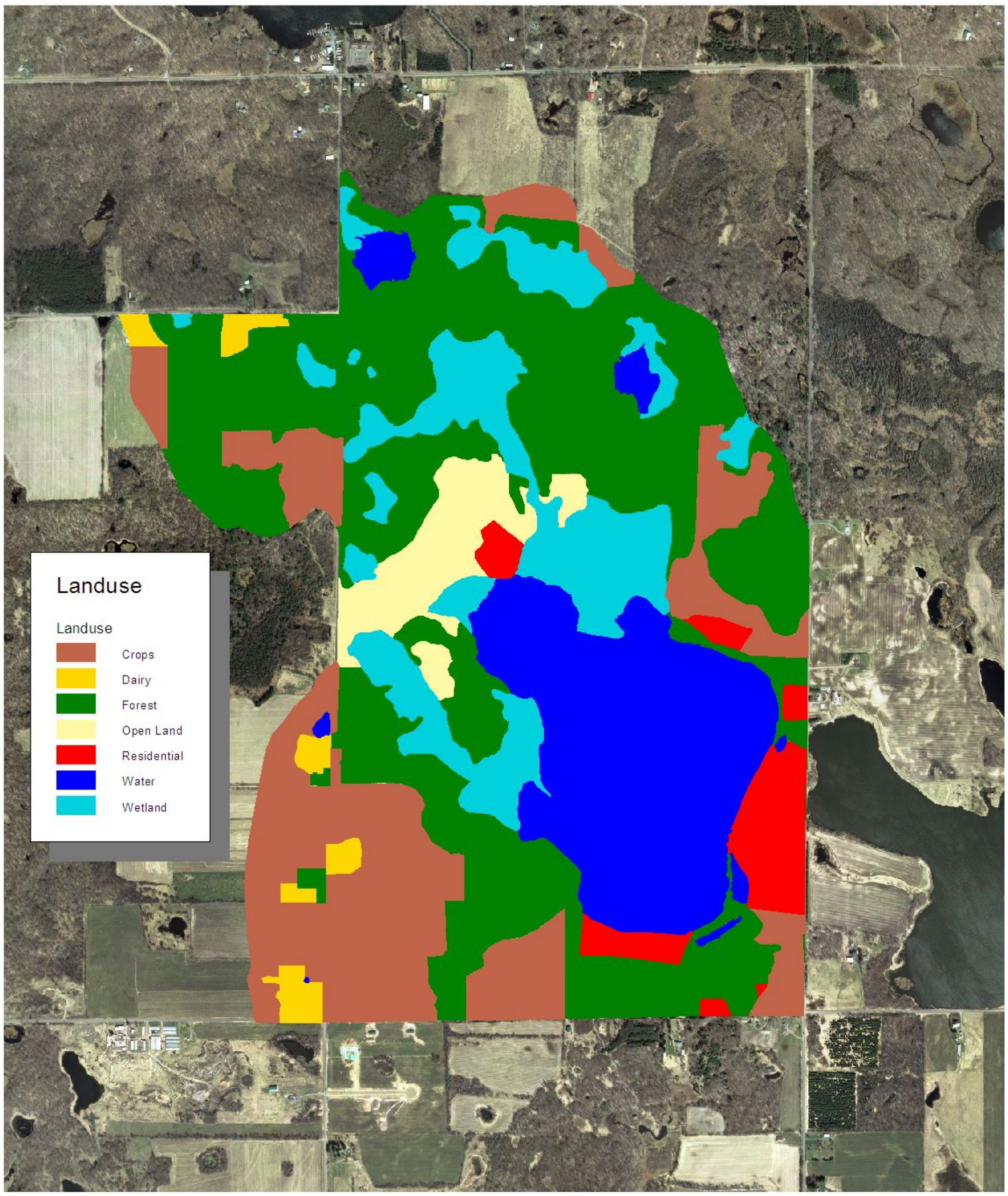
Precipitation in the area has an average annual rate of 31 inches. The lake level was recorded almost daily by volunteers during the summer and fall of 2008. Wild Goose Lake received 16.255 inches of rain fall from May 15 to November 3. The lake responded very little to precipitation events, indicating groundwater may be a larger source than surface water input. The seemed lake showed a response to rain events over 0.2 inches. From the highest level recorded to the lowest level, Wild Goose Lake dropped 1.09 feet in 2008. With 16 inches of rainfall, evaporation obviously exceeded precipitation.



Watershed modeling

The Wisconsin Lake Modeling Suite (WiLMS) was used to model current conditions for Wild Goose Lake and verify monitoring and in lake nutrient loading. Phosphorous is the key parameter in the modeling scenarios because it is the limiting nutrient for algal growth in most lakes.

Wild Goose Lake Landuse



Based on average evaporation and precipitation and runoff coefficients for Polk County the watershed load was calculated to be 419 pounds of phosphorous annually. Septic systems only accounted for about 1.1% according to the model.

To model the internal load of the lake was estimated using in situ data quantifying the increases in phosphorous concentrations in the fall. Using this method it was predicted that 156 pounds of phosphorous are released from the sediment. That is 27.2% of the annual phosphorous budget. However, there were blue-green algae blooms during this same time and that may have skewed the samples that were taken as an input to the model. Continuous nutrient data should be taken in order to continue a trend and update the lakes nutrient budget as needed (especially as land-use changes). The idea that the algae blooms are skewing the model is also indicated with the Nurnberg 1984 phosphorous model. This model predicts that the P concentration (μg/l) should be 86 while the observed data is 46 μg/l.

This data was used to select the Vollenweider 1982 Shallow Lake Model:

$P = 1.02\left[\frac{P_{in}}{1+\sqrt{T_w}}\right]^{0.88}$ Where P = the predicted mixed lake total phosphorous concentration in mg/m^3, P_{in} = the average inflow phosphorous concentration in mg/m^3, and T_w = the lakes hydraulic retention time in years. This model seemed to be the best fit for Wild Goose Lake as it predicted the total phosphorous to be 53 ug/l versus the observed 46. Had there not been a drought in 2008 the lake may have been very close to 53 ug/l, and has been in the past (April 1998, July 2001, and June 2008). Wild Goose Lake is the classic shallow lake, well mixed and seems to be changing stable states i. e. plant dominated v. algae dominated.

Too be sure, this paints a picture that the effectiveness of traditional watershed practices may not be sufficient if Wild Goose Lake turns the corner to an algal dominated state. As such, in-lake alternatives such as biomanipulation should be kept in mind as the association moves forward. Fisheries of the resource should also be quantitatively assessed.

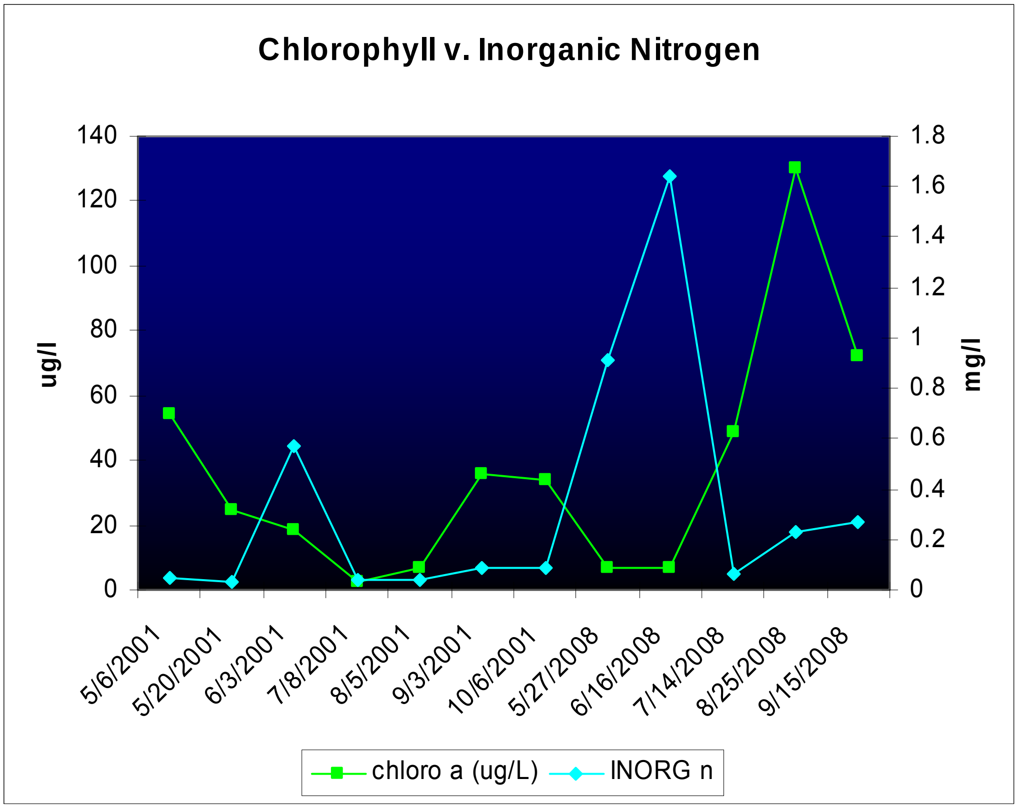
Traditional Lake models do not predict, water column phosphorous in shallow lakes well. However, WiLMS does have an expanded trophic response module that allows the prediction of nuisance algal bloom frequency. Based on the data collected, it is predicted that Wild Goose Lake will have nuisance blooms between 87.9-90.7% of the growing season. This is classic of the phytoplankton dominated state of shallow lake ecosystems. However there were other factors that likely elevated the chlorophyll a reading that will be discussed in the algae section of this report.

In-lake water quality

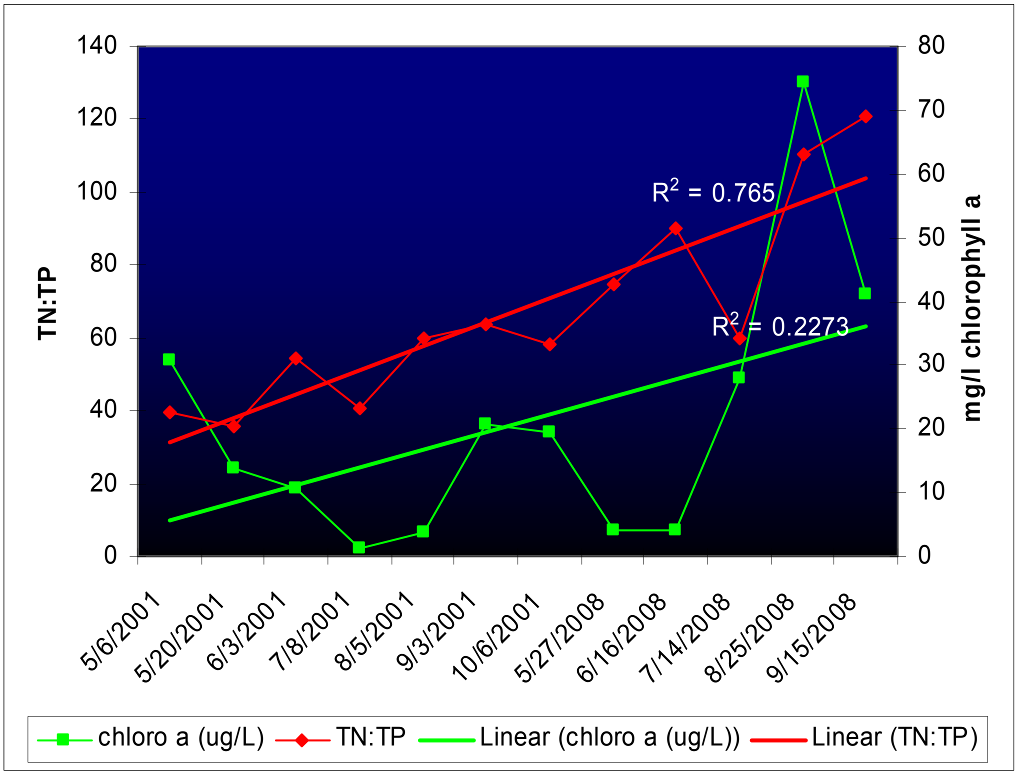
Water quality samples were collected five times on Wild Goose Lake at the "deep" hole in 2008 and communicated through email updates. All samples were analyzed for two types of phosphorus, three types of nitrogen, chlorophyll a, and total suspended solids.

Total phosphorus concentrations in Wild Goose Lake averaged 0.046 mg/L, ranging from 0.039 to 0.054 mg/L. Total phosphorus includes phosphorus bound in plant and algae matter, suspended in the water column attached to fine particles, and dissolved in the water column. It is an indicator of how much phosphorus is in the system. This total phosphorus concentration is slightly elevated; as 0.030 mg/L is enough total phosphorus to fuel an algae bloom, however, shallow systems do tend to have higher phosphorous levels due to the land area : water volume ratio. The soluble reactive phosphorus (SRP) is only the dissolved portion of phosphorus that is readily available to plants and algae. Wild Goose Lake averaged 0.004 mg/L SRP with a range from 0.002 to 0.006 mg/L, very stable and almost constant.

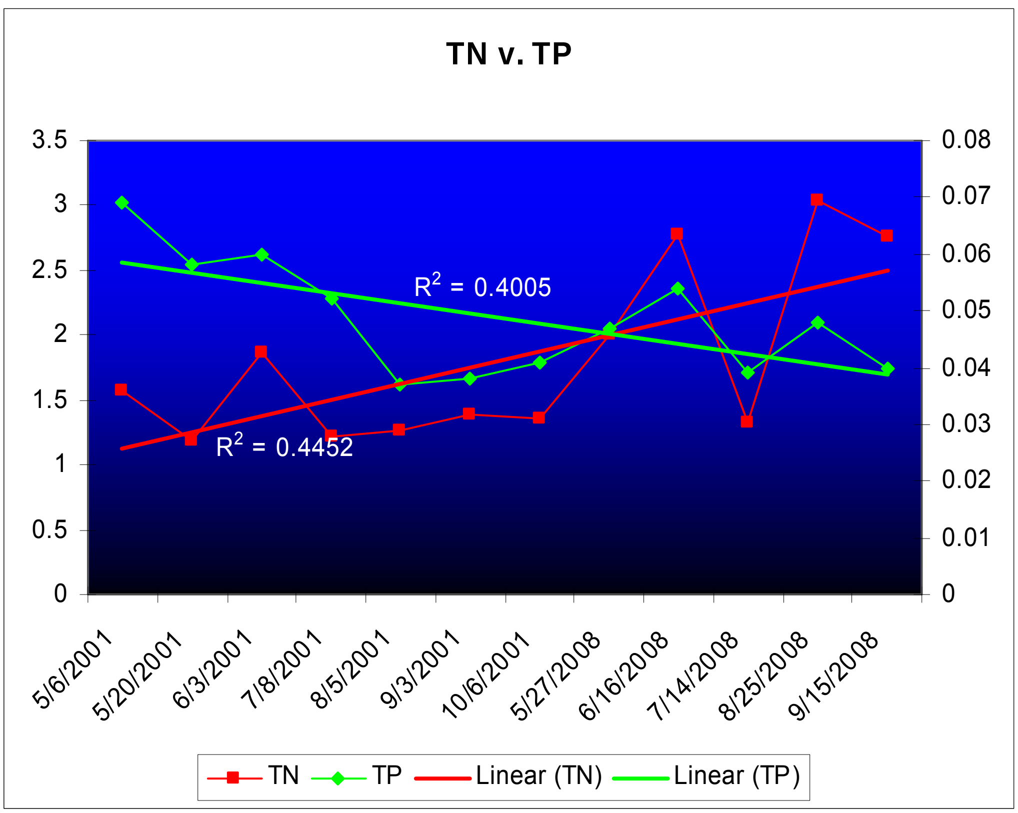
Nitrogen was also analyzed. The most abundant form of nitrogen found in Wild Goose Lake was Total Kjeldahl nitrogen (TKN) at 2.21 mg/L. Kjeldahl nitrogen is organic nitrogen plus ammonium. Subtracting the ammonium concentration from TKN gives the organic nitrogen found in plant and algae material in Wild Goose Lake (1.76 mg/L). The two forms of nitrogen (nitrite-nitrate and ammonium) that are readily available were also abundant at 0.23 and 0.45 respectively. This again raises the question that algae are driving the nutrient conditions in the lake rather than vice versa. It is know that as algae increases the concentration of Nitrogen decreases, and it did in Wild Goose Lake; the concentration of inorganic nitrogen went from 1.64 mg/l to 0.36 mg/l by the end of the growing season. This could be a climactic condition based on the drought, or a symptom of a lake regime shift. The spike in nitrogen, along with blue-green algae blooms is alarming being Wild Goose Lake only has an alkalinity of 8 mg/l, generally you do not see blue-green algae dominance at this alkalinity. The low alkalinity does explain the aquatic macrophyte community that will be discussed in another section.



Generally, phosphorous is considered the limiting nutrient in Northwest Wisconsin lakes. However, the nitrogen seems to be driving the system. Likely, cyanobacteria (blue-green algae), is fixing nitrogen from the atmosphere. This can be seen in the total nitrogen, total phosphorous ration (TN:TP). Generally lake managers look fro a TN:TP ratio of 20:1. However, in Wild Goose we are seeing ratios of 69:1 and historically the lake has always been 30:1 or greater. This supports the idea that the blue-green algae are fixing the nitrogen from the atmosphere and their cell tissue was incorporated into the samples as can be seen in the TN:TP v. chlorophyll a chart. Meanwhile, the total phosphorous is going down possibly due to the lack of runoff. Therefore, the association should continue to monitor both nitrogen and phosphorous to get a long term tend of this data, and possibly predict when the lake may bloom.



140
120
100
80
60
40
20
0
TN:TP
80
70
60
50
40
30
20
10
0
mg/l chlorophyll a
R^2 = 0.765
R^2 = 0.2273
5/6/2001
5/20/2001
6/3/2001
7/8/2001
8/5/2001
9/3/2001
10/6/2001
5/27/2008
6/16/2008
7/14/2008
8/25/2008
9/15/2008
chloro a (ug/L)
TN:TP
Linear (chloro a (ug/L))
Linear (TN:TP)

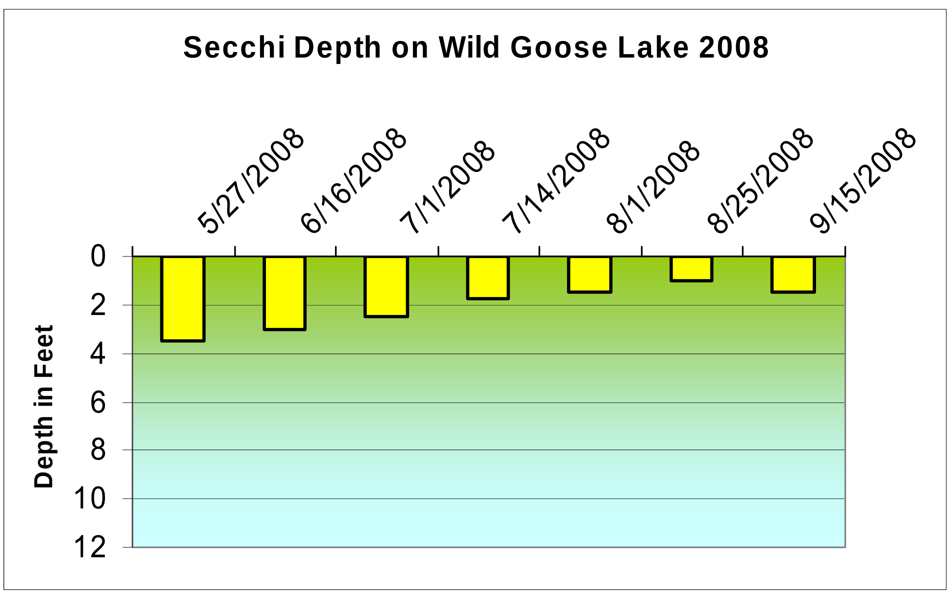


TN v. TP
3.5
3
2.5
2
1.5
1
0.5
0
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
R^2 = 0.4005
R^2 = 0.4452
5/6/2001
5/20/2001
6/3/2001
7/8/2001
8/5/2001
9/3/2001
10/6/2001
5/27/2008
6/16/2008
7/14/2008
8/25/2008
9/15/2008
TN
TP
Linear (TN)
Linear (TP)

The total suspended solids were negligible, but did increase with the algal blooms.

The average chlorophyll a concentration in Wild Goose was 53 mg/l. However the concentration was only 7 mg/l in May and June, and spiked to a very high 130 mg/l by the end of August. While chlorophyll *a* gives a general indication of the amount of algae growth in the water column, but cannot be directly correlated with biomass. Mildly eutrophic lakes can have chlorophyll *a* concentrations of 15 µg/L. With the high potential of internal load there is likely a positive feedback from the lake sediments through bacterial breakdown of algal cell tissue and the sediment resuspension by wind and boats, feeding algae growth. Chlorophyll a is a good estimation of the amount of algae growth in the lake and should also be monitored with the nutrient suite.

The average Secchi depth in Wild Goose Lake was just over 2 feet. Secchi depth is a measure of the amount of light that can penetrate the water column. The Secchi depth is affected by dissolved and suspended materials in the water column, as well as phytoplankton. The Secchi Depth has remained pretty constant since 1996. However, what we may be seeing is a shift from diatom phytoplankton dominance (as seen in the 2001 study albeit with very little collected data) to a cyanobacteria phytoplankton community as seen in this study, which again will be discussed in detail in another section.

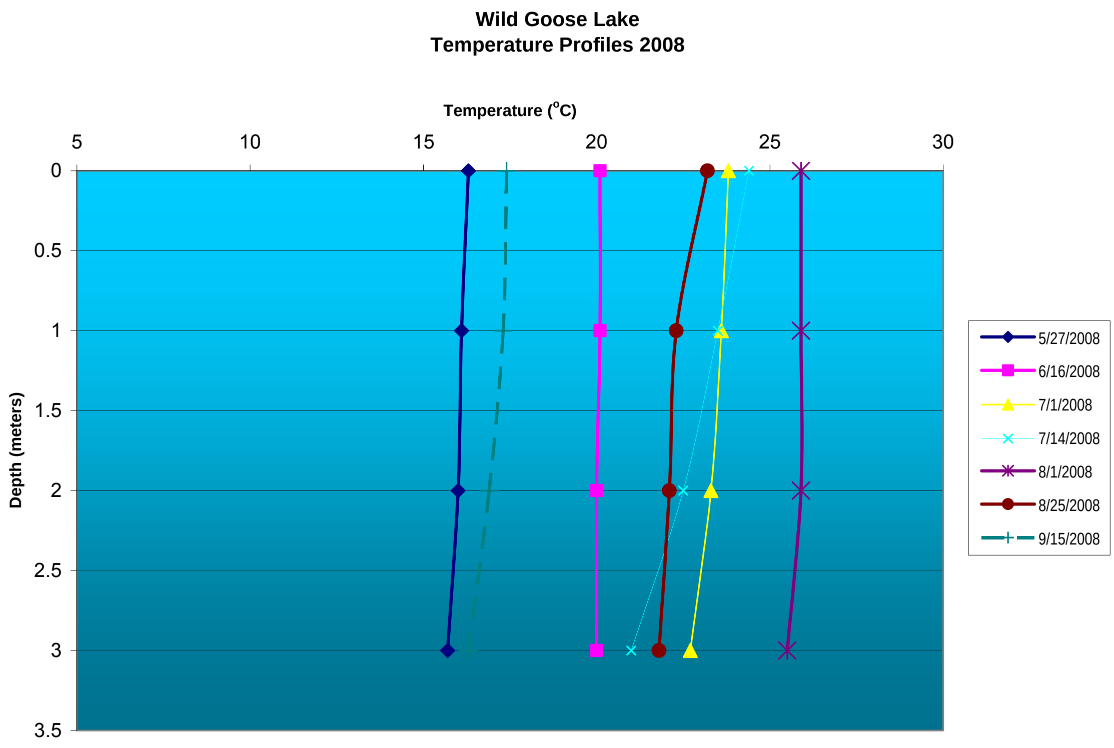


Water column profiles

Lake ecosystems are reliant on oxygen, carbon dioxide, and nitrogen that they obtain from the atmosphere to perform basic ecosystem functions. Oxygen is the most important element as it is required by all aquatic organisms in order to survive. The solubility of oxygen and other gases depends on the water temperature, the amount of wind mixing that brings water into contact with the atmosphere, the biological activity that consumes or produces gas within a lake, and gas composition of groundwater and surface water entering a lake.

The profile of Wild Goose Lake was taken at the deepest point approximately every two weeks May through September. Using an YSI 85 multi-parameter probe; temperature, dissolved oxygen, conductivity, and salinity readings were recorded at each meter of water depth. The temperature and oxygen profiles of a lake are important to understand the mixing of oxygen and nutrients in the water column.

The warmest water temperature on the surface of Wild Goose Lake was 25.9 ^{o}C on August 1, 2008. The coldest, measured lake water at the surface was 16.3 ^{o}C on May 27, 2008. The water temperature on any given day was only about 1-3 degrees different at the bottom of the lake than at the top.

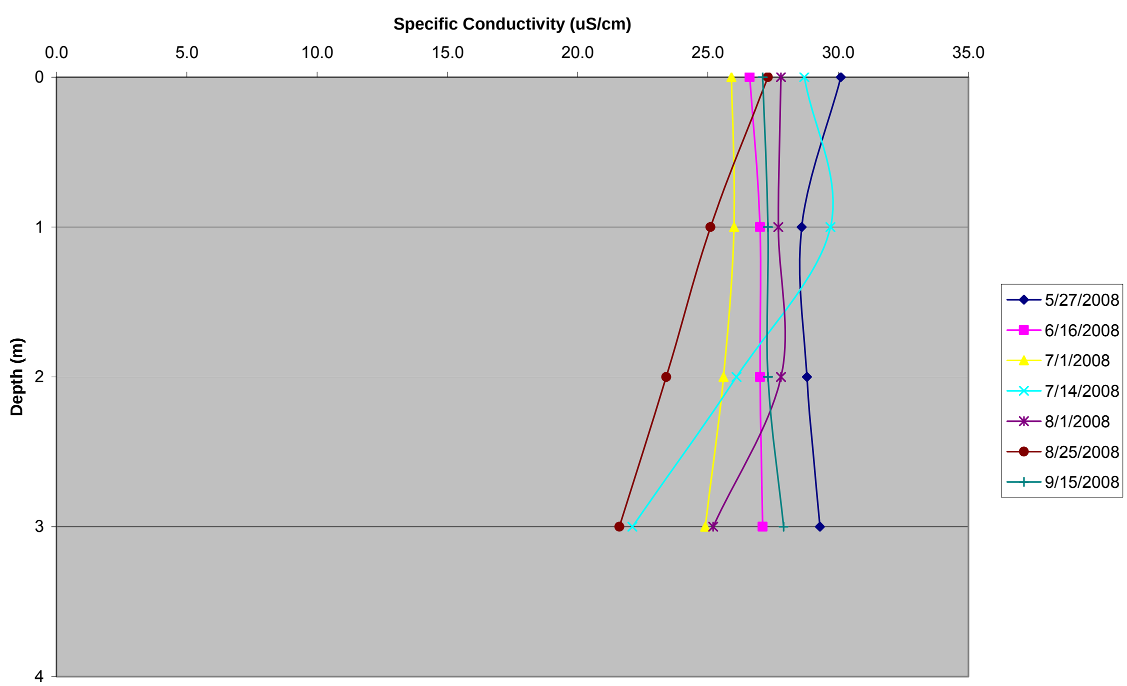


Wild Goose Lake has a mixed water column that does not stratify throughout the summer. The lake does not develop water temperature (thus density) differences that create distinct layers in the water column; wind and wave action are able to mix the water of the lake. The constant mixing of lake water enables oxygen from the atmosphere to be mixed into the water column of most of the lake, but also inputs nutrients from the sediments adding to the lake's fertility.

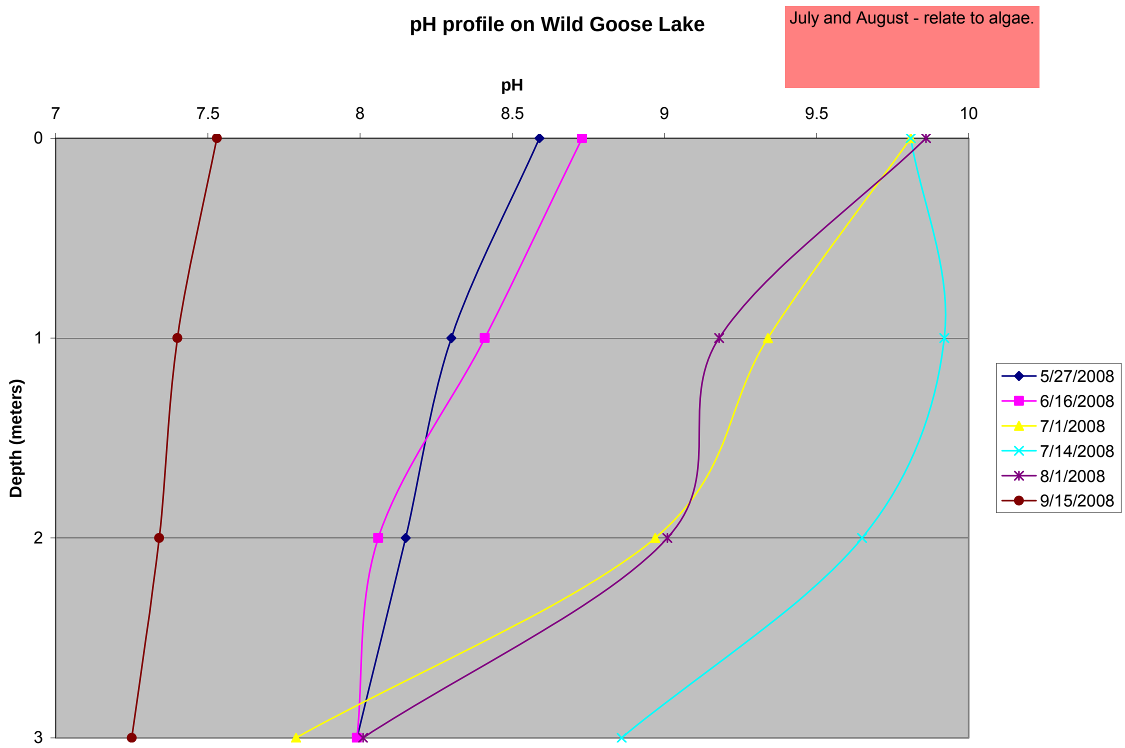
The oxygen profile of Wild Goose Lake throughout the 2008 growing season is graphed below. The oxygen concentration ranged from 8.58 to 7.13 mg/L at the surface. The oxygen concentrations at the bottom of the lake (at 3 meters depth) ranged from 5.01 to 7.51 mg/L. As temperature rises, the ability for a gas to remain in a dissolved state declines. Generally, dissolved oxygen concentrations are higher in spring and late summer/fall when temperatures are cooler. Again, the oxygen profile shows how well mixed that Wild Goose Lake is.

The specific conductance on Wild Goose Lake is an indicator of the low alkalinity that was tested with the water samples. Specific conductance is simply conductivity (μS/second) normalized at 25°C. The specific conductance on Wild Goose is one of the lowest in the county and indicates the Wild Goose may be more susceptible to change than some other lakes in the area.

Specific Conductance on Wild Goose Lake



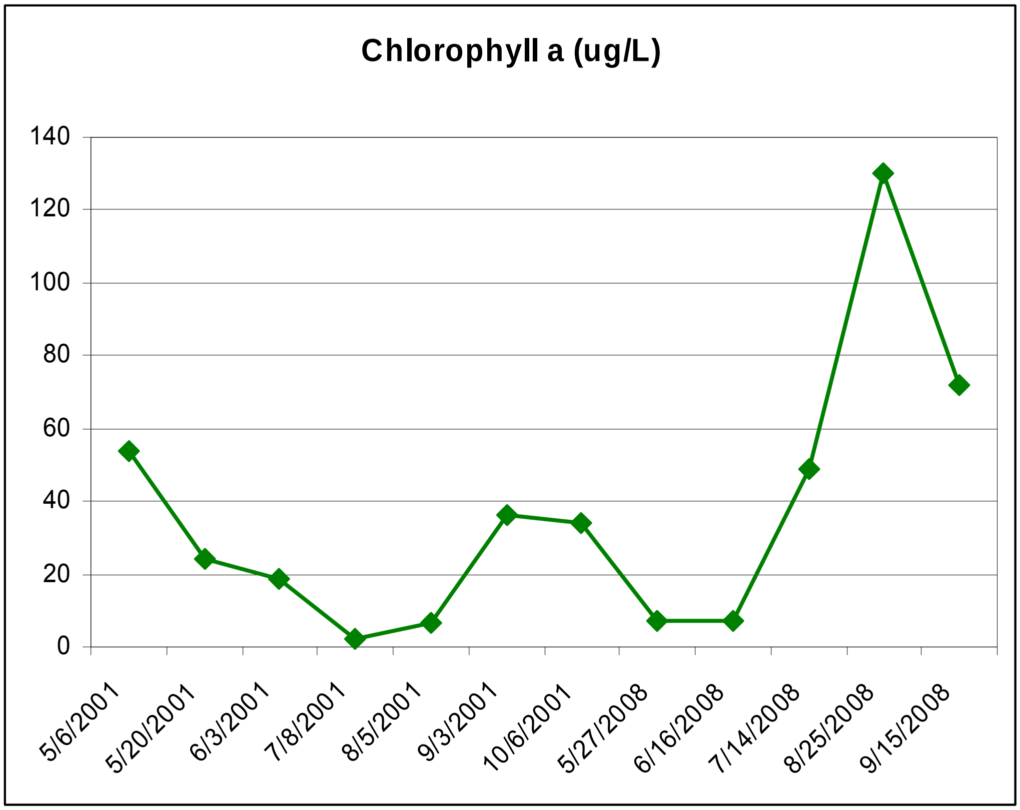
pH profiles were also taken on Wild Goose Lake using a YSI 60 pH meter. Algae can cause the pH of a system to increase as it depletes the bicarbonate in the lake (of which Wild Goose has very little). As can be seen on the chart below, July, August, and September have a surface pH two to three orders of magnitude higher than May and June. Previously the highest pH reading for the lake was 8.24 on April 27th 1998. Again, this shows the importance of continuous monitoring and the especially sensitive nature of shallow lakes.

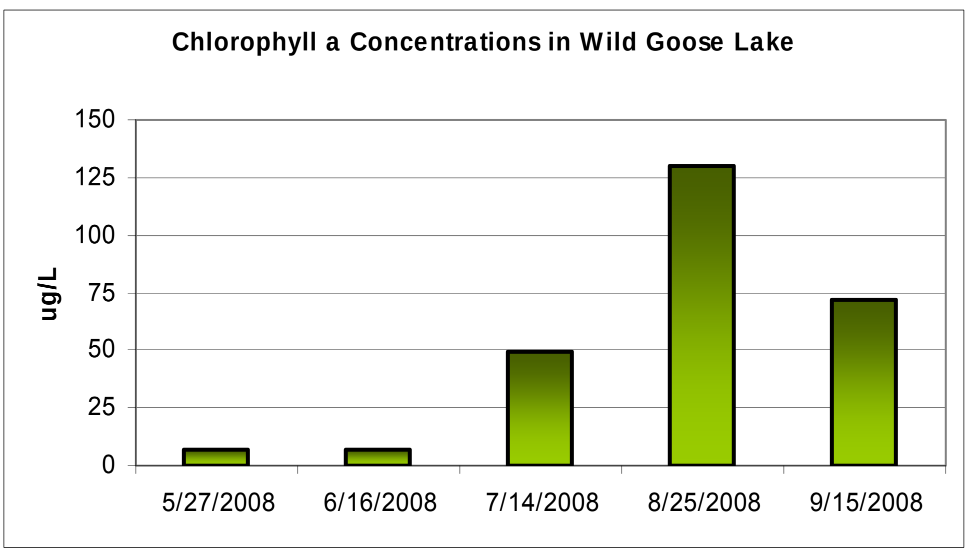


Chlorophyll *a* and Algae

While algae are natural and essential to the food web, too much of the wrong class can cause problems. It is critical to know how much and what types of algae are present. All green plants and algae use chlorophyll to convert sunlight to useable energy during photosynthesis. All plants and algae contain chlorophyll *a*, but some also contain other types. Chlorophyll *a* is used as an indirect measure of algae in the water column. Wild Goose Lake had an average chlorophyll *a* concentration of 53 µg/L. The values ranged from 7 µg/L in early May to 130 µg/L in August. Ideally, chlorophyll *a* concentrations should be below 20 µg/L to maintain water clarity. The couple of spikes in 2001 are nowhere near the 130 µg/l seen in 2008, likely because of the concentration of different algae classes.

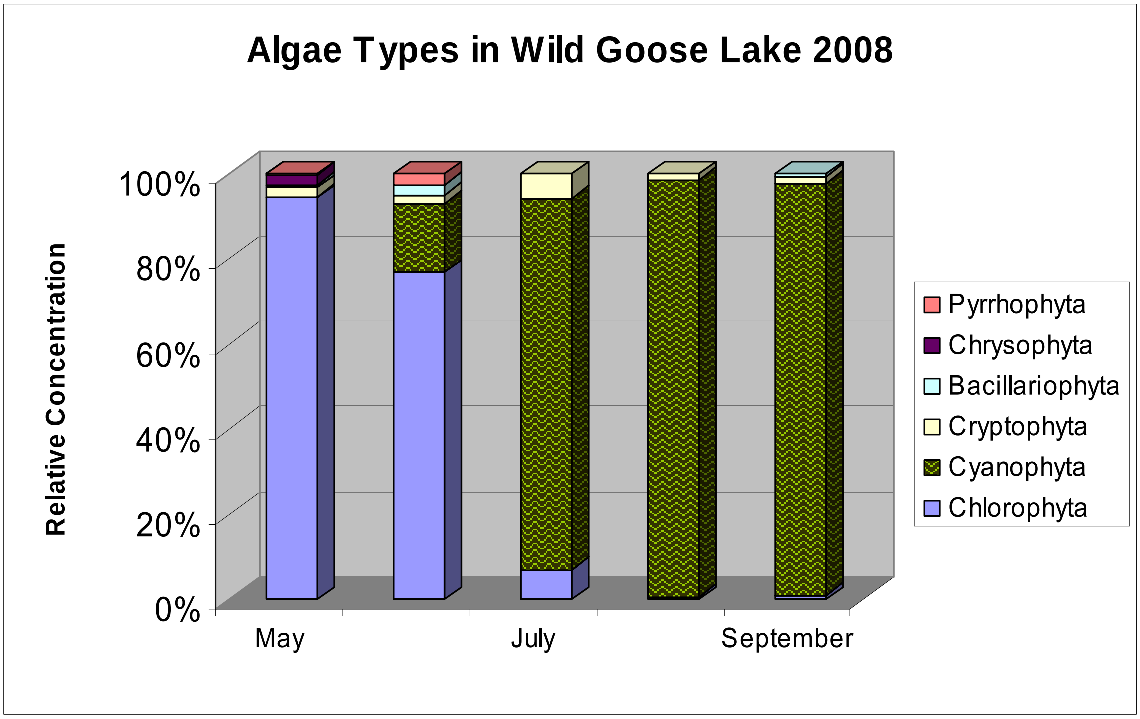
The types of algae in Wild Goose Lake were also quantified. Plants and algae are the first link in the food web, but not all types of algae are as easily consumed by zooplankton in the lake. Six classes of algae were quantified in Wild Goose Lake. These classes are Basillariophyta, Chlorophyta, Cryptophyta, Cyanophyta, and to a lesser extent Chrysophyta, and Pyrrhophyta.





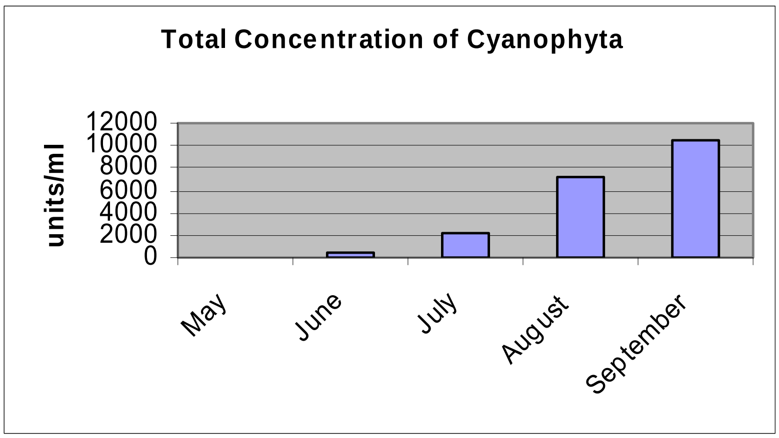
The species composition of algal communities change seasonally in response to light, temperature, nutrients, grazing of zooplankton, and rain events. In Wild Goose Lake, these factors changed the water conditions. The September sample had a decreased chlorophyll a concentration , as well as, TP concentration, a slight decrease in overall algae concentration, but a moderate increase in green algae counts, which could be an indicator that by reducing the in-lake nutrients there is hope to change the algal composition, and hopefully establish plants, which is the goal in shallow lake management.

As mentioned previously, phosphorus was abundant in the lake water column while inorganic nitrogen was tied up. Some types of algae are able to capitalize on this type of system. Cyanobacteria (blue-green algae) can acquire nitrogen from the atmosphere as a gas (N_2) instead of through the water column with a structure called heterocysts. They have a competitive advantage in Wild Goose Lake where nitrite and nitrate were low. In fact, blue green algae were the dominant algae type from July on.

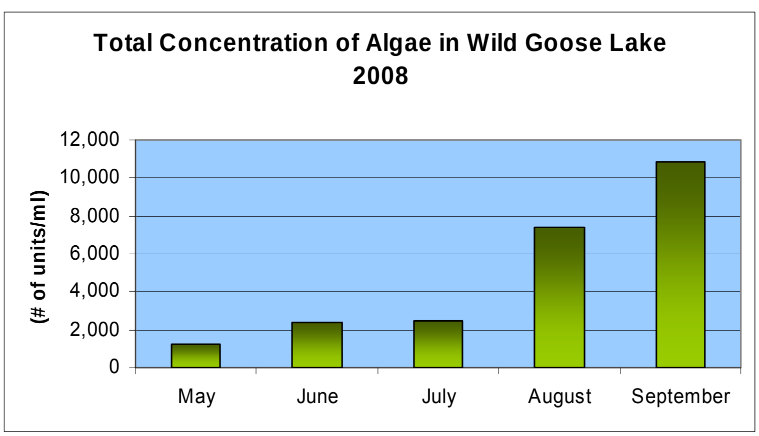


The pattern of ups and downs in species composition is typical in all lake systems, however shallow eutrophic lakes tend to be dominated by cyanobacteria (blue-green algae) which could reach a threshold of balance and, in conjunction with the animal community, helps maintain the turbid phytoplankton dominated state, through positive feedback mechanisms. Wild Goose Lake still has a very sensitive viable plant community and is not at the turbid water state at this point.

While blue-green algae, also called cyanophyta or cyanobacteria, have been around for millions of years and typically do bloom each summer, blue-green algae blooms may be more frequent because of the increased nutrients reaching our waters or being released from the sediments themselves, or likely in the case of Wild Goose, fixing nitrogen straight from the atmosphere. One of the primary concerns with cyanobacteria beyond aesthetics stems from the production of cyanotoxins. Cyanotoxins are naturally produced chemical compounds that are sometimes found inside the cells of certain blue green algae species. These chemicals can affect the skin and mucous membranes with an allergy-like reaction, cause damage to the liver or internal organs, or affect the central nervous system, depending on the type of toxin that an algae species produces. The environmental conditions are not known of exactly when cyanotoxins will be produced, but scientists have found that when blue green algae is present in concentrations over 100,000 cells/ml toxin production is more likely to occur. The difference between the algae units of cells/ml and units/ml depends on how the algae live, either as a free cell or colonial. The blue green algae species that are capable of producing toxins were counted as individual cells per milliliter of sample (in addition to the natural units that they occur in) to determine their ultimate concentration.



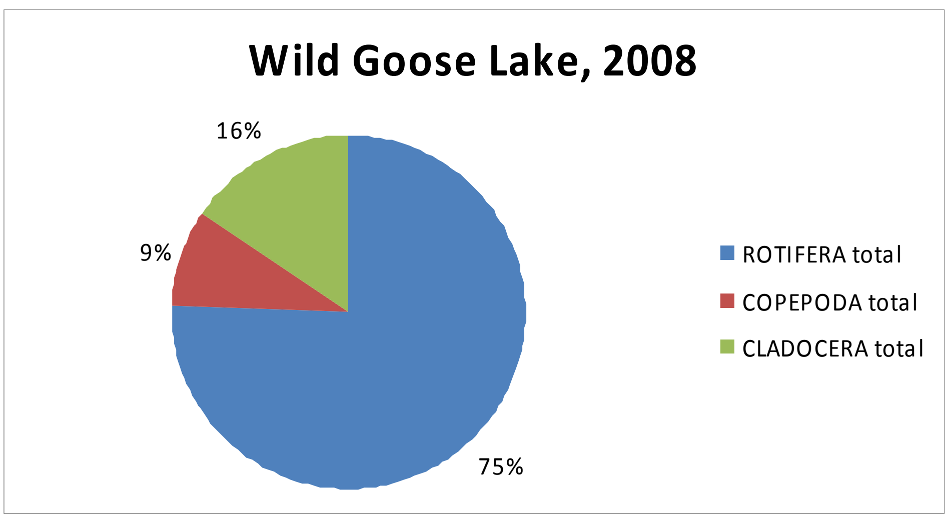
On Wild Goose Lake, there was one sample (September) where blue green algae concentrations were above 100,000 cells/ml. August had a concentration of 7251. While concentrations over 10,000 units per ml are capable of producing toxins, we do not know why or when this will occur. If blue-green blooms continue to persist it may be necessary to begin an algae monitoring regime and start testing for toxins.



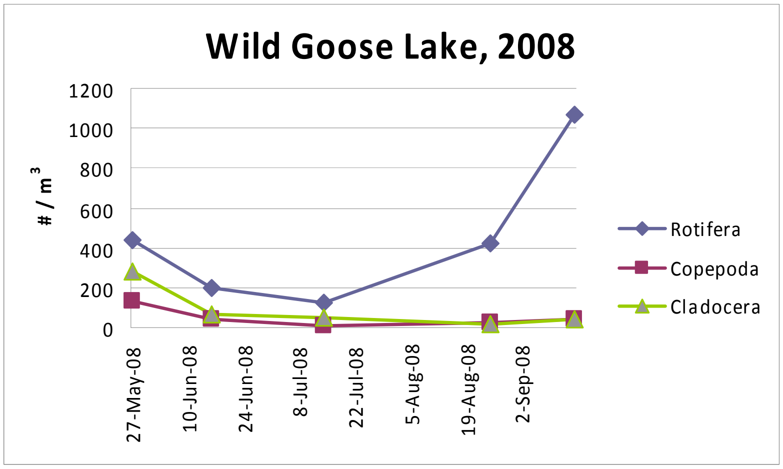
Zooplankton

Zooplanktons are small aquatic animals. They are one of the primary links between the processes of the lake ecosystems. For instance, zooplankton can mediate noxious algal blooms by heavy grazing *per se*. Selective, species-specific or size-specific grazing causes selective mortality among the phytoplankton, which in turn will affect the competitive balance between different phytoplankton species (Andersson 1988). A shift in algal species composition can change the zooplankton community, exacerbating the algal blooms and stressing the fish community, including the development of game-fish fry. Fish predation from planktivorous fish (pan fish) can drastically reduce zooplankton populations and also lead to algae blooms. In some lakes biomanipulation is used to manage this effect; using picivorous fish to reduce the planktivors, increasing zooplankton to reduce algae. This in turn improves the water clarity. With the healthy pike and perch population (personal communication with residents) in Wild Goose Lake this should not be an issue. However with bass population rising (personal communication) and the increased size limit on large mouth bass many Northern Wisconsin lakes are seeing a shift in their fish communities affecting the zooplankton and algae. The DNR fish manager should be contacted to see where Wild Goose Lake is at.

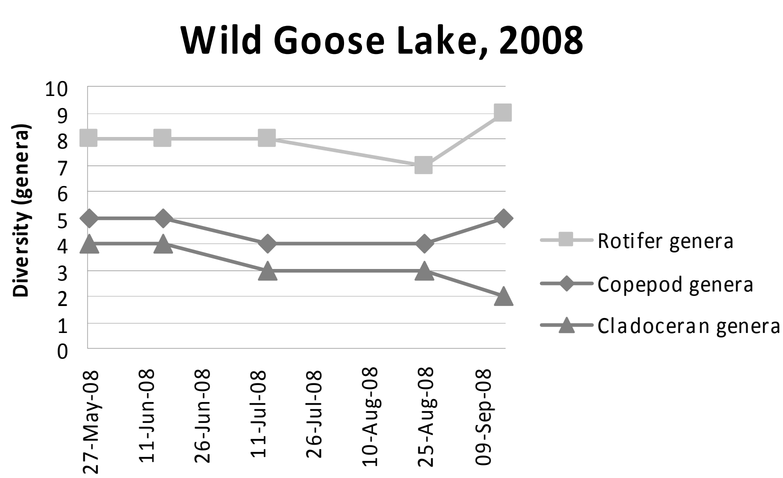
Zooplankton also responds to changes to lakeshore and littoral zone community. Changes in aquatic plants, and shoreland habitat impact plankton either directly or indirectly (Lafrancois 2009), especially in shallow lakes where zooplankton likely have to migrate horizontally to avoid predation from fish and other invertebrates.



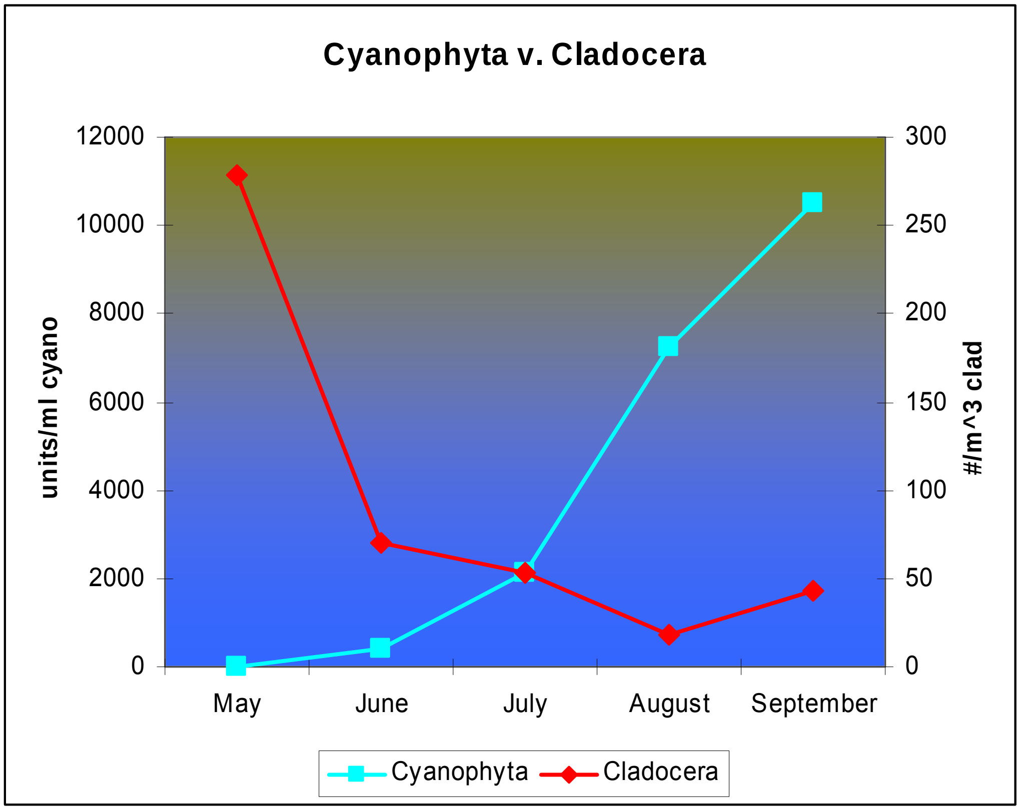
The three primary components of the zooplankton community are rotifers, copepods and cladocerans. Rotifers are size selective omnivores that eat algae, zooplankton and sometimes each other; they are not capable of reducing algal biomass. Copepods are also size selective omnivores, and are heavily preyed upon by fish. Some have specific feeding habits, and they are highly variable in size. Cladocerans are filter feeders that are an important part of the food web. Species of cladocerans (particularly Daphnia) are well known in reducing algal biomass and helping to maintain a clear water regime in lake ecosystems. Below are the relative concentrations of the three major groups of zooplankton for Wild Goose Lake in 2008.



This analysis showed that the zooplankton population in the lake is characteristic of eutrophic lakes with high predation by planktivorous fish. As seen in the charts above the lake is dominated by rotifers; these are the smallest zooplankton and are tolerant of fish predation. However, the presence of some larger species in low numbers indicates good potential for a more robust zooplankton community that could be capable of mitigating an algae bloom. There is a possibility that calcium limitation rather than fish predation is the cause of the zooplankton community structure. If that is the case, it is imperative that the in-lake plant community remain intact in order to mitigate nutrients that could cause an algae bloom in the future.



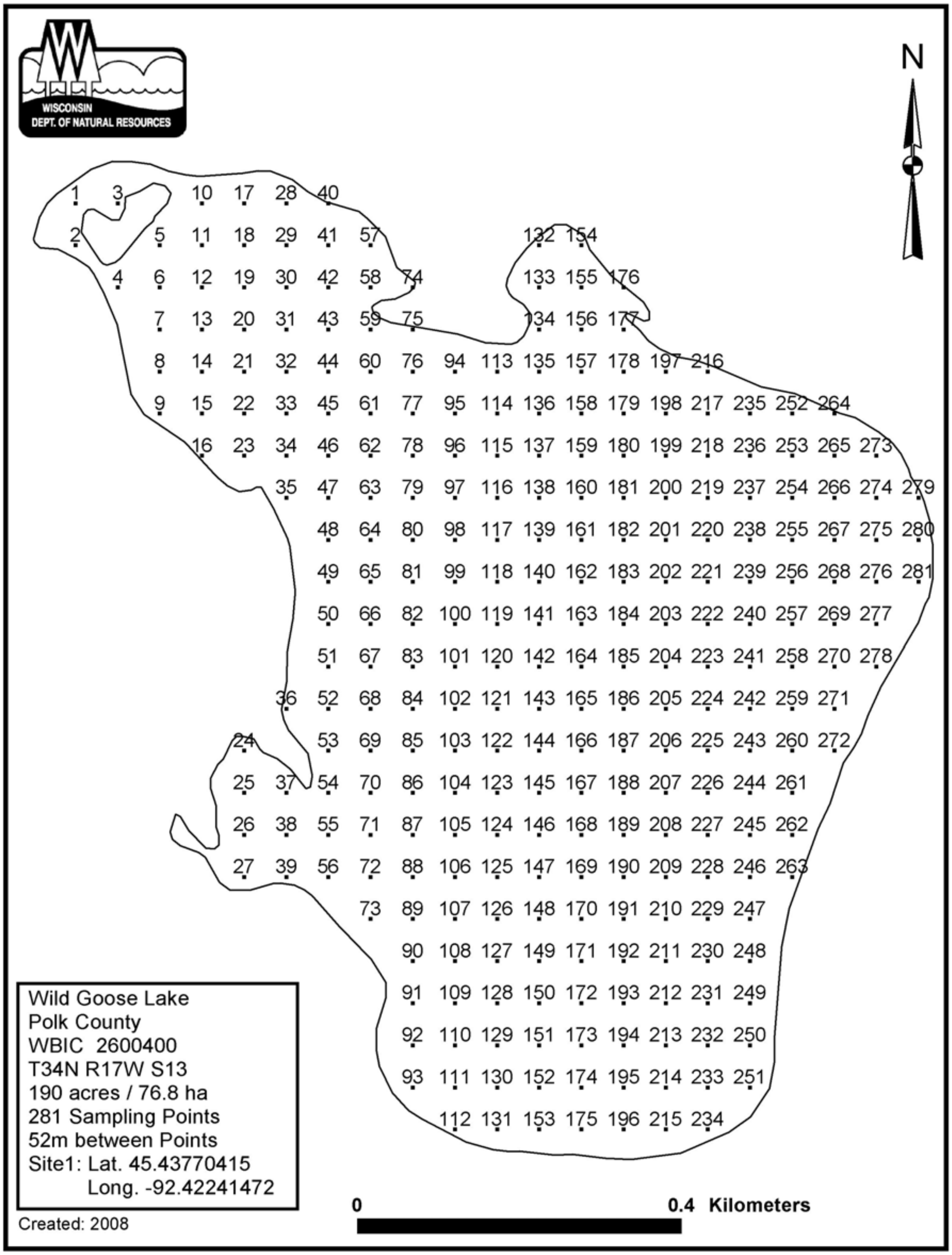
If blue-green algae blooms persist it could severely alter the zooplankton community of Wild Goose Lake. As the concentration of cyanobacteria rose in 2008 the cladoceran community crashed. It is generally assumed that cladocera do not like colonial cyanobacteria and the most abundant species in Wild Goose was *Aphanizomenon sp.* (likely *Aphanizomenon flos-aqua*). Fortunately, the ephippia or eggs of zooplankton can "rest' in the sediment for decades and hatch when conditions are right.



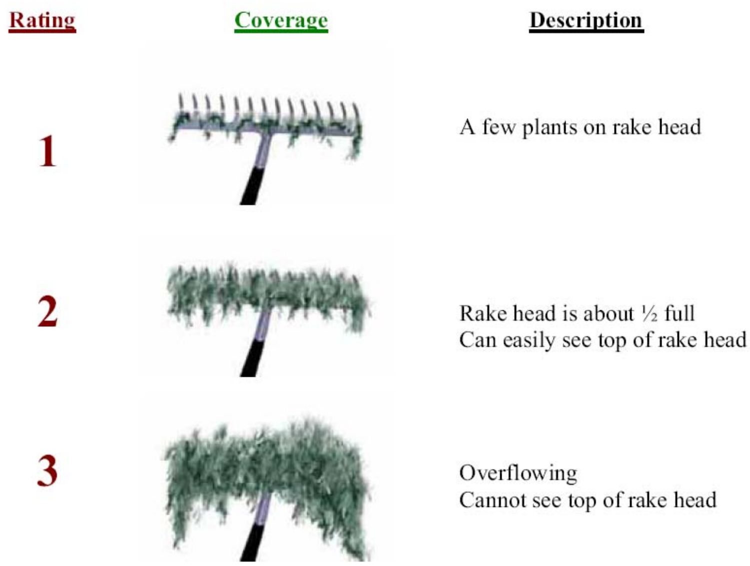
The benthic invertebrates were not able to be analyzed because of problems with preservation.

Aquatic Vegetation

The aquatic macrophyte survey was carried out on Wild Goose Lake on August 18th and 19th, 2008. 281 sampling points were established in and around the lake using a standard formula that takes into account the shoreline shape and distance, islands, water clarity, depth and total lake acres. Points were generated in ArcView (a GIS program) and downloaded to a GPS unit. These points were then sampled in field.



All plants found were identified to species (except *Nitella* which did not have oocytes present). During the point intercept survey, we located each survey point using a handheld mapping GPS unit, and at each point, depth was recorded. Every point that was not too shallow or terrestrial was sampled (shallow communities were characterized visually). At each of these points, we used a rake (either on a pole or a throw line depending on depth) to sample an approximately 1 meter section of the benthos. All plants on the rake, as well as any that were dislodged by the rake were identified, and assigned a rake fullness value of 1 to 3 as an estimation of abundance (figure below). We also recorded visual sightings of plants within six feet of the sample point. Substrate (lake-bottom) type was assigned at each site where the bottom was visible or it could be reliably determined using the rake.



Rake fullness rating (UW Extension 2007)

Data collected was entered into a spreadsheet for analysis. The following statistics were generated from the spreadsheet:

- Frequency of occurrence for all sample points in lake
- Relative frequency
- Total sample points
- Sample points with vegetation
- Simpson's diversity index
- Maximum plant depth
- Species richness
- Floristic Quality Index

The following are explanations of the various analysis values:

<u>Frequency of occurrence for each species</u>- Frequency of occurrence is expressed as a percentage and there are two values for this. The first is the percentage of all sample points that this plant was sampled. The second is the percentage of littoral sample points that the plant was sampled. The first value shows how often the plant would be encountered everywhere in the lake, while the second value shows if only within the depths plants potentially grow. In either case, the greater this value, the more frequent the plant is in the lake. If one wants to compare to the whole lake, we look at the frequency of all points and if one wants to focus only where plants are more probable, then one would look at frequency in the littoral zone.

Frequency of occurrence example:
Plant A sampled at 35 of 150 total points = 35/150 = 0.23 = 23%
Plant A's frequency of occurrence = 23% considering whole lake sample.
This frequency can tell us how common the plant was sampled in the entire lake.

Relative frequency-This value shows, as a percentage, the frequency of a particular plant relative to other plants. This is not dependent on the number of points sampled. The relative frequency of all plants will add to 100%. This means that if plant A had a relative frequency of 30%, it occurred 30% of the time compared to all plants sampled or makes up 30% of all plants sampled. This value allows us to see which plants are the dominant species in the lake. The higher the relative frequency the more common the plant is compared to the other plants.

Sample sites with vegetation- The number of sites where plants were actually collected. This gives a good idea of the plant coverage of the lake. If 10% of all sample points had vegetation, it implies that about 10% of the lake is covered with plants.

Relative frequency example:
Suppose we were sampling 10 points in a very small lake and got the following results:
Frequency sampled
Plant A present at 3 sites 3 of 10 sites
Plant B present at 5 sites 5 of 10 sites
Plant C present at 2 sites 2 of 10 sites
Plant D present at 6 sites 6 of 10 sites
One can see that Plant D is the most frequent sampled at all points with 60% (6/10) of the sites having plant D. However, the relative frequency allows us to see what the frequency is compared the other plants, without taking into account the number of sites. It is calculated by dividing the number of times a plant is sampled by the total of all plants sampled. If we add all frequencies (3+5+2+6), we get a sum of 16. We can calculate the relative frequency by dividing by the individual frequency.
Plant A = 3/16 = 0.1875 or 18.75%
Plant B = 5/16 = 0.3125 or 31.25%
Plant C = 2/16 = 0.125 or 12.5%
Plant D = 6/16 = 0.375 or 37.5%
Now we can compare the plants to one another. Plant D is still the most frequent, but the relative frequency tells us that of all plants sampled at those 10 sites, 37.5% of them are Plant D. This is much lower than the frequency of occurrence (60%) because although we sampled Plant D at 6 of 10 sites, we were sampling many other plants too, thereby giving a lower frequency when compared to those other plants. This then gives a true measure of the dominant plants present.

Species	Common Name	Relative Frequency (%)	Frequency of occurrence %
Brasenia schreberi	Watershield	19.81	38.18
Elatine minima	Waterwort	visual	visual
Eleocharis acicularis	Needle spikerush	visual	visual
Eriocaulon aquaticum	Pipewort	1	1.82
Juncus palocarpus f. submersus	Brown-fruited rush	visual	visual
Myriophyllum tenellum	Dwarf water-milfoil	1	1.82
Nitella	Nitella	visual	visual
Nuphar variegata	Spatterdock	2.9	5.45
Nymphaea odorata	White water lily	11.4	21.82
Polygonum amphibium	Water smartweed	visual	visual
Pontederia cordata	Pickerelweed	2.9	5.45
Potamogeton robbinsii	Robbins pondweed	38.1	72.73
Sagittaria latifolia	Common arrowhead	1	1.82
Schoenoplectus subterminalis	Water bulrush	1	1.82
Schoenoplectus tabernaemontani	Softstem bulrush	1	1.82
Utricularia gibba	Creeping bladderwort	4.8	9.09
Utricularia purpurea	Large purple bladderwort	11.4	21.82

Species list and frequency values

Species richness-The number of different individual species found in the lake. There is a number for the species richness of plants sampled, and another number that takes into account plants viewed but not actually sampled during the survey. Wild goose is not a highly diverse lake with only 15 species being sampled, and 21 total when visual observations are counted.

Simpson's diversity index- Simpson's Index **(**D**)** measures the probability that two individuals randomly selected from a sample will belong to the same species (or some category other than species).

$$D = \frac{\sum n(n-1)}{N(N-1)}$$

Where D = Simpson's Diversity, n= the total number of organisms of a particular species, N=the total number of organisms of all species.
To measure how diverse the plant community is, Simpson's index is calculated. This value can range from 0 to 1.0. The greater the value, the more diverse the plant

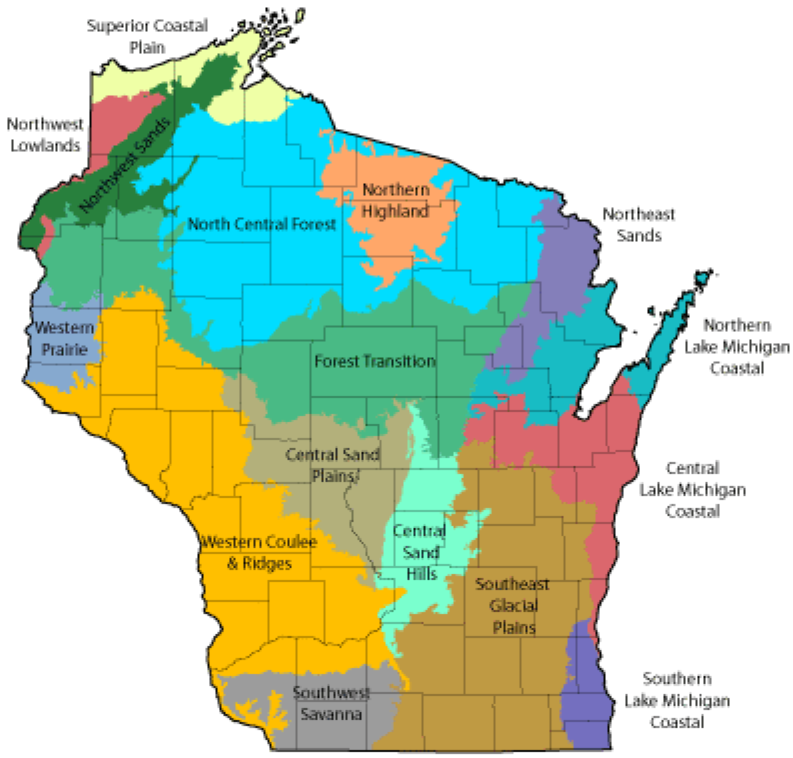
community is in a particular lake. In theory, the value is the chance that two species sampled are different. An index of “1” means that the two will always be different (very diverse) and a “0” would indicate that they will never be different (only one species found). In theory, the more diverse the plant community is, the better the lake ecosystem.

Simpson’s diversity example:
If one went into a lake and found just one plant, the Simpson’s diversity would be “0.” This is because if we went and sampled randomly two plants, there would be a 0% chance of them being different, since there is only one plant.
If every plant sampled were different, then the Simpson’s diversity would be “1.” This is because if two plants were sampled randomly, there would be a 100% chance they would be different since every plant is different.
These are extreme and theoretical scenarios, but they do make the point. The greater the Simpson’s index is for a lake, the greater the diversity since it represents a greater chance of two randomly sampled plants being different.

The Simpson’s diversity index on Wild Goose Lake was calculated to be 0.78. So although the species richness may not be as high as some other area lakes, there are likely to be two or more species at each site.

Maximum depth of plants-This depth indicates the deepest that plants were sampled. Generally more clear lakes have a greater depth of plants while lower water clarity limits light penetration and reduces the depth at which plants are found. The maxium rooting depth on Wild Goose Lake was eight feet (2.45 meters).

Floristic Quality Index- The Floristic Quality Index is designed to evaluate 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.
It takes into account the species of aquatic plants found and their tolerance for changing water quality and habitat modification using the equation $I = \overline{C}\sqrt{N}$ (where *I* is the floristic quality, $\overline{C}$ 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 index uses a conservatism value assigned to various plants ranging from 1 to 10. A high conservatism value indicates that a plant is intolerant of change while a lower value indicates tolerance. Those plants with higher values are more apt to respond adversely to water quality and habitat changes. The FQI is calculated using the number of species and the average conservatism value of all species used in the index. Therefore, a higher FQI, indicates a healthier lake plant community. It should be noted that invasive species of a value of 0.



Wisconsin Eco-region Map (WDNR)

Summary of North Central Harwood Forest Values for Floristic Quality Index:
Mean species richness = 14
Mean average conservatism = 5.6
Mean Floristic Quality = 20.9*
*Floristic Quality has a significant correlation with area of lake (+), alkalinity(-), conductivity(-), pH(-) and Secchi depth (+). In a positive correlation, as that value rises so will FQI, while with a negative correlation, as a value rises, the FQI will decrease and vice versa.

Species observed for FQI = 18 (14)
Average conservatism = 7.28 (5.6)
Floristic Quality = 30.89 (20.9)

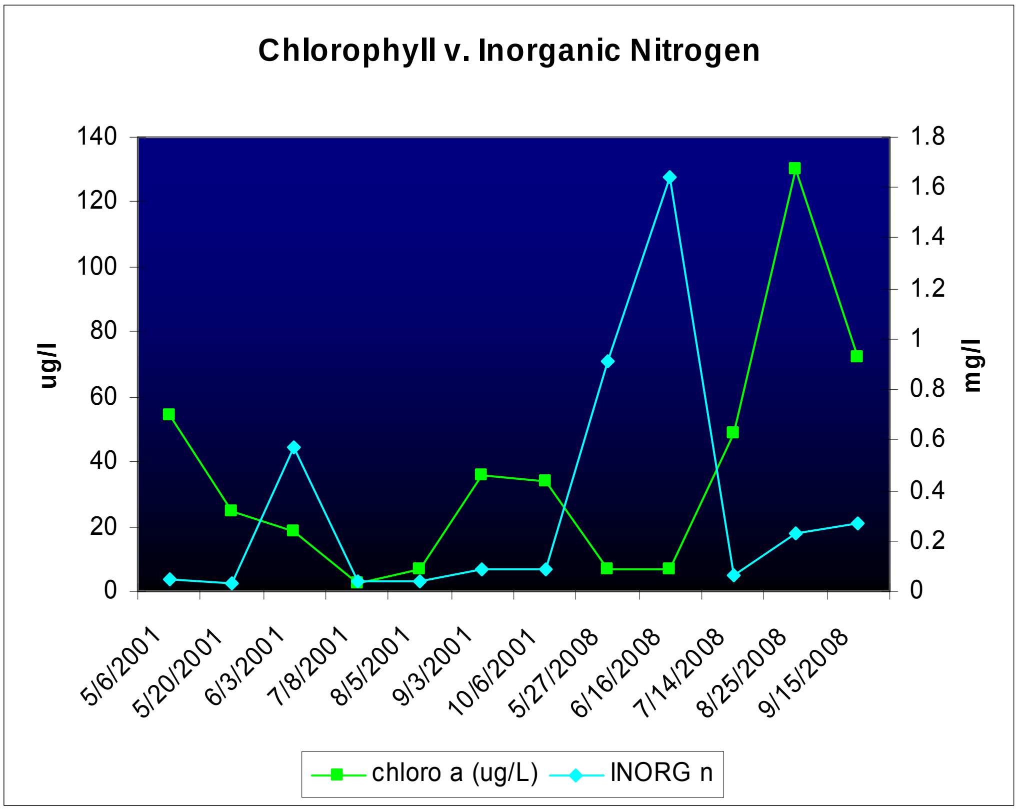
Based on the data collected the aquatic macrophyte community of Wild Goose Lake is extremely sensitive and is likely a barometer of the lakes health. Wild Goose has a very low alkalinity and almost all of the plant observed have a very narrow range of alkalinity and pH where they are found. Additionally the isoetid part of the plant community (small near shore plants) is extremely sensitive to sedimentation as well. *Isoetes lacustris* was collected while doing dredges for invertebrates but not in the plant survey. The aquatic plant community should constantly be monitored to assess the lakes health as traditional water chemistry measurements may not be sufficient to truly assess the health of Wild Goose.

Discussion

Wild Goose Lake is quite obviously a very special ecosystem. Wild Goose is a soft-water lake which is relatively rare in this part of the country.

During the 2008 sampling season the average total phosphorous was 46 parts per billion. Anything over 30 part per billion is considered eutrophic. However, it was not until September that the cell counts of cyanobacteria (blue-green algae) were over 10,000 colonies per unit of water. So, although the algal community appears to be changing, it is not to a point that is of a health concern.

Likely because it was an especially dry, sunny summer, the blue-green algae are using the available phosphorous from the internal loading. It appears as though the nitrogen content of the lake is ever increasing. This is likely because the blue-greens are fixing N form the atmosphere, as stated earlier in this report. Nitrogen fixation by cyanobacteria requires phosphorous and light, and it is well known that when algae increases the inorganic portion of nitrogen decreases. This is indeed what we saw.



The algae community should continue to be monitored on normal precipitation years to get a true picture of the community dynamics. Several years of data would be required to bet a good baseline of the algal community dynamics.

Although the zooplankton appears as though it is subject to high fish predation, it could be that they are unable to graze on the algae because they are limited by mouth-gape size. The aphanizomenon is colonial blue - green algae and is the dominant algae in August and September, just as the zooplankton collapses. Many grazing zooplankton are limited by their mouth-gape size when grazing algae as stated above. Many blue-greens defend against grazing by forming colonies so they cannot be grazed upon. While there is not a way to manage for atmospheric nitrogen fixation, continued monitoring of the zooplankton along with algae could be an indirect way of monitoring the fish community and lake health.

As stated the aquatic plant community of Wild Goose Lake is extremely sensitive, and should be constantly monitored. This is the barometer of the lakes health. The plant community more closely resembles a soft-water lake in Denmark than a typical Polk County lake. Extreme care should be taken to reduce any human induced sedimentation. Loss of the aquatic plant community in Wild Goose Lake would be catastrophic!

Eriocaulon aquaticum **and** ***Sagittaria latifolia*** **in Wild Goose Lake**

Because Wild Goose Lake is the prototypical shallow soft-water lake it is more biologically driven than many of its deeper counterparts. Getting a clear understanding of the seasonal and annual community shifts and species turnover is essential for the long-term management of the lake.

Recommendations

Monitor the biological populations of the lake. The composition of algae, zooplankton, benthic invertebrates, fish, and aquatic macrophytes need to be continuously monitored along with traditional water quality parameters in order to assess the success of a management. Because of the resilience and biological buffering mechanisms of both the plant dominated and phytoplankton dominated state of shallow lakes, there may be biological indicators that will predict a switch between the two and additional management actions, such as biomanipulation, can be taken.

Apply for grants for the association to acquire undeveloped land, but development rights, or conservation easements.

Any new construction in the watershed shall have proper erosion control measures in place, especially with the extreme sensitivity of the aquatic plant community. 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.

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

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.

Riparian vegetation, aquatic plants, and coarse woody habitat (fallen trees and logs) should be left where it stands, or installed to preserve the water quality of Wild Goose Lake and provide habitat for young game fish and zooplankton.

Because there is a long record of ecological change in the lakes sediment, a sediment core sample should be considered. Knowing the historical conditions prior to European settlement and the subsequent drivers of change could help with management techniques and set benchmarks for other shallow systems in

Polk County, the state and throughout the mid-west, especially those with low alkalinity.

Recreational boating should be moderated on shallow lakes. Non-motorized sports will have less impact on water quality and turbidity than personal water craft (PWC) and motorized boats. At a minimum, slow-no-wake speeds should be implemented and the 200-foot from shore law upheld.

Residents should begin a 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 Wild Goose Lake residents.

Area residents and fisherman should inspect boating and fishing equipment to prevent the introduction of invasive species into Wild Goose 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.

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Appendix A

Zooplankton Report