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

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Wild Goose Lake 2008

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Introduction

Wild Goose Lake was first assessed by the Polk County Land & Water Resources Department (LWRD) in 2001. The Wild Goose Lake Association had been collecting secchi disc and nitrogen data and wanted to know the causes of the low secchi disc within the lake. The conclusions of that study were that Wild Goose Lake may be nitrogen limited as opposed to phosphorous and the lake should be reassessed in five years, and the Land & Water Resources Department has been at lake meetings since that time.

The last several years Wild Goose Lake has seen algae blooms that most residents were not familiar with. Typically Wild Goose Lake is brown in color and green and blue-green algae have not been much of a problem. This prompted the Wild Goose Lake Association and the Polk County LWRD to apply fro another lake planning grant to reassess the lake and attempt to devise new management strategies.

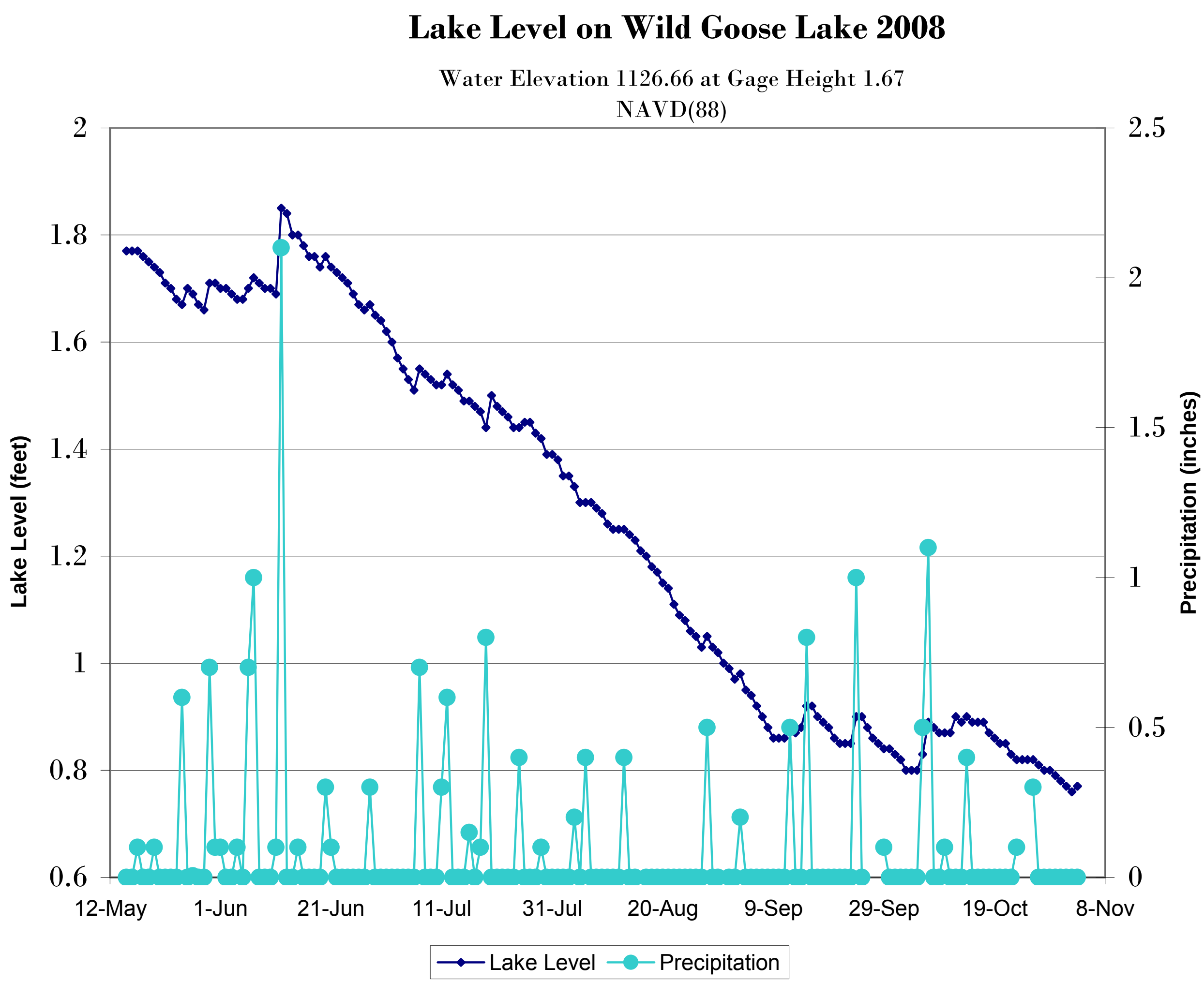
The study on Wild Goose Lake was performed by the Polk County Land and Water Resources Department with assistance from the Wild Goose Lake Association and financial assistance from a Department of Natural Resources Lake Planning Grant (LPL-1224-08). The samples were collected during the growing season 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 hardwood bog sit sin a bay to the northwest of the lake and drains into the lake via an intermittent stream. Only 37% of the shoreline is developed with residential cabins right now, the rest is native forest land and bog community.

The watershed drainage area of Wild Goose Lake is 998.7 acres with many of rural land uses, including rural residential, very little agriculture, and forest communities. Inputs to the lake stretch back as far as 1.5 miles away near the Village of Balsam Lake. Wild Goose Lake is connected to East Lake via a road culvert. Wild Goose Lake flows 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 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 exceeded precipitation and the lake responded accordingly.

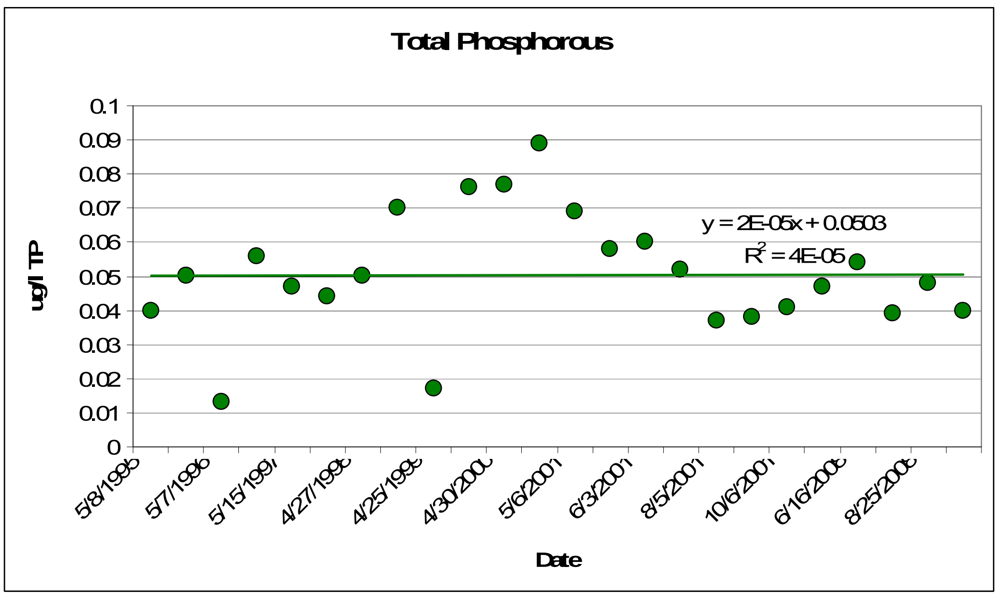


Lake Level on Wild Goose Lake 2008
Water Elevation 1126.66 at Gage Height 1.67
NAVD(88)
Lake Level (feet)
Precipitation (inches)
2
1.8
1.6
1.4
1.2
1
0.8
0.6
2.5
2
1.5
1
0.5
0
12-May
1-Jun
21-Jun
11-Jul
31-Jul
20-Aug
9-Sep
29-Sep
19-Oct
8-Nov
Lake Level
Precipitation

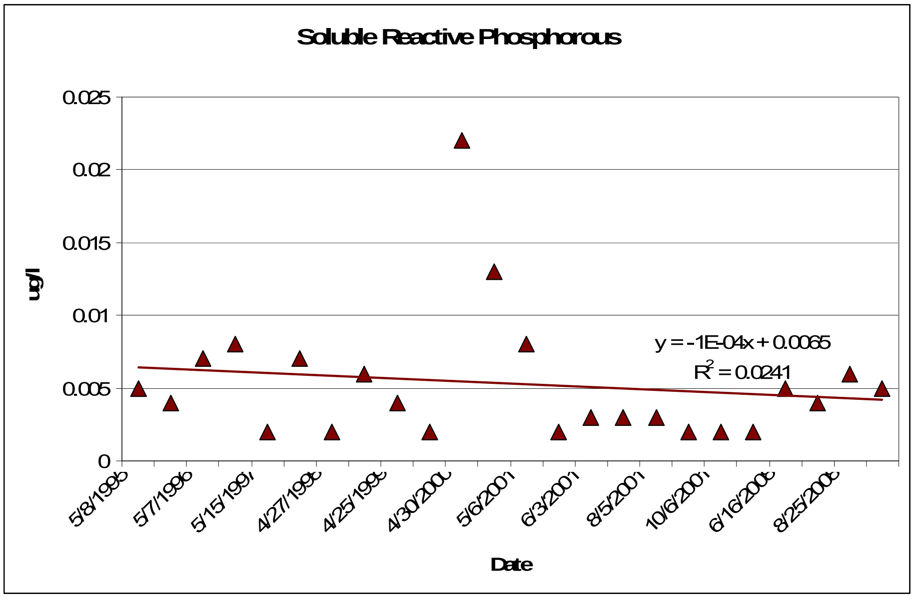
In-lake water quality

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.

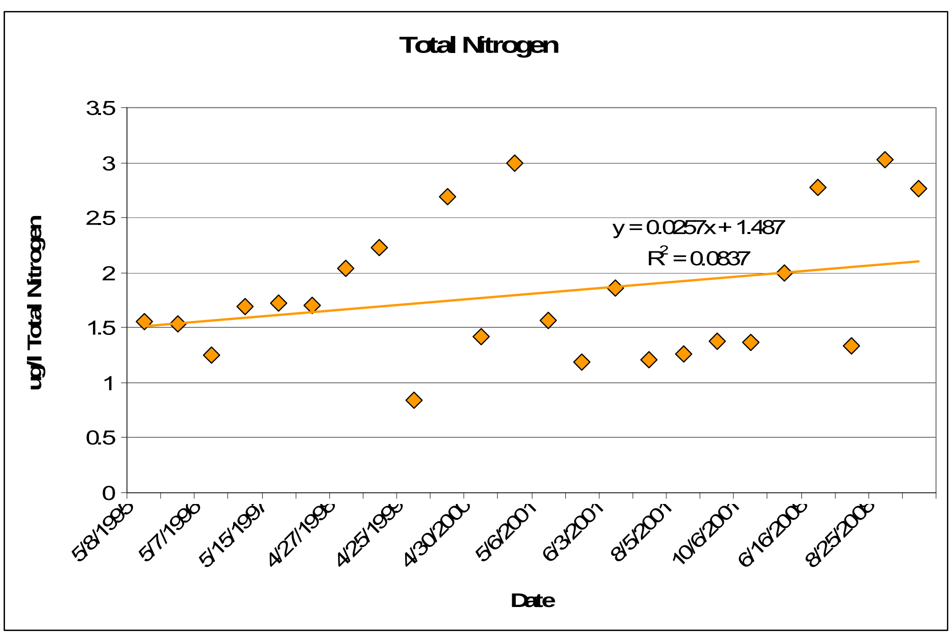
Total phosphorus concentrations in Wild Goose Lake averaged 0.046 mg/L, ranging from 0.039 to 0.054 mg/L in 2008. Total phosphorus includes phosphorus bound in plant and algae matter, suspended in the water column attached to fine particles, and dissolved in the water column. It is an indicator of how much phosphorus is in the system. The 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. Total phosphorous has been collected on Wild Goose Lake intermittently since 1995. When compared to the 2008 data the trend shows that the phosphorous level in the lake has been almost constant. However there are gaps in the data and the association should consider collecting basic water chemistry data so the lake's nutrient budget can be updated as needed.



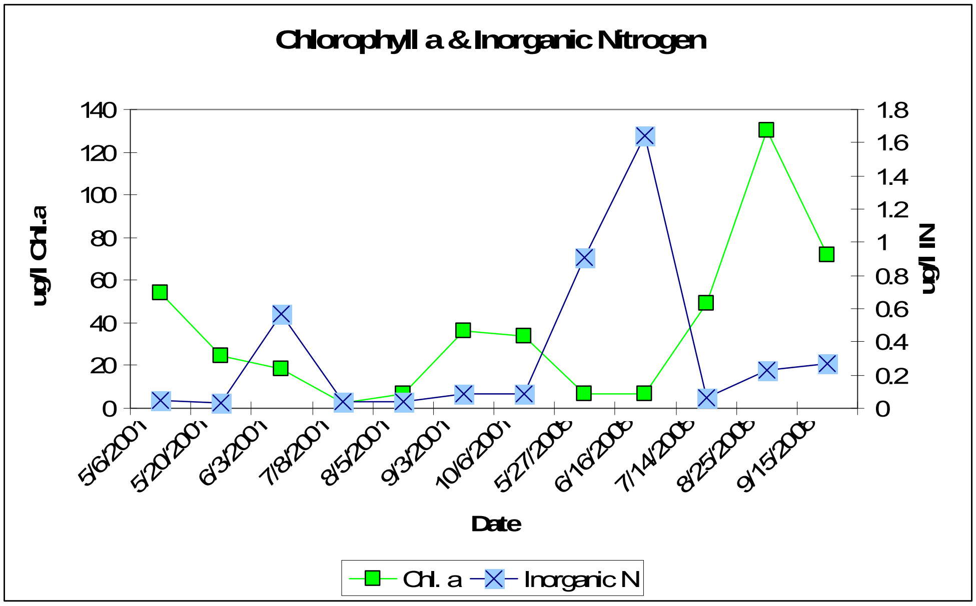
The soluble reactive phosphorus (SRP) is only the dissolved portion of phosphorus that is readily available to plants and algae. Wild Goose Lake averaged 0.004 mg/L SRP with a range from 0.002 to 0.006 mg/L, very stable and almost constant, as it has been since 1995. There are a couple of outliers from 2001 and years of missing data, so again collecting basic water should be done in order to keep the lakes nutrient budget up to date.



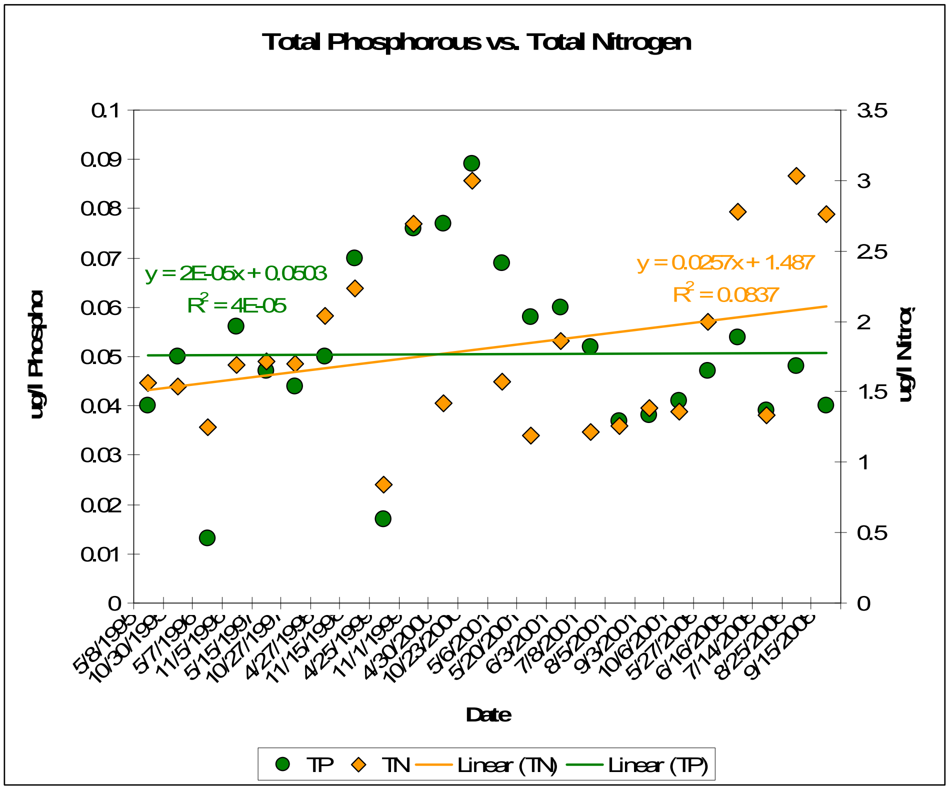
Nitrogen was also analyzed. The most abundant form of nitrogen found in Wild Goose Lake was Total Kjeldahl nitrogen (TKN) at 2.21 mg/L. Kjeldahl nitrogen is organic nitrogen plus ammonium. Subtracting the ammonium concentration from TKN gives the organic nitrogen found in plant and algae material in Wild Goose Lake (1.76 mg/L). The two forms of nitrogen (nitrite-nitrate and ammonium) that are readily available were at 0.23 and 0.45 respectively. Because Wild Goose Lake has also been collecting nitrogen data since 1995 and total nitrogen appears to be rising slightly, it raises the question whether algae are driving the nutrient conditions in the lake rather than vice versa.



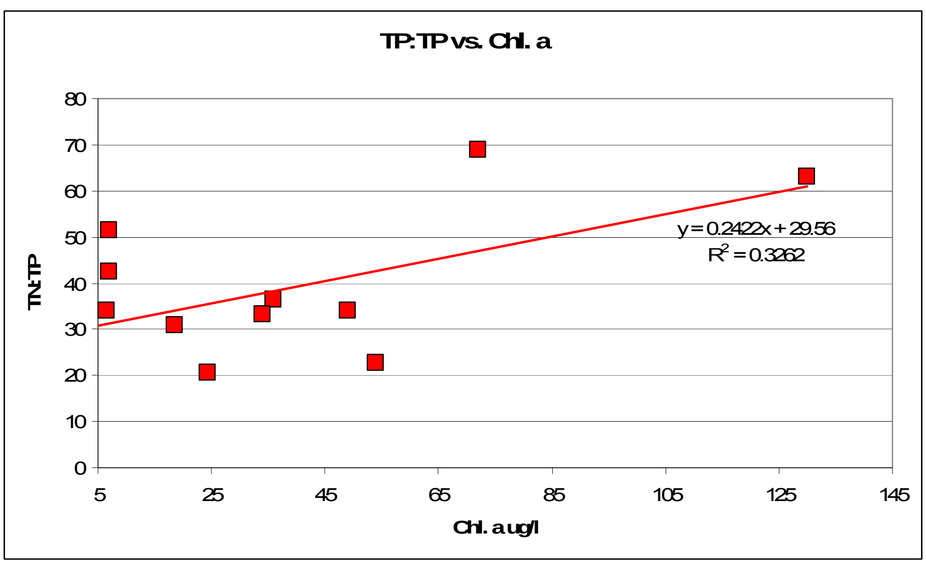
It is know that as algae increases the concentration of inorganic nitrogen decreases, and it did in Wild Goose Lake; the concentration of inorganic nitrogen went from 1.64 mg/l to 0.36 mg/l by the end of the growing season. This could be a climactic condition based on the drought, or a symptom of a lake 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 (Dr. Mark Edlund personal communication). The low alkalinity does explain the sensitive aquatic macrophyte community that will be discussed in another section.



Generally, phosphorous is considered the limiting nutrient in Northwest Wisconsin lakes. However, nitrogen appears to have a large influence on 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 saw ratios of 69:1 in 2008. Historically the lake has been closer to 30:1. Meanwhile, the total phosphorous appears to be going down very slightly, possibly due to the lack of runoff, or the holes in years of data collected.

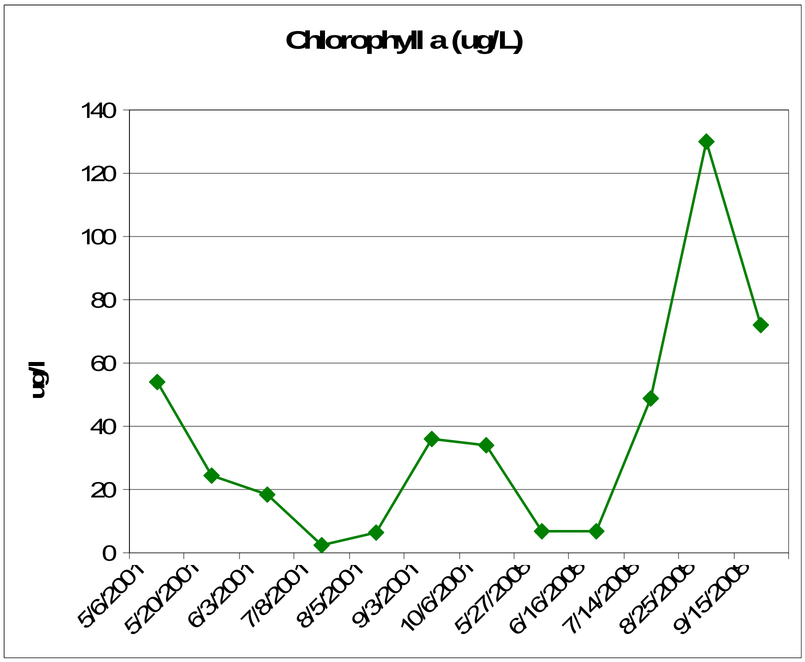


This supports the idea that the blue-green algae are likely fixing nitrogen from the atmosphere and their cell tissue was incorporated into the samples as can be seen in the TN:TP v. chlorophyll a graph. Therefore, the association should continue to monitor both nitrogen and phosphorous to get a long term tend of this data, and possibly predict when the lake may bloom.

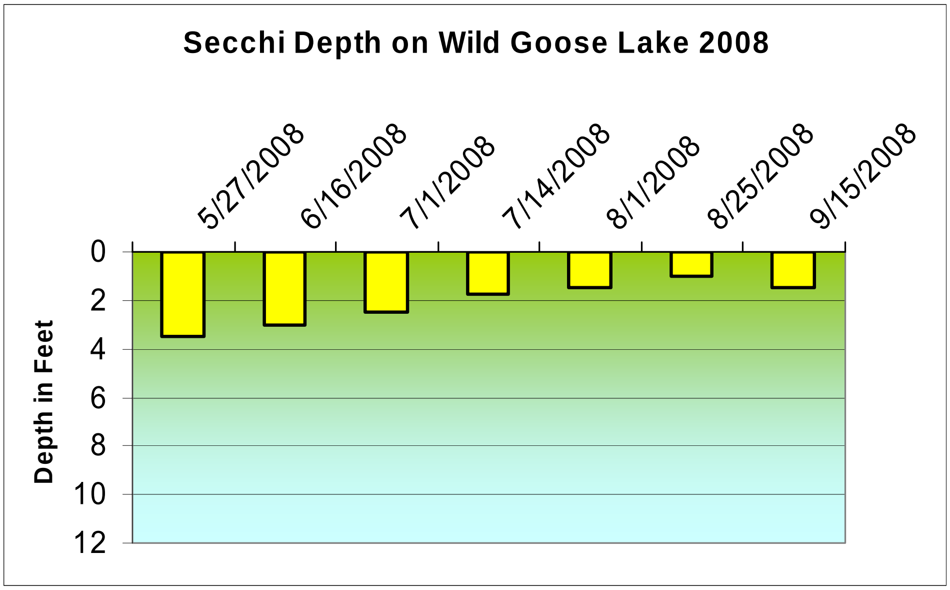


The total suspended solids were negligible, but did increase slightly with the algal blooms.

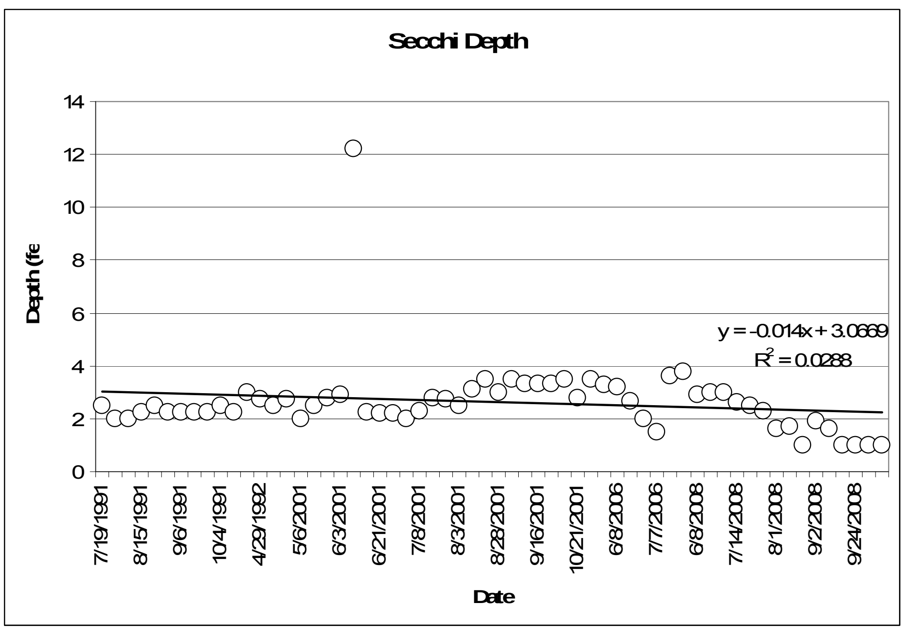
The average chlorophyll a concentration in Wild Goose was 53 mg/l. However the concentration was only 7 mg/l in May and June, and spiked to a very high 130 mg/l by the end of August. There was only a slight spike in 2001. While chlorophyll *a* gives a general indication of the amount of algae growth in the water column, it 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 sediment resuspension by wind and boats. Chlorophyll a is an 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 in 2008 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 1991. However, it does appear that the secchi depth is dropping slightly while the chlorophyll a is rising. Again, there are years missing and constant monitoring should be done.

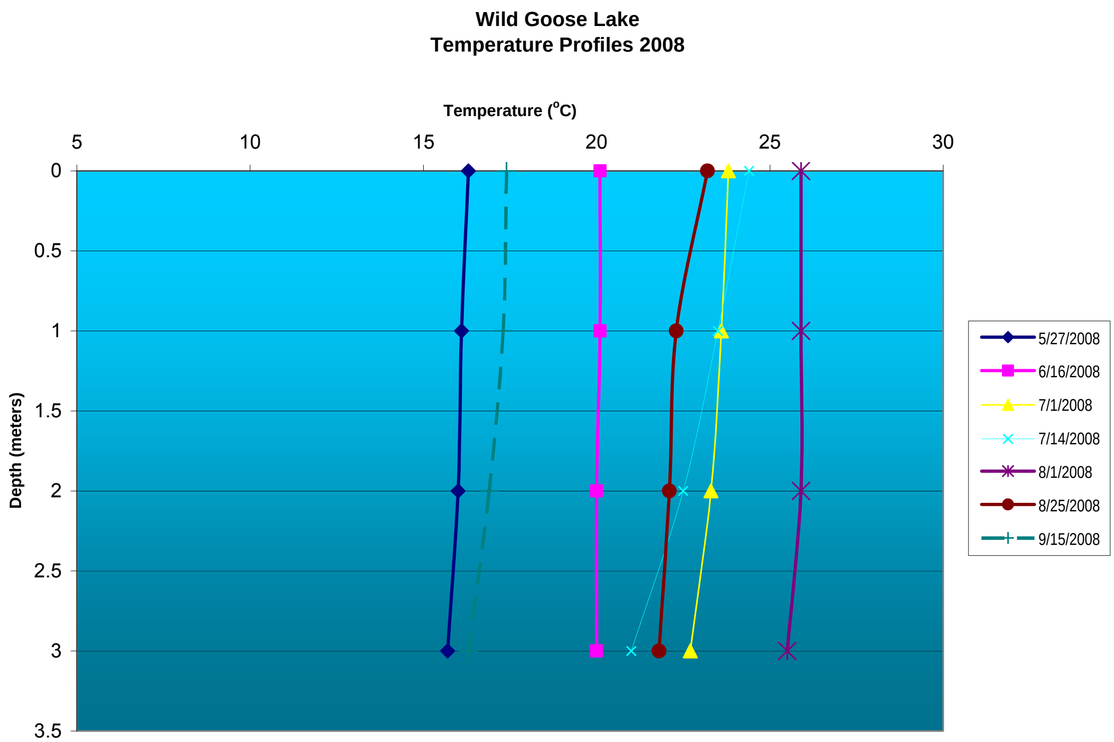


Water column profiles

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.

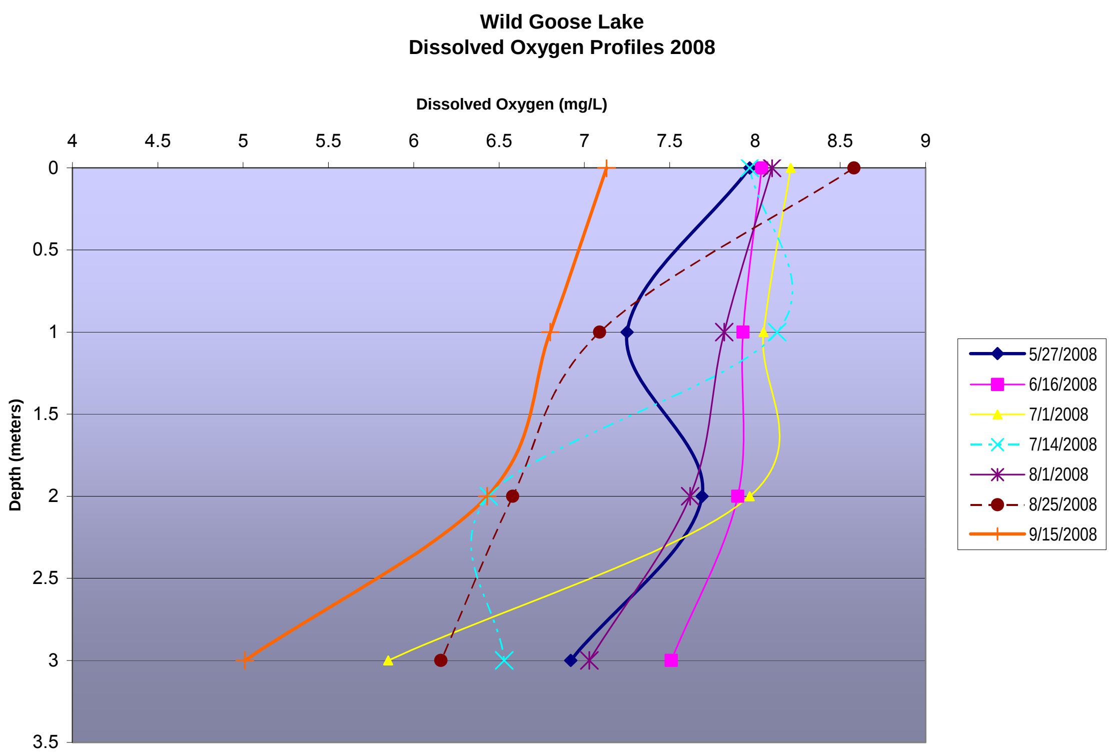
The profile of Wild Goose Lake was taken at the deepest point approximately every two weeks May through September. Using a YSI 85 multi-parameter probe; temperature, dissolved oxygen, conductivity, and salinity readings were recorded at each meter of water depth. The temperature and oxygen profiles of 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 °C on August 1, 2008. The coldest, measured lake water at the surface was 16.3 °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.

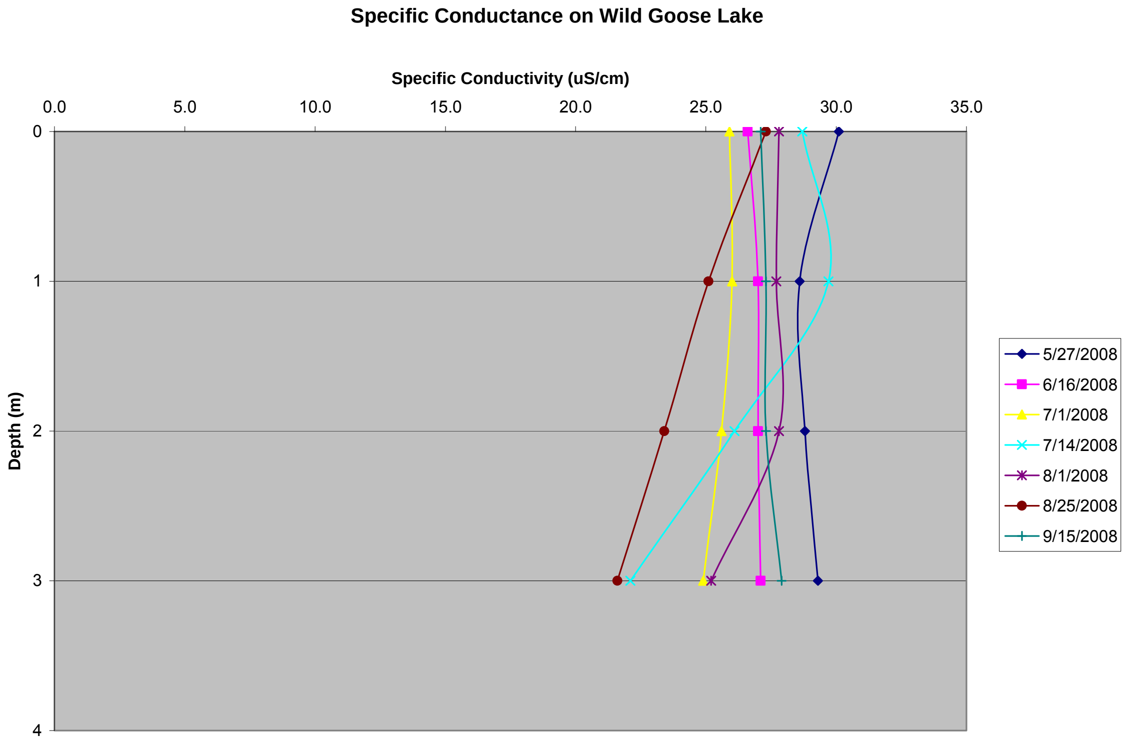


Wild Goose Lake has a mixed water column that does not stratify throughout the summer. The lake does not develop water temperature (thus density) differences that create distinct layers in the water column; wind and wave action are able to mix the water of the lake. The constant mixing of lake water 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.

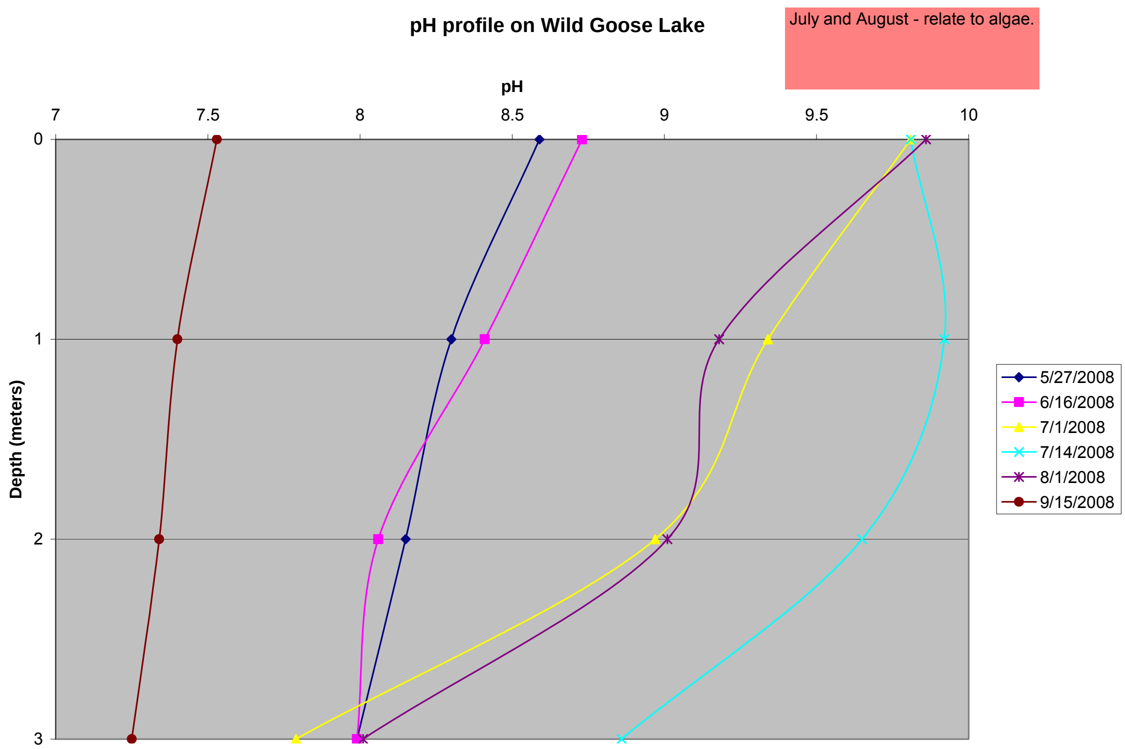
The oxygen profile of Wild Goose Lake throughout the 2008 growing season is graphed below. The oxygen concentration ranged from 8.58 to 7.13 mg/L at the surface. The oxygen concentrations at the bottom of the lake (at 3 meters depth) ranged from 5.01 to 7.51 mg/L. As temperature rises, the ability for 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.

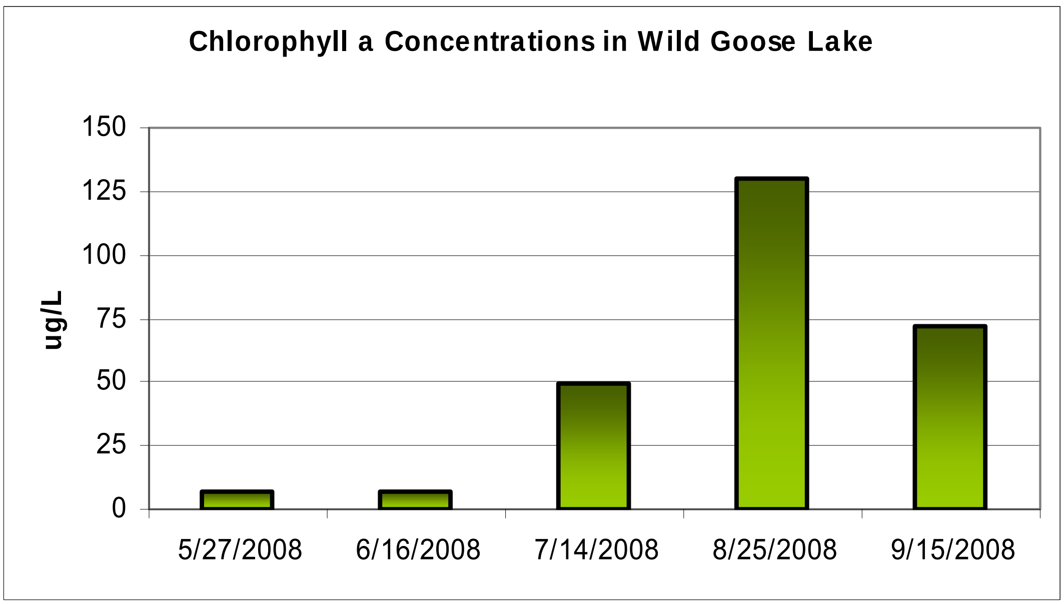


pH profiles were also taken on Wild Goose Lake using a YSI 60 pH meter. Algae can cause the pH of a system to increase as it depletes the bicarbonate in the lake (of which Wild Goose has very little). As can be seen on the chart below, June, July, and August, has a surface pH higher than the rest of the samples taken. June is when blue-green algae start to appear in significant numbers and they become to dominant group by July and August. 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. pH can be an indication that an algae bloom is about to occur and having in situ data can prepare residents for that occurrence. Also, this data can help prioritize when algae sampling should occur.

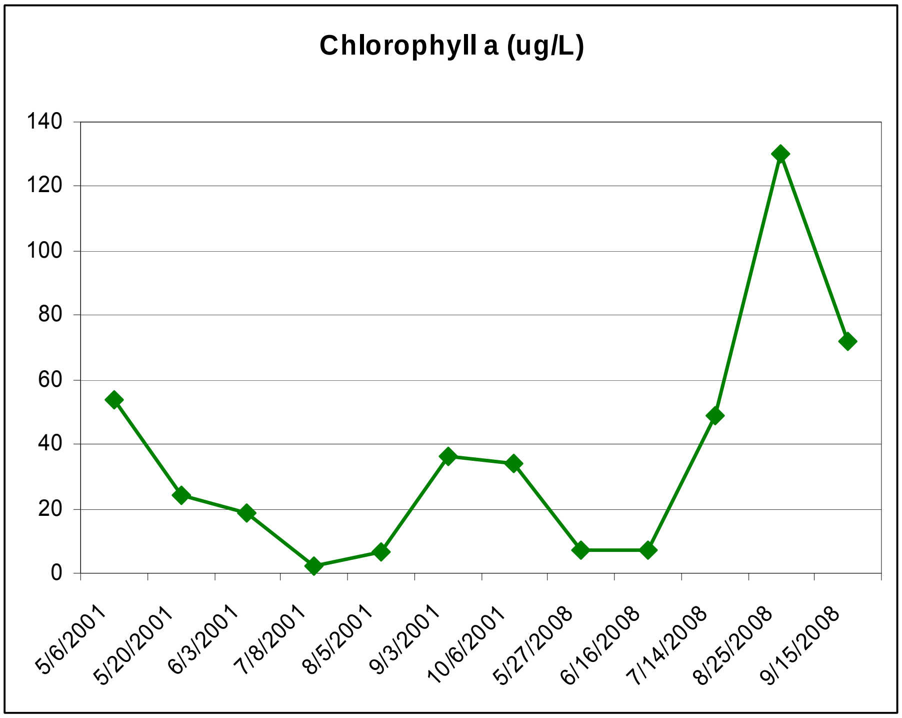

pH profile on Wild Goose Lake
July and August - relate to algae.
pH
7
7.5
8
8.5
9
9.5
10
0
1
2
3
Depth (meters)
5/27/2008
6/16/2008
7/1/2008
7/14/2008
8/1/2008
9/15/2008

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.



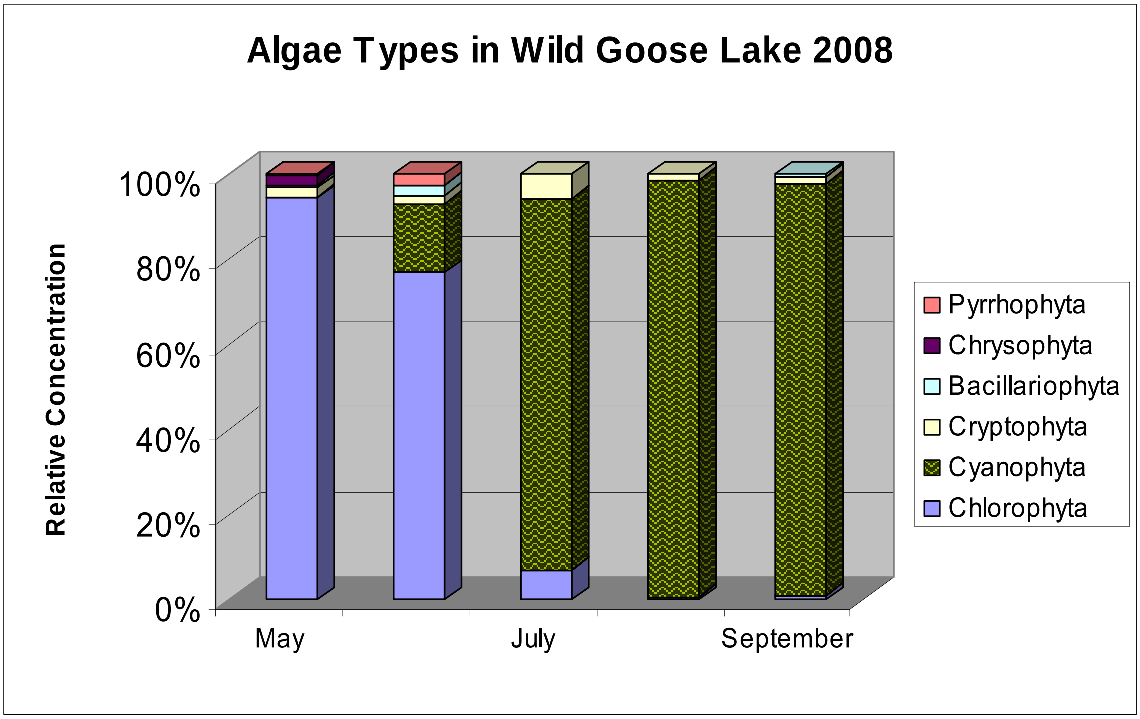
None of the chlorophyll a data in 2001 is anywhere near the 130 µg/l seen in 2008, likely because of the concentration of different algae classes. Different algae classes have different concentrations of pigments. So, for example, if the system where dominated by diatoms there would be a much different chlorophyll a concentration than if it was dominated by blue-green algae.



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.

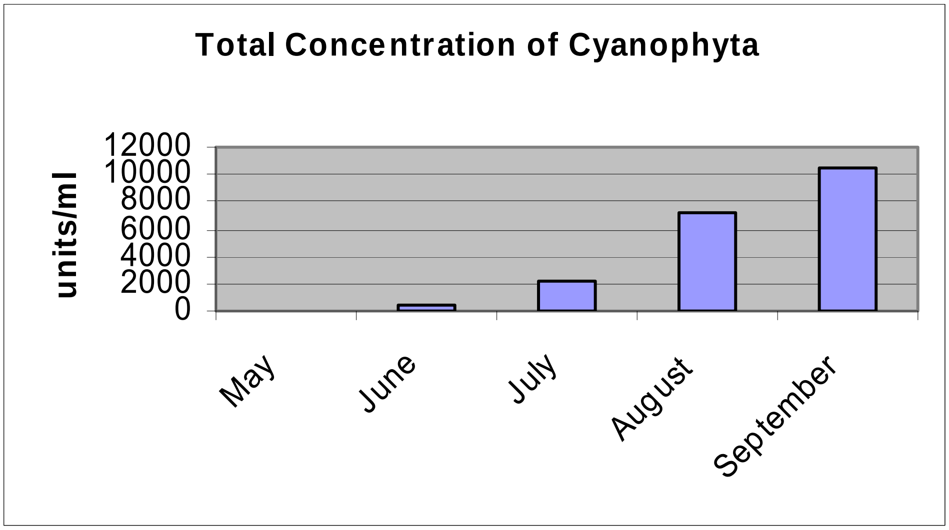
The species composition of algal communities change seasonally in response to light, temperature, nutrients, grazing by zooplankton, and rain events; in Wild Goose Lake, these factors changed the water conditions. The September sample had a decreased chlorophyll a concentration, as well as, TP concentration, 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 maintain the aquatic plant community, 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 possibly 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.

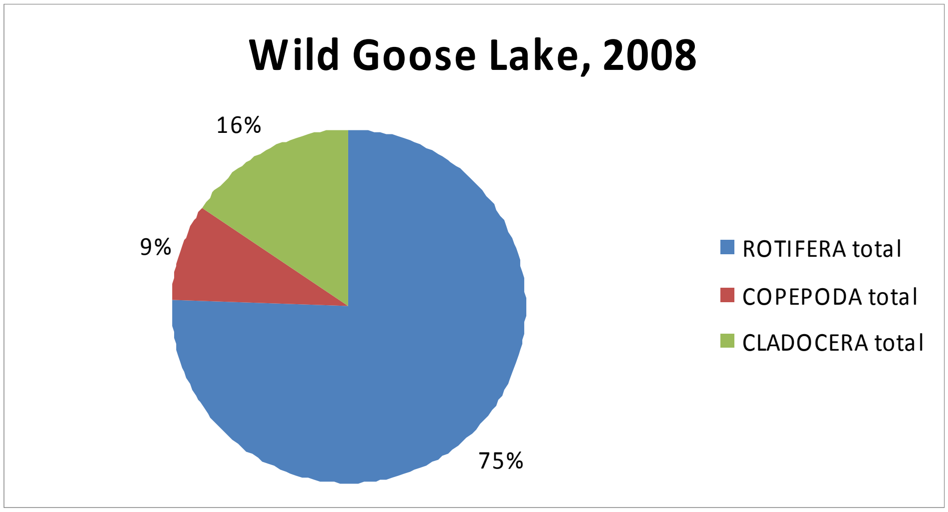


On Wild Goose Lake, there was one sample (September) where blue green algae concentrations were above 100,000 cells/ml. August had a concentration of 7251. While concentrations over 100,000 units per ml are capable of producing toxins, we do not know why or when this will occur. If blue-green blooms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

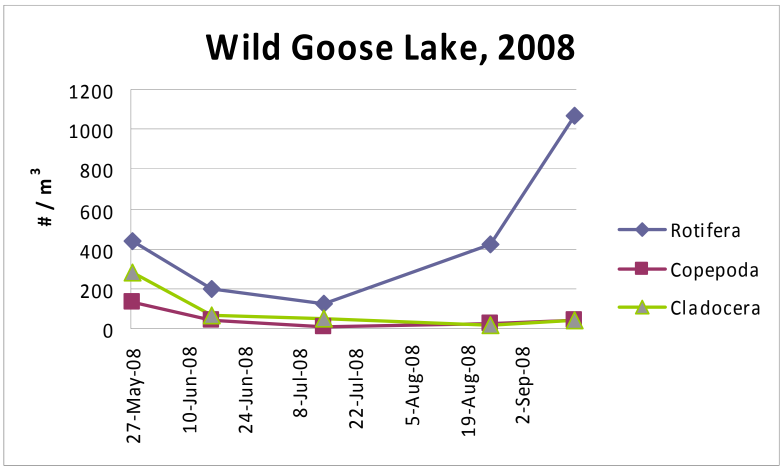
Zooplankton

Zooplankton 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 an algal bloom 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 the Wild Goose Lake fishery is at.

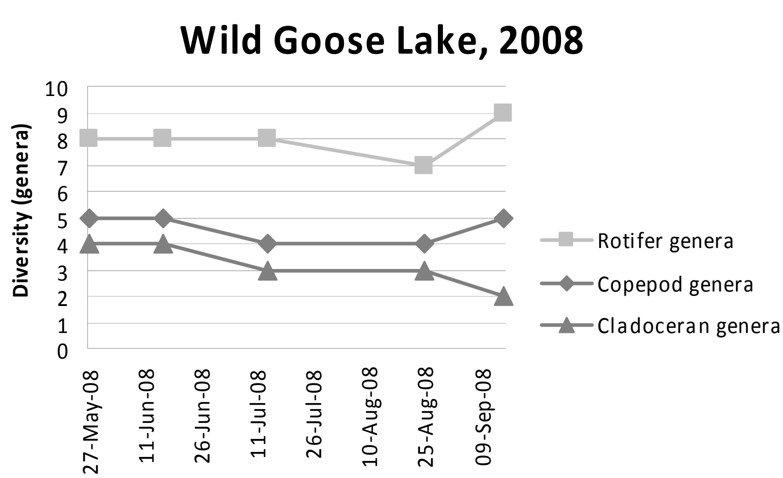
Zooplankton also responds to changes to lakeshore and littoral zone community. Changes in aquatic plants, and shoreland habitat impact plankton either directly or indirectly (Lafrancois 2009), especially in shallow lakes where zooplankton likely have to migrate horizontally to avoid predation from fish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



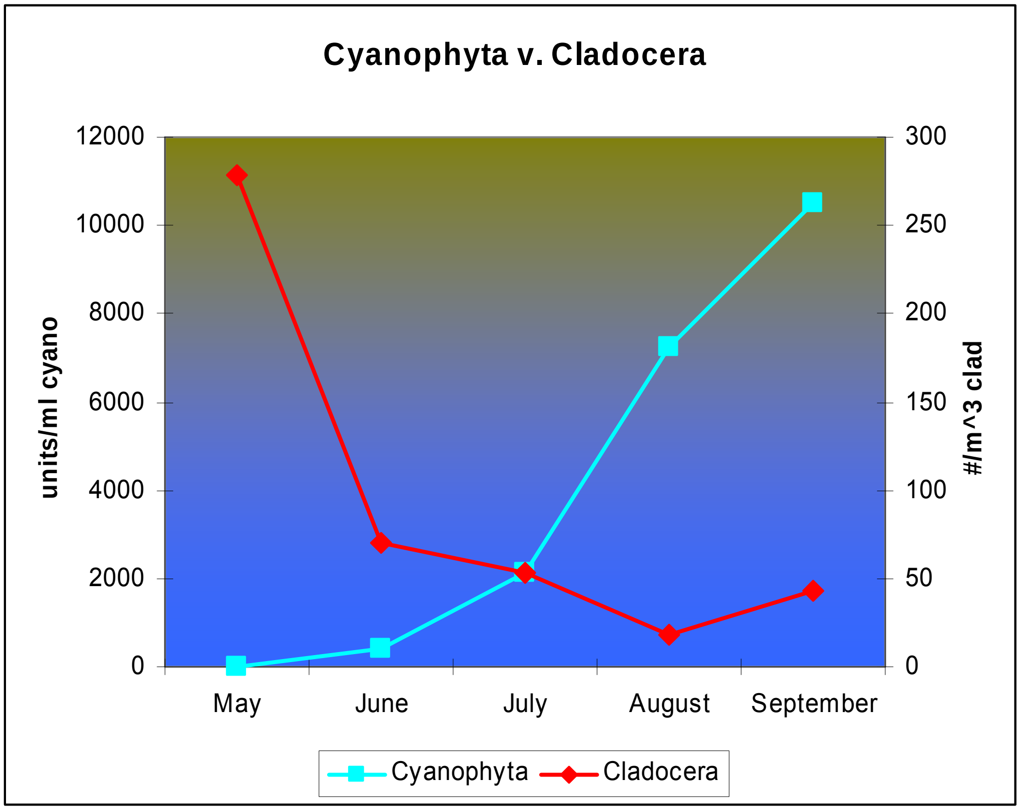
The three primary components of the zooplankton community are rotifers, copepods and cladocerans. Rotifers are size selective omnivores that eat algae, zooplankton and sometimes each other; they are not capable of reducing algal biomass. Copepods are also size selective omnivores, and are heavily preyed 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.



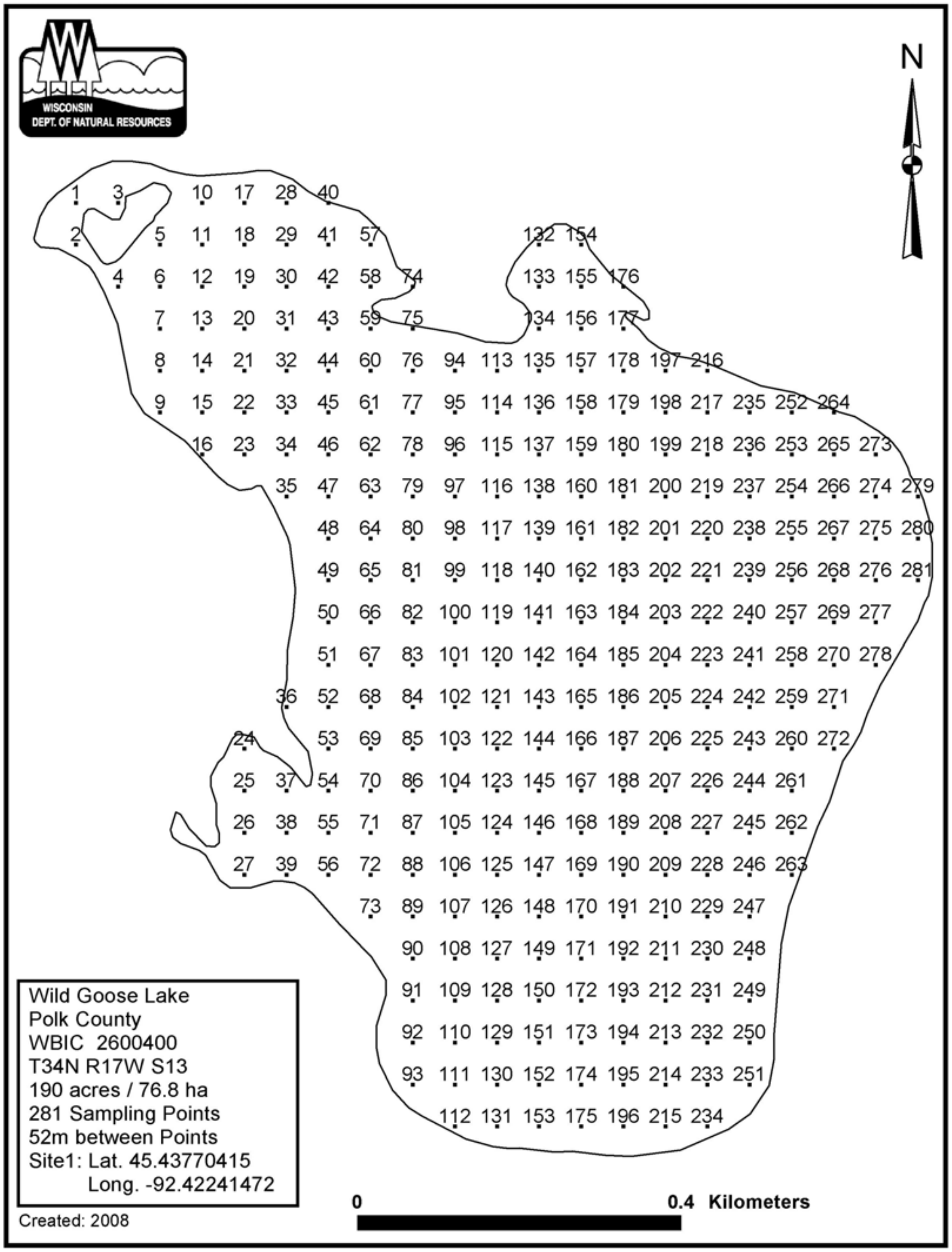
If blue-green algae blooms persist it could severely alter the zooplankton community of Wild Goose Lake. As the concentration of cyanobacteria rose in 2008 the cladoceran community crashed. It is generally assumed that cladocera do not like colonial cyanobacteria and the most abundant species in Wild 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.

Rating	Coverage	Description
1		A few plants on rake head
2		Rake head is about ½ full Can easily see top of rake head
3		Overflowing Cannot see top of rake head

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:

Frequency of occurrence for each species- 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.

<u>Relative frequency</u>-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.

<u>Sample sites with vegetation</u>- 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:
<u>Frequency sampled</u>
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).

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

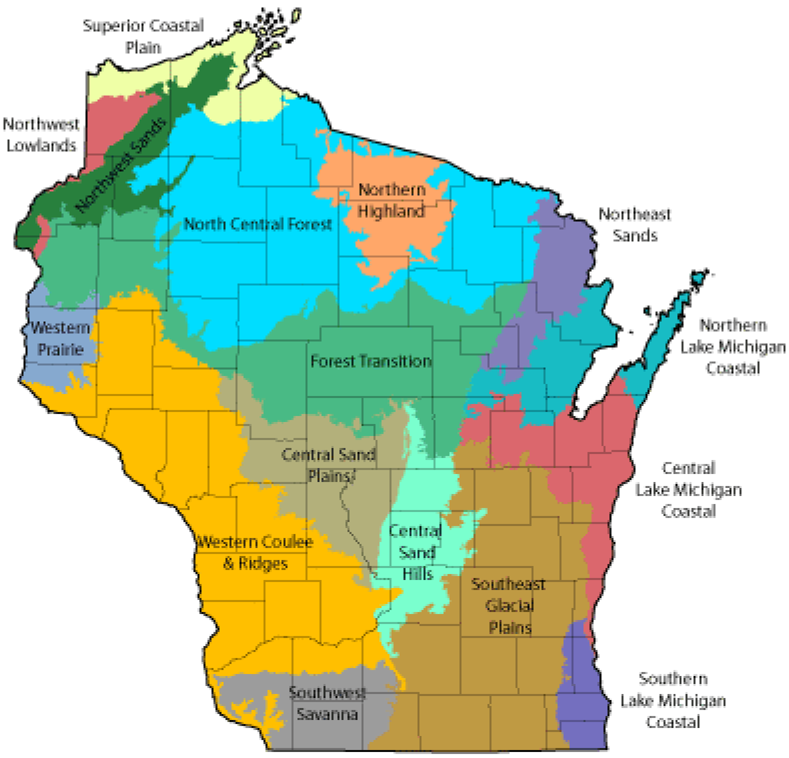
Where D = Simpson's Diversity, n= the total number of organisms of a particular species, N=the total number of organisms of all species.
To measure how diverse the plant community is, Simpson's index is calculated. This value can range from 0 to 1.0. The greater the value, the more diverse the plant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

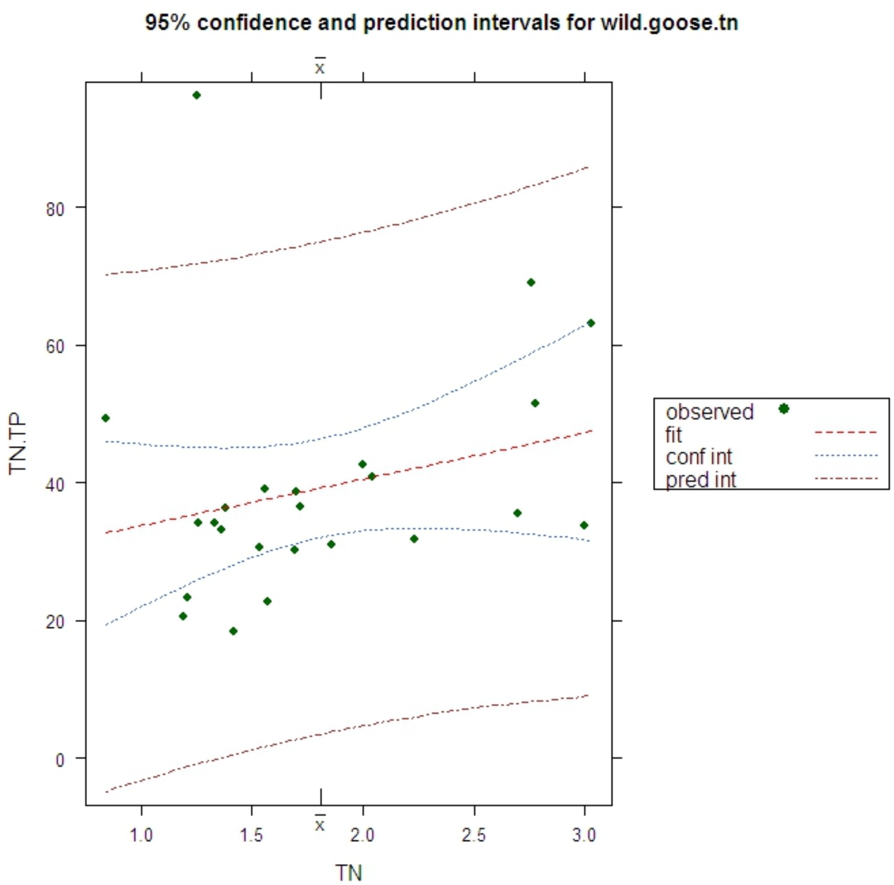
Based on the data collected the aquatic macrophyte community of Wild Goose Lake is extremely sensitive and is likely a barometer of the lakes health. Wild Goose has a very low alkalinity and almost all of the plant observed have a very narrow range of alkalinity and pH where they are found. Additionally 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

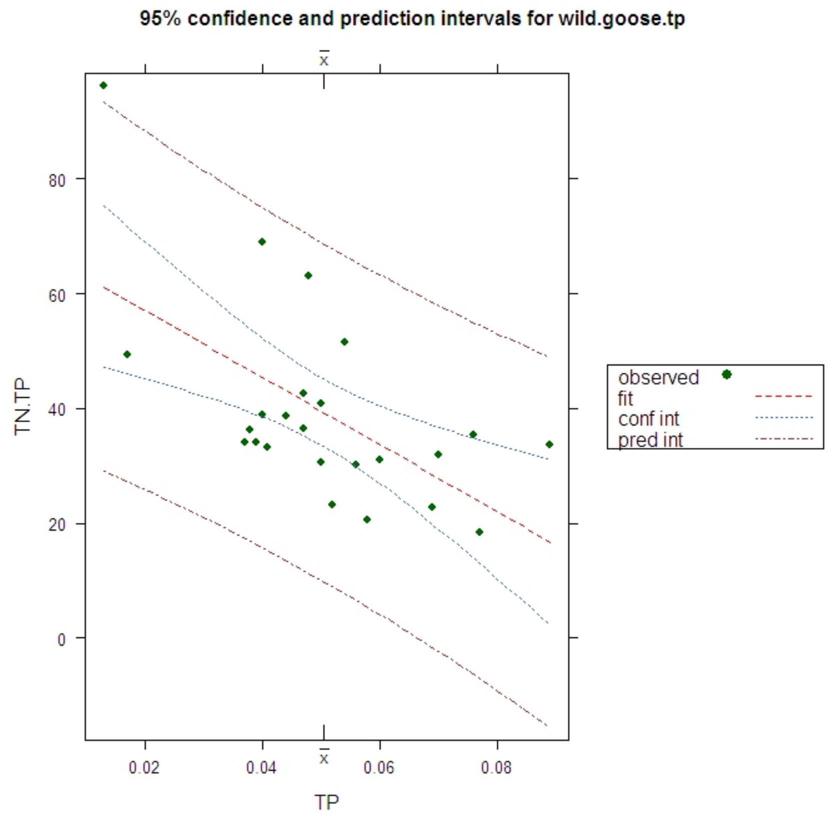
Wild Goose is a soft-water lake which is relatively rare in this part of the state. This makes Wild goose Lake more susceptible to change than other lakes with in the county.

During the 2008 sampling season the average total phosphorous was 46 parts per billion. Anything over 30 parts 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 a health concern yet.

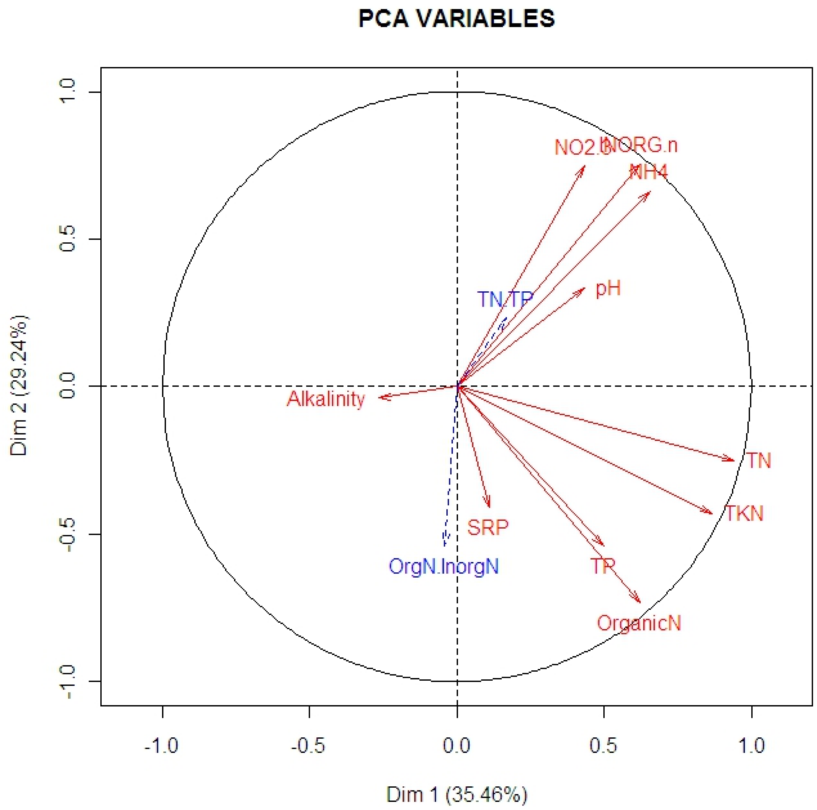
Because it was an especially dry, sunny summer, the blue-green algae are likely using the available phosphorous from the internal loading. It appears as though the nitrogen content of the lake is increasing. Using the statistics program R the confidence interval was plotted. The statistics show a pretty good fit for the increase of total nitrogen in relation to the TN:TP ratio. The association monitored nitrogen regularly before the 2001 study and should consider monitoring the basic limnological nutrient suite on an annual basis in order to get a long-term trend and adjust the nutrient budget as needed.



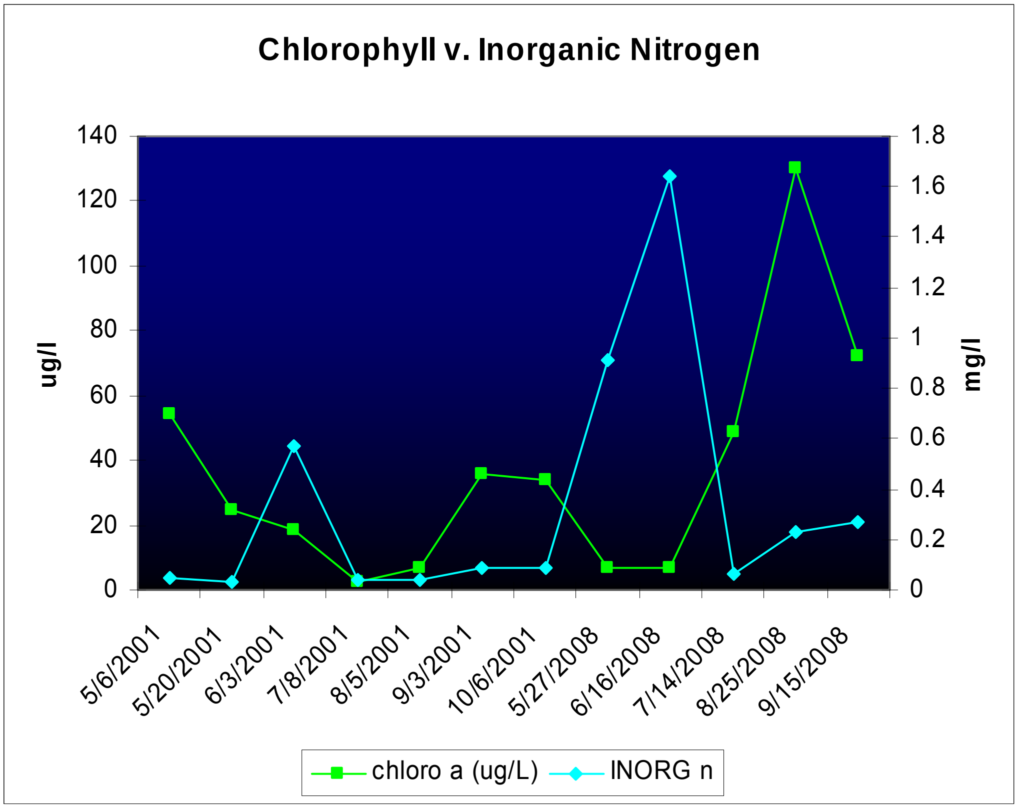
The total phosphorous did not show as tight a correlation, that is there was not as many data points within the 95% confidence interval (however they where all in the prediction interval), with the TN:TP ratio, again suggesting that monitoring the whole nutrient suite, is probably needed for Wild Goose Lake.



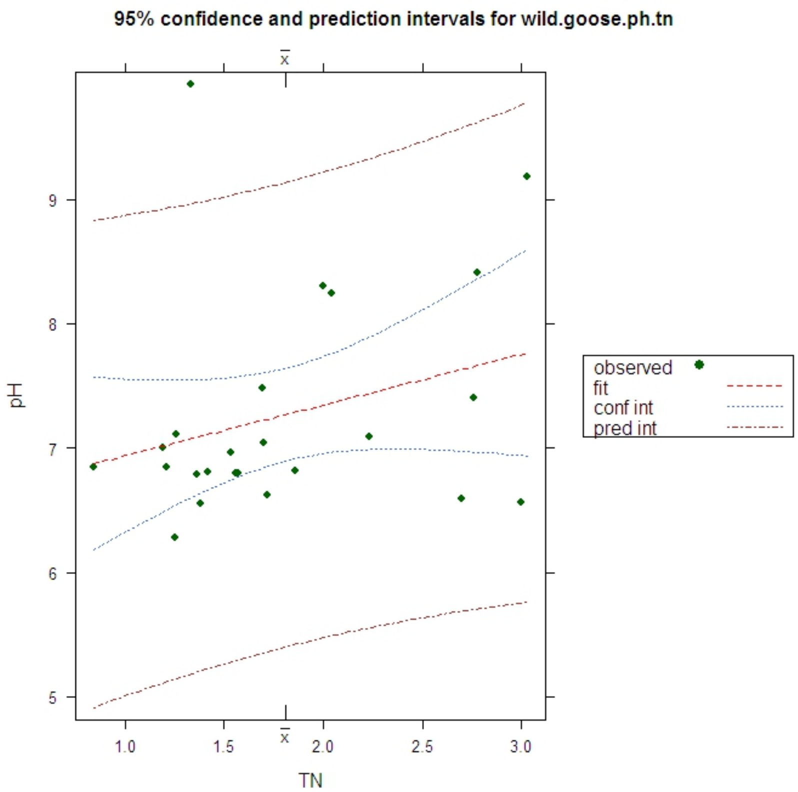
When eigenvalues (eigenvalues are a set of scalars associated with a matrix equation) are calculated and plotted for all variables in a principal component analysis you can see that the total phosphorous and organic portion of the nitrogen is closely related. However, the TN:TP ratio is correlated with the nitrogen that is readily utilized by algae and pH again suggesting that when blue-greens dominate the system they cause a nitrogen load. The available evidence supports this (the first two dimensions account for 65% of the gradients); however more monitoring will be needed to verify.



The data suggests the increase in nitrogen could be 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 increase the inorganic portion of nitrogen decreases while total nitrogen increases, and this is what we saw.



Again using R the pH was plotted against the total nitrogen. As algae increase in abundance pH usually rises in a lake (see the algae section of this report). Again the statistics show a very good correlation of rising pH against the total nitrogen suggesting that when there is drought conditions the blue-green portion of the algal community have a competitive advantage because of their ability to fix nitrogen.



Algae may be an important barometer of Wild Goose Lake's health. 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 and management options could be adjusted accordingly.

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 a colonial blue - green algae and is the dominant algae in August and September, just as the cladocera collapse. 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 a barometer of the lakes health. The plant community more closely resembles a soft-water lake in than typical Polk County lakes. Extreme care should be taken to reduce any human induced sedimentation. Loss of the aquatic plant community in Wild Goose Lake would be very detrimental to the system.

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. Hence, the algae, zooplankton, and aquatic macrophytes should continue to be monitored with the nutrient suite.

Wild Goose Lake is a Natural Heritage Inventory Water (NHI) and is considered an Area of Special Natural Resources Interest (ASNRI). The lake is of special interest because of the eagles that nest there year after year and ospreys that frequent the lake. Residents have monitored the eagles for many years and should continue to do so.


Eagle nest and fledgling north side Wild Goose Lake 2008

Eagles and osprey likely frequent the lake because of the fishery and the riparian habitat. As stated earlier in this report, there is a significant portion of the shoreline that is not developed and is in a natural state. The forested riparian areas provide perch and nesting sites for the eagles and osprey and fallen trees and course wood that fall into the littoral zone provide habitat, and indirectly food, for young fish as well as beneficial invertebrates such as dragonflies and mayflies. Efforts should be made to acquire development right or property in order to protect the undeveloped riparian area.

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 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.

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. A sediment core could also be used to predict when blue-green algae blooms may occur through the use of fossilized pigments and geochemical proxies.

Apply for grants for the association to acquire undeveloped land, but development rights, or conservation easements. This habitat is critical for both eagles and osprey as well as other avifauna. In addition the coarse woody habitat that forested buffers provide for fish and invertebrates make natural riparian areas very valuable to lake ecosystems.

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 Wild Goose Lake is a Natural Heritage Inventory Water (NHI) and is considered an Area of Special Natural Resources Interest (ASNRI) the association should work with DNR fisheries biologists and the Polk County LWRD to establish Critical habitat areas in the lake's littoral zone. This will not only provide habitat for fish and invertebrates, but protect the sensitive aquatic plant community.

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. Preventing sedimentation to the lake will help protect the sensitive aquatic plant community and fish spawning areas.

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. These practices will limit additional nutrients from entering the lake and help keep algal blooms in check.

New residents should be alerted of local Zoning laws to prevent misunderstandings and violations. As stated above sedimentation and additional nutrients harm the ecological status of the lake.

No phosphorus fertilizers shall be applied in shoreland areas of Polk County. Additional phosphorous from fertilizers could trigger additional algae blooms.

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

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 to protect littoral zone and riparian habitat.

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. The addition of invasive species such as Eurasian water milfoil or zebra mussels will disrupt the lakes ecosystem and be drivers of change, biological and possibly trophic status.

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Appendix A

Pontoon Classroom

A pontoon classroom was held for Wild Goose Lake Association members on July 11th, 2009. Residents were shown zooplankton and algae in a field microscope, chironomids from a dredge sample, aquatic macrophytes and limnological monitoring techniques.

Discussing bladderwort north end of Wild Goose Lake

Focusing on algae for residents to observe


Explaining algae enumeration


Chironomus sp**. from a mid-lake dredge sample**

Appendix B

Zooplankton Report

ZOOPLANKTON OF WILD GOOSE AND WARD LAKES, POLK CO. WI, 2008.

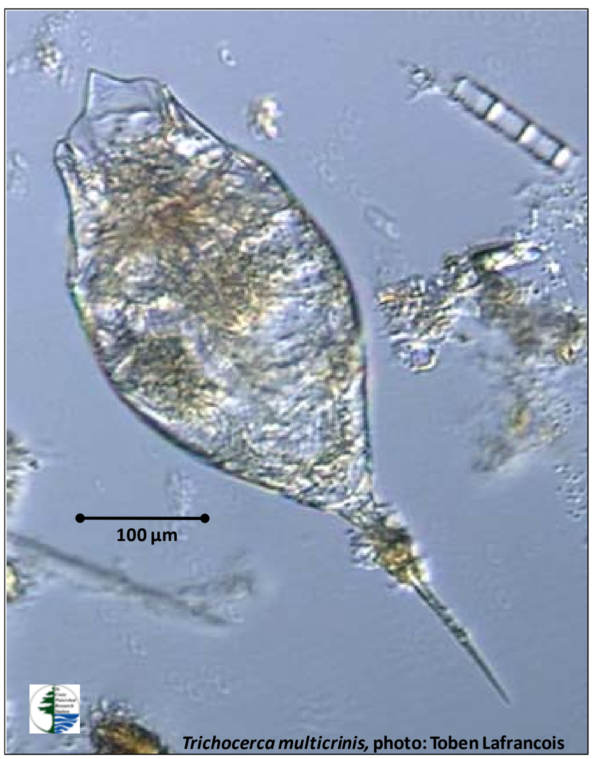
Toben Lafrançois, PhD.

Research Associate

St. Croix Watershed Research Station

Science Museum of Minnesota

March 2009



Trichocerca multicrinis, photo: Toben Lafrancois

Suggested reference: Lafrancois, T. 2009. Zooplankton of Wild Goose and Ward Lakes, Polk Co. WI, 2008. Final report to Polk County Land and Water Resources Dept., March 2009.

EXECUTIVE SUMMARY

Zooplankton form a critical link between bottom-up and top-down processes in lakes. They are voracious consumers of algae and bacteria, and are also a favorite fish food of planktivorous panfish, minnows and fry of larger fish. In this way, zooplankton connect two of the most important features of lake management- water clarity and fishing. Examining zooplankton community composition, abundances, and presence of sensitive or tolerant organisms is like looking under the hood of a car because it shows how important lake processes are mechanically connected.

Zooplankton were sampled monthly from May to September of 2008 from Ward and Wild Goose Lakes, Polk County, Wisconsin. Vertical tows were taken at the deepest point of each lake. Organisms were counted and enumerated at the St. Croix Watershed Research Station, Marine on St. Croix, Minnesota.

Basic analysis shows that the zooplankton in both lakes are characteristic of eutrophic lakes with high predation by planktivorous fish. Zooplankton diversity and abundance in Ward and Wild Goose Lakes were both dominated by rotifers (the smallest zooplankton, tolerant of fish predation). Several species present are tolerant of eutrophication. The lakes had similar communities in spring, but diverged over the season. Wild Goose had significantly more cladoceran (water flea) genera ($p = 0.011$), but significantly lower overall zooplankton density ($p = 0.036$). Larger copepods and cladocerans were present but rare. Presence of some larger species in low numbers indicates good potential for a more robust zooplankton community (more capable of mitigating algal blooms).

It is difficult to infer more about zooplankton based on a single tow per lake per sample because zooplankton are notoriously patchy. Stability of taxa found over time indicate that these data are suitable for cluster analysis along environmental gradients to determine driving factors in these two lakes. Interpreting the current state of these lakes requires reference conditions from historical data like diatom and zooplankton analysis in sediment cores to determine lake states pre-settlement.

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INTRODUCTION AND METHODS

ZOOPLANKTON BACKGROUND INFORMATION

Zooplankton are small aquatic animals (specimens from this study range from 0.03 mm long to 3 mm long). Three primary components of the zooplankton community are rotifers, copepods, and cladocerans. Single celled organisms were not found in this survey, most likely due to over-dessication in sample preservative. Organisms of the phylum Rotifera are either soft-bodied or have a hard lorica (shell). All rotifers have mouthparts with bristles that undulate like two little wheels, giving this group their name. Rotifers are small, ranging from 0.03 mm to 1.00 mm long, depending on the species. They are size-selective omnivores that eat algae, protozoa, and sometimes each other. Rotifers are preyed on by other plankton but only incidentally by fish. Some have long spines or gelatinous sheaths to deter predators.

Copepods are crustaceans (phylum Arthropoda, subphylum Crustacea) of two orders (Calanoida and Cyclopoida). Other orders of copepods are benthic (live in the sediments) or parasitic on fish and are not usually included in studies of plankton. Copepods are multi-segmented animals that are size selective omnivores, eating algae and other plankton. Some have more specific feeding habits. Copepods are highly variable in size, depending on the species, ranging from 0.3 mm to 3.0 mm long (and even larger in some cases). They can be eaten by larger plankton and are a favorite fish food (either planktivores like pan fish and minnows or fry of larger fish).

Cladocerans are also crustaceans (phylum Arthropoda, subphylum Crustacea) of similar size range than copepods but very distinct morphologically. Cladocerans filter-feed by creating a current with fan-like legs protected by a hard but un-segmented carapace. Most cladocerans are parthogenetic, females producing clonal eggs. Males are produced in times of environmental stress and sexual reproduction occurs for one or two generations. Cladocerans are voracious consumers of algae and are also a favorite food of fish.

Zooplankton are often an overlooked component of aquatic systems, but their role in ecosystem function is extremely important. Lake systems are valued primarily for water clarity and fishing or other recreation. Both of these values are strongly linked to water quality and ecosystem health. Zooplankton are the primary link between the ‘bottom up’ processes and ‘top down’ processes of the ecosystem. Bottom up processes, like increased nutrients, can cause noxious algal blooms. Zooplankton can mediate these blooms by heavy grazing. On the other hand, shifts in algal composition caused by increased nutrients can change zooplankton community composition, exacerbating algal blooms and stressing planktivorous fish and / or the development of fry. Top down processes include fish predation, where increased planktivorous fishes (e.g. pan fish) can drastically reduce zooplankton populations and lead to algal blooms. In some lakes a trophic cascade is used to manage this effect, using piscivorous fish to reduce planktivorous fish populations, increasing plankton to reduce algae— and consequently improving water clarity.

Zooplankton also respond to changes in watershed and lakeshore management. Changes in aquatic plants, landscape use in the watershed, and buffer zones around a lake impact plankton directly or indirectly. Understanding the plankton in a lake (both algae and zooplankton) is like looking under the hood of a car, showing the mechanisms that connect lake management, ecosystem effects, water clarity, and fishing.

METHODS, FIELD SAMPLING

Zooplankton were sampled from Ward Lake and Wild Goose Lake in 2008 by Polk County personnel. Samples were taken monthly from May to September. At the deepest point of each lake, a zooplankton tow net (54um mesh[1]) was lowered nearly to the bottom and drawn vertically to the surface at a constant rate. Samples were rinsed from the net into a collection jar and preserved in 80% ETOH for counting. The area of the net's mouth and the depth of the tow were recorded, allowing calculation of the volume of water each sample represents.

METHODS, LABORATORY

Zooplankton were identified at the St. Croix Watershed Research Station, Marine on St. Croix MN (a non-profit research branch of the Science Museum of Minnesota). Samples were rinsed in a 54um net and placed in Falcon centrifuge tubes with 30 to 35 ml of 80% ETOH (depending on the density of sample). The Falcon tube was vigorously agitated and sub-sampled with a 1ml Hempsten-Stempel pipette. This subsample was placed in a Sedgwick rafter cell for counting. Two samples (one from each lake) were sub-sampled six times and counted to assess the number of subsamples needed to get a) maximum taxa richness and b) numbers within 1 STD of the mean on a subsequent count. Ten out of twenty rows were counted (starting at row 1, skipping every other row). Three such sub-samples were counted for each lake sample except two from Wild Goose Lake (August and September) because only two were required to achieve reliable counts. Numbers were then converted to n/m^3 based on the Falcon tube volume and tow volume. The methods listed here reflect the particular conditions of these lakes and sampling design. They were tested for sufficiency but should not be reproduced in other systems without re-testing adequacy.

An Olympus BX50F4 Microscope was used for counting and digital pictures of whole organisms. The most widely accepted taxonomic keys were used (Balcer et al., 1984; Thorp et al., 1997; Smith et al., 2001) as well as online resources (U. New Hampshire, 2003). It should be noted that available keys are not always in agreement, and some contain errors. Complete taxonomic certainty requires further research including examination of live animals and several different preservation techniques not suitable for population assessment as performed here. Results from the present analysis will be consistent with other studies of zooplankton because these keys represent the best available taxonomy to date. A list of taxonomic certainty and related issues is shown in Table 1. Online images and keys are extremely useful but were taken with caution because not all taxa are represented in these keys and not all branches in the decision trees are taxonomically definitive. The online resources were used primarily as confirmation for particular species or genera that were considered represented with confidence by the source.

DATA ORGANIZATION AND COMMUNITY INDICES

Zooplankton abundances were converted to numbers per cubic meter (n/m^3), equivalent to 1,000 liters or 1.31 cubic yards (the SI name for this volume is the stère). Care should be taken when inferring total zooplankton population in a lake at any given time because the density is based on a single tow at one point and zooplankton are notoriously patchy in distribution. The numbers are robust for general comparisons over time, however. Stability of plankton community composition over sampling dates supports the inference that zooplankton abundances reported are representative of the larger community.

Zooplankton communities change naturally over the season (community phenology), so data were analyzed over time (a total of 5 monthly samples in 2008) and as a whole year mean for gross comparison with other lakes.

[1] Assuming a standard two net; this value could be 80 µm depending on what Polk Co. staff used.

Densities are tabulated by species if available, by genus, and by major group (Rotifera, Copepoda, and Cladocera). The latter is the most coarse distinction but is ecologically meaningful due to the major differences between these groups compared to similarities between genera within a group. Some species with known environmental tolerances are noted in Table 1.

Several basic community measures were calculated. Over-all generic richness is simply the raw number of genera. Taxa richness (lowest detectable taxonomic resolution) was also tabulated. All other metrics used incorporate density and diversity in various ways. Shannon diversity (Shannon-Weiner Index) is a measure of information, treating taxa as types and abundance as frequency. The advantage of using information theory applied to diversity is that it measures both abundance and evenness at once. The disadvantage is that the index is difficult to interpret ecologically. Values in aquatic systems generally range from 1 to 5, with 5 being the highest diversity with maximum evenness. Shannon evenness is a related measure that converts Shannon diversity to expresses evenness directly. Values range from 0 (minimum evenness) to 1 (maximum evenness, or each taxa equally abundant).

Simpson diversity (Ds) is a difficult number to interpret, and is included in the analyses below for use in further analysis if desired. Simpson's reciprocal index (1/Ds) is sometimes used to exaggerate the scale, but again it is difficult to interpret and not used below. Simpson's index (1-Ds) is used below because it represents a more intuitive scale and has direct ecological interpretation. Simpson diversity (1-Ds) is the probability that from two randomly selected members of the community, the second organism encountered is a different type than the first. This is a useful measure relating diversity to evenness. Berger-Parker dominance is simply the per-cent of the total number of organisms composed by the most common organism. Communities with higher dominance (above 50%) tend to be impaired in one way or another, such that even with high diversity, only one type of organism is found. Jaccard's similarity is 100·(c/A+B-c), where c is the number of genera in common, A and B are the numbers of genera in samples A and B, respectively. This measures the per cent similarity between two communities (irrespective of abundance), with 100% equivalent to total similarity. The lake similarity index for the whole year is NOT a mean of monthly similarity, but pools all taxa for the year in each lake for an overall comparison.

ZOOPLANKTON COMMUNITY ANALYSIS, WARD LAKE

Zooplankton abundances for Ward Lake are sorted by date in Table 2 and summarized with basic community analysis in Table 4. Mean generic richness was 13.8 genera, and mean species richness was 16.8 taxa (not all taxa could be identified at species level). Most of both the generic and species diversity is rotifer diversity. Rotifers dominated the zooplankton community of Ward Lake, both over time (Figure 1) and as a whole (Figure 2). Dominance (% composition) of rotifers averaged at 89.98% (mean over the whole year, Table 5). Looking at the dominant genera, the rotifer *Keratella* spp. was dominant throughout all sampling periods (Table 4) but the relative dominance changed over sampling periods. *Keratella* is a genera that is very tolerant of fish presence due to its small size and hard lorica. The most common non-rotifer overall was the small cyclopoid copepod *Microcyclops* sp.

ZOOPLANKTON COMMUNITY ANALYSIS, WILD GOOSE LAKE

Zooplankton abundances for Wild Goose Lake are sorted by date in Table 3 and summarized with basic community analysis in Table 4. Mean generic richness was 15.4 genera and mean species richness was 18 taxa (not all taxa could be identified at the species level). Most of both generic and species richness is due to rotifer diversity. Rotifers dominated the zooplankton community of Wild Goose lake over time (Figure 3) and as a whole (Figure 4).

Dominance (% composition) of rotifers averaged at 75.65% (mean over the whole year, Figure 6). The rotifer *Keratella* spp. was dominant throughout all sampling periods but one, where the cladoceran *Bosmina* was dominant (Table 4). The relative dominance changed over sampling period. The most common non-rotifers overall were the small cyclopoid copepod *Microcyclops* sp. and the cladoceran *Bosmina longirostrus*, with the caveat that not all samples were preserved well enough to distinguish the genera *Bosmina* from *Eubosmina*. Both genera are found in the area. In this survey *B. longirostrus* was positively identified, but many individuals did not retain the sensory bristle or other characters required to distinguish the genera so the two genera are lumped together for analysis. *Eubosmina* spp. were not positively identified, however. Live samples would help differentiate the two.

Comparison of Ward and Wild Goose Lake zooplankton communities, 2008

Community measures for Ward and Wild Goose lakes are compared in Table 4 and shown graphically in Figures 7-10. Both Ward and Wild Goose Lakes are rotifer dominated communities, indicating heavy fish predation on the cladocerans and copepods with corresponding reduction of the capacity for zooplankton to be a controlling factor of algal blooms. A few features are of note. For both lakes, Simpson's Diversity Index (1-Ds) looks fairly good (Figure 9). However, given the dominance of rotifers as a group, the Simpson's Diversity of genera is misleading, and diversity of the major groups is low (Figure 10). This should be interpreted not in terms of 'diversity' alone (since the maximum diversity of the three groups is three), but as a measure of evenness. The score is a composite of number of groups (taxa diversity) and evennes (the relative abundance of different groups). A low diversity score tested against the 3 main groups is really another measurement expressing the dominance of rotifers.

The basic community measures were compared with a simple T-test as a preliminary comparative measure. Means for the entire year were compared against the monthly variance. The results are informative but should be taken with caution because variance over the year represents community phenology and is not necessarily random. Wild Goose Lake showed significantly greater diversity of cladoceran genera ($p = 0.011$) but had significantly lower total zooplankton density ($\#/m^3$, $p = 0.036$). Differences in zooplankton density are shown in Figure 7.

Jaccard's similarity of the two zooplankton communities, expressed as a % of shared genera, are listed in Table 6 and shown in Figure 11. The two lakes are most similar in spring, then diverge. This could be the result of several factors, including differences in temperature, depth, fish species present (top-down effects, and algal species present (bottom-up effects). Further analysis using ecological gradients could help tease out the key processes.

Future analyses and recommendations

The zooplankton counts here are as robust as possible given a single sample per lake per date. These data allow decent comparisons between lakes and can track major changes in community phenology. The very basic abundances and indices presented in this report can detect large scale impacts over time if the survey is repeated.

Three major limitations to these data can be addressed by future work. First, zooplankton community phenology can be obscured by patchy spatial distribution. In order to make inferences about populations in a given lake and to avoid both type I and II errors in lake to lake comparisons, at least 3 samples are needed per lake (scaled up to lake size).

Secondly, it is difficult to assess the meaning of the indices reported here without an ecological context. This can be addressed using the data reported here by cluster analysis across environmental gradients to identify factors associated with changes in the zooplankton community. Finally, some zooplankton are preserved in sediment cores, particularly cladocerans, allowing a pre-settlement state to be inferred. Paleobiology offers a context for determining the nature and extent of impacts currently impacting a lake. Zooplankton presence in sediment cores can characterize both background state of the lake as well as year to year variation pre-settlement (i.e., pre-fish stocking) and over recent history (i.e., eutrophication). These additional analyses are highly recommended to make the most use of the biological data presented here.

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TABLES

TABLE 1. SPECIES PRESENT AND TAXONOMIC NOTES, POLK COUNTY 2008.

Polk Co, WI: 2008			
Ward Lake and Wild Goose Lake	**% Certain**	**Taxonomic notes**	**Ecological notes**
ROTIFERA			
Anuraeopsis sp.	100		
Ascomorpha saltans	90		
Asplanchna spp.	100		
Asplanchna herricki	100		
Asplanchna priodonta	90	Organs not always preserved	
Collotheca mutabilis	90		
Conochiloides natans	90		
Conochilus unicornis	80	Cannot always see antennae, could be other species (but certain of genus)	
Filinia terminalis	70	Very close to 10 micrometers on the terminal setae, but almost always 8 to 9; strange, since terminalis is cold stenotherm and longiseta is warm stenotherm, so based on ecology should be F. longiseta (and could be, keys can be very off),	(Cold or warm stenotherm?)
Harringia sp.	100		Benthic species
Kellicottia spp.	100		
Kellicottia bostoniensis	100		Indicates high P
Kellicottia longiseta	100		Indicates high P
Kerratella spp.	100		
Keratella cochlearis cochlearis/robustus	100	The two subspecies can be separated by size but many were on the border; very similar ecology.	
Keratella hiemalis	100		
Lecane sp.	80		
Monostyla spp.	90	Some keys uncertain, lump with *Lecane* spp.	
Monostyla bulla	90		
Monostyla lunaris	90		
Polyarthra spp.	100		
Polyarthra euryptera	80	Fins sometimes shrivelled, made species call based on size (see taxonomic refs)	

Polyarthra major	80	Fins sometimes shrivelled, made species call based on size (see taxonomic refs)	
Polyarthra remata	90	Fins sometimes shrivelled, made species call based on size (see taxonomic refs)	
Pompholyx (prob. *sulcata*)	70	Not all characters very clear	
Synchaeta sp.			
Trichocerca spp.	100		
Trichocerca cylindrica	90	Some mashed enough to possibley be something else	
Trichocerca multicrinis	100		Associated with eutrophication
Trichocerca similis			
Trichotria sp.	100		
Nauplii (not counted in richness)	100		
Calanoid nauplius	100		
Cyclopoid nauplius	80	Counted ambiguous specimens as cyclopoid	
COPEPODA			
Cryptocyclops sp.	90	Have 5th leg pictures	
Cyclops sp.	90	Have 5th leg pictures; keys do not all match	
Diacyclops sp.	100		
Diaptomus sp.	100		Very large, tend to be easy fish prey.
Epischura lacustris	80	Keys to Epischura in both major keys, but body not bent.	
Microcyclops sp.	100		
Paracyclops sp.	90	Have 5th leg pics; keys don't all match	
Thermocyclops sp.	90	Have 5th leg pics; keys don't all match	
CLADOCERA total			
Bosmina/Eubosmina spp.	100	Sensory bristle location highly variable, sometimes absent. Both genera are known from the area.	Live samples or samples in 50% ETOH would allow positive ID.
Ceriodaphnia sp.	100		Fish tolerant
Daphnia spp.	100		
Daphnia ambigua			
Daphnia galeata mendotae	100		
Daphnia laevis	100		
Daphnia lumholtzi	100		Invasive

Daphnia pulex	90	Rostrum pattern not always apparent	
Daphnia rosea	80	Keys to D. rosea, but could easily be galeata without helmet; some also keyed to dubia.	
Diaphanosoma spp.	70	All available keys do not necessarily jive. Several pictures of *Diaphanosoma* have 3 segmented antennal rami, which is a character for *Sida.*	
Diaphanosoma bergei	70		
Diaphanosoma brachyurum	70		
Holopedium gibberum	100		
Sida crystalina	70	All available keys do not necessarily agree on generic characters.	
HEXAPODA			
Chaoborus sp.	100	With better preserved samples could put a species on these.	The 'ghost midge', voracious planktivore. Kairomones can induce helmets in Daphnia spp.

TABLE 2. WARD LAKE ZOOPLANKTON ABUNDANCE, POLK CO. (WI) 2008..

Polk Co, WI: 2008	Ward	Ward	Ward	Ward	Ward	**Ward**
Abundance summary	27-May-08	16-Jun-08	14-Jul-08	25-Aug-08	15-Sep-08	**MEAN**
	#/m^3	**#/m^3**	**#/m^3**	**#/m^3**	**#/m^3**	**#/m^3**
ROTIFERA total	3784.65	1114.35	3391.35	2470.2	917.7	**2335.65**
Anuraeopsis sp.	0	0	0	0	0	**0**
Ascomorpha saltans	0	65.55	17.25	0	24.15	**21.39**
Asplanchna spp.	13.8	34.5	3.45	0	6.9	**11.73**
Asplanchna herricki	13.8	0	0	0	6.9	4.14
Asplanchna priodonta	0	34.5	3.45	0	0	7.59
Collotheca mutabilis	0	0	0	6.9	0	**1.38**
Conochiloides natans	34.5	0	0	0	0	**6.9**
Conochilus unicornis	10.35	13.8	282.9	462.3	3.45	**154.56**
Filinia terminalis	0	0	0	13.8	0	**2.76**
Harringia sp.	0	0	0	0	0	**0**
Kellicottia spp.	72.45	24.15	37.95	0	31.05	**33.12**
Kellicottia bostoniensis	72.45	24.15	10.35	0	31.05	27.6
Kellicottia longiseta	0	0	27.6	0	0	5.52
Kerratella spp.	3201.6	531.3	1914.75	1562.85	558.9	**1553.88**
Keratella cochlearis cochlearis/robustus	3105	531.3	1914.75	1562.85	555.45	1533.87
Keratella hiemalis	96.6	0	0	0	3.45	20.01
Lecane sp.	0	0	0	0	3.45	**0.69**
Monostyla spp.	0	3.45	0	0	0	**0.69**
Monostyla bulla	0	3.45	0	0	0	0.69
Monostyla lunaris	0	0	0	0	0	0
Polyarthra spp.	293.25	362.25	203.55	44.85	34.5	**187.68**
Polyarthra euryptera	0	134.55	48.3	0	0	36.57
Polyarthra major	0	0	0	0	0	0
Polyarthra remata	293.25	227.7	155.25	44.85	34.5	151.11
Pompholyx sulcata	120.75	79.35	917.7	262.2	203.55	**316.71**
Synchaeta sp.						
Trichocerca spp.	37.95	0	13.8	117.3	51.75	**44.16**
Trichocerca cylindrica	27.6	0	13.8	10.35	27.6	15.87
Trichocerca multicrinis	10.35	0	0	106.95	24.15	28.29
Trichocerca similis	0	0	0	0	0	0
Trichotria sp.	0	0	0	0	0	**0**
Nauplii (not counted in richness)	520.95	341.55	51.75	155.25	0	**213.9**
Calanoid nauplius	34.5	27.6	6.9	24.15	0	18.63
Cyclopoid nauplius	486.45	313.95	44.85	131.1	0	195.27
COPEPODA total	345	279.45	58.65	79.35	127.65	**178.02**
Calanoid total	44.85	24.15	10.35	6.9	20.7	**21.39**
Cyclopoid total	300.15	255.3	48.3	72.45	106.95	**156.63**
Cryptocyclops sp.	0	10.35	0	0	0	**2.07**
Cyclops sp.	0	6.9	0	3.45	17.25	**5.52**
Diacyclops sp.	48.3	3.45	24.15	24.15	10.35	**22.08**

Diaptomus sp.	31.05	24.15	10.35	6.9	10.35	**16.56**
Epischura lacustris	13.8	0	0	0	10.35	**4.83**
Microcyclops sp.	248.4	234.6	20.7	44.85	79.35	**125.58**
Paracyclops sp.	3.45	0	3.45	0	0	**1.38**
Thermocyclops sp.	0	0	0	0	0	**0**
CLADOCERA total	106.95	124.2	75.9	10.35	120.75	**87.63**
Bosmina/Eubosmina spp.	0	0	0	0	0	**0**
Ceriodaphnia sp.	0	0	0	0	0	**0**
Daphnia spp.	106.95	124.2	72.45	10.35	120.75	**86.94**
Daphnia ambigua	0	24.15	0	0	0	4.83
Daphnia galeata mendotae	96.6	48.3	65.55	6.9	93.15	62.1
Daphnia laevis	0	0	0	0	0	0
Daphnia lumholtzi	0	3.45	0	0	0	0.69
Daphnia pulex	10.35	24.15	6.9	3.45	27.6	14.49
Daphnia rosea	0	24.15	0	0	0	4.83
Diaphanosoma spp.	0	0	0	0	0	**0**
Diaphanosoma bergei	0	0	0	0	0	**0**
Diaphanosoma brachyurum	0	0	0	0	0	**0**
Holopedium gibberum	0	0	0	0	0	**0**
Sida crystalina	0	0	3.45	0	0	**0.69**
HEXAPODA	0	0	13.8	13.8	0	5.52
Chaoborus sp.	0	0	13.8	13.8	0	**5.52**

TABLE 3. WILD GOOSE LAKE ZOOPLANKTON ABUNDANCE, POLK CO. (WI) 2008.

Polk Co, WI: 2008	Wild Goose	Wild Goose	Wild Goose	Wild Goose	Wild Goose	**Wild Goose**
WILD GOOSE LAKE 2008	27-May-08	16-Jun-08	14-Jul-08	25-Aug-08	15-Sep-08	**MEAN**
	#/m3	#/m3	#/m3	#/m3	#/m3	**#/m3**
ROTIFERA total	434.616	195.02	121.191	419.293	1067.585	**447.541**
Anuraeopsis sp.	0	0	8.358	66.864	0	**15.0444**
Ascomorpha saltans	70.844	10.348	4.179	4.179	0	**17.91**
Asplanchna spp.	1.592	0	0	0	1.433	**0.605**
Asplanchna herricki	0	0	0	0	0	**0**
Asplanchna priodonta	1.592	0	0	0	1.433	**0.605**
Collotheca mutabilis	0	0	1.393	0	0	**0.2786**
Conochiloides natans	0	0	0	0	25.794	**5.1588**
Conochilus unicornis	7.164	0	5.572	5.572	0	**3.6616**
Filinia terminalis	0	1.592	16.716	11.144	70.217	**19.9338**
Harringia sp.	0	0	2.786	2.786	0	**1.1144**
Kellicottia spp.	19.9	3.98	0	57.113	18.629	**19.9244**
Kellicottia bostoniensis	19.9	3.98	0	57.113	18.629	**19.9244**
Kellicottia longiseta	0	0	0	0	0	**0**
Kerratella spp.	179.896	150.444	39.004	221.487	379.745	**194.1152**
Keratella cochlearis cochlearis/robustus	179.896	148.852	39.004	221.487	379.745	**193.7968**
Keratella hiemalis	0	1.592	0	0	0	**0.3184**
Lecane sp.	0	0	0	0	0	**0**
Monostyla spp.	0	1.592	0	32.039	0	**6.7262**
Monostyla bulla	0	0	0	0	0	**0**
Monostyla lunaris	0	1.592	0	32.039	0	**6.7262**
Polyarthra spp.	141.688	11.144	2.786	9.751	199.187	**72.9112**
Polyarthra euryptera	0	0.796	1.393	0	47.289	**9.8956**
Polyarthra major	0	0	1.393	0	2.866	**0.8518**
Polyarthra remata	141.688	10.348	0	9.751	149.032	**62.1638**
Pompholyx sulcata	0	0	0	0	0	**0**
Synchaeta sp.	0	0	0	0	4.299	**0.8598**
Trichocerca spp.	11.144	15.92	40.397	8.358	368.281	**88.82**
Trichocerca cylindrica	7.96	15.92	40.397	8.358	329.59	**80.445**
Trichocerca multicrinis	3.184	0	0	0	34.392	**7.5152**
Trichocerca similis	0	0	0	0	4.299	**0.8598**
Trichotria sp.	2.388	0	0	0	0	**0.4776**
Nauplii (not counted in richness)	164.772	37.412	16.716	40.397	22.928	**56.445**
Calanoid nauplius	12.736	13.532	0	4.179	0	**6.0894**
Cyclopoid nauplius	152.036	23.88	16.716	36.218	22.928	**50.3556**
COPEPODA total	133.728	44.576	9.751	25.074	44.423	**51.5104**
Calanoid total	13.532	7.164	6.965	2.786	2.866	**6.6626**
Cyclopoid total	120.196	37.412	2.786	22.288	41.557	**44.8478**
Cryptocyclops sp.	0	7.164	0	0	0	**1.4328**
Cyclops sp.	0	0	0	0	0	**0**

Diacyclops sp.	19.9	2.388	0	0	15.763	**7.6102**
Diaptomus sp.	11.144	7.164	6.965	2.786	1.433	**5.8984**
Epischura lacustris	2.388	0	0	0	1.433	**0.7642**
Microcyclops sp.	96.316	12.736	2.786	19.502	25.794	**31.4268**
Paracyclops sp.	3.98	15.124	0	0	0	**3.8208**
Thermocyclops sp.	0	0	0	2.786	0	**0.5572**
CLADOCERA total	278.6	70.048	52.934	18.109	42.99	**92.5362**
Bosmina/Eubosmina spp.	236.412	2.388	1.393	0	0	**48.0386**
Ceriodaphnia sp.	0	1.592	0	1.393	0	**0.597**
Daphnia spp.	39.004	57.312	15.323	8.358	31.526	**30.3046**
Daphnia ambigua	31.044	7.96	0	0	0	**7.8008**
Daphnia galeata mendotae	0	1.592	0	0	0	**0.3184**
Daphnia laevis	6.368	47.76	15.323	6.965	31.526	**21.5884**
Daphnia lumholtzi	1.592	0	0	0	0	**0.3184**
Daphnia pulex	0	0	0	0	0	**0**
Daphnia rosea	0	0	0	1.393	0	**0.2786**
Diaphanosoma spp.	0	8.756	0	0	0	**1.7512**
Diaphanosoma bergei	0	6.368	0	0	0	**1.2736**
Diaphanosoma brachyurum	0	2.388	0	0	0	**0.4776**
Holopedium gibberum	0.796	0	0	0	0	**0.1592**
Sida crystalina	2.388	0	36.218	8.358	11.464	**11.6856**
HEXAPODA	0	0	0	0	0	**0**
Chaoborus sp.	0	0	0	0	0	**0**

TABLE 4. ZOOPLANKTON COMMUNITY INDICES, WARD AND WILD GOOSE LAKES OF POLK CO. (WI) 2008.

Polk Co, WI: 2008	Ward	Ward	Ward	Ward	Ward	**Ward**	Wild	Wild	Wild	Wild	Wild	**Wild**
	39595	39615	39643	39685	39706	**MEAN**	39595	39615	39643	39685	39706	**MEAN**
Generic richness	14	14	14	12	15	**13.8**	17	16	14	16	14	**15.4**
Rotifer richness	8	8	8	7	9	**8**	8	7	9	10	8	**8.4**
Copepod richness	5	5	4	4	5	**4.6**	5	5	2	3	4	**3.8**
Cladoceran richness	1	1	2	1	1	**1.2**	4	4	3	3	2	**3.2**
Taxa richness (species)	17	18	17	14	18	**16.8**	19	21	15	17	18	**18**
Rotifera	10	9	10	8	11	**9.6**	9	9	10	10	12	**10**
Copepoda	5	5	4	4	5	**4.6**	5	5	2	3	4	**3.8**
Cladocera	2	4	3	2	2	**2.6**	5	7	3	4	2	**4.2**
TOTAL N/m3	4236.6	1518	3539.7	2573.7	1166.1	**2606.82**	**846.944**	**309.644**	**183.876**	**462.476**	**1154.998**	***591.5876***
Shannon diversity (H')	1.0529343	1.8393967	1.34738	1.2885721	1.7470611	**1.5226832**	2.004712	1.8148846	2.1277987	1.8033162	1.6883097	**2.2777206**
Shannon Evenness (J)	0.3989812	0.69699	0.5105535	0.5185596	0.6451362	**0.580143**	0.7075754	0.6545813	0.8062723	0.6504088	0.6397397	**0.8329973**
Reciprocal Simpson's Index (1-Ds)	0.4186868	0.7847112	0.6299767	0.5859826	0.7205857	**0.61736**	0.826333	0.7206414	0.8516242	0.7271311	0.7551409	**0.8391768**
Berger-Parker Dominance (d)	0.7557003	0.35	0.5409357	0.6072386	0.4792899	**0.5960826**	0.2791353	0.4858612	0.2121212	0.4789157	0.3287841	**0.3281259**
Dominant genus	Keratella	Keratella	Keratella	Keratella	Keratella	**Keratella**	Bosmina/Eu	Keratella	Keratella	Keratella	Keratella	**Keratella**
Simpson's Index (Ds)	0.5813132	0.2152888	0.3700233	0.4140174	0.2794143	**0.38264**	0.173667	0.2793586	0.1483758	0.2728689	0.2448591	**0.1608232**

TABLE 5. COMPARISON OF MAJOR ZOOPLANKTON GROUPS, WARD AND WILD GOOSE LAKES OF POLK CO. (WI) 2008. CARE SHOULD BE TAKEN INTERPRETING THE INDICES, SEE TEXT.

Polk Co, WI: 2008	Ward	Ward	Ward	Ward	Ward	**Ward**	Wild Goose	Wild Goose	Wild Goose	Wild Goose	Wild Goose	**Wild Goose**
Major group diversity	27-May-08	16-Jun-08	14-Jul-08	25-Aug-08	15-Sep-08	**MEAN**	27-May-08	16-Jun-08	14-Jul-08	25-Aug-08	15-Sep-08	**MEAN**
	#/m3	#/m3	#/m3	#/m3	#/m3	**#/m3**	#/m3	#/m3	#/m3	#/m3	#/m3	**#/m3**
ROTIFERA total	3784.65	1114.35	3391.35	2470.2	917.7	**2335.65**	434.616	195.02	121.191	419.293	1067.585	**447.541**
COPEPODA total	345	279.45	58.65	79.35	127.65	**178.02**	133.728	44.576	9.751	25.074	44.423	**51.5104**
CLADOCERA total	106.95	124.2	75.9	10.35	120.75	**87.63**	278.6	70.048	52.934	18.109	42.99	**92.5362**
TOTAL N	4236.6	1518	3525.9	2559.9	1166.1	**2601.3**	846.944	309.644	183.876	462.476	1154.998	**591.5876**
Shannon diversity (H')	0.3978835	0.7432775	0.1881896	0.16438	0.6654981	**0.3944749**	0.9995533	0.9064236	0.7889864	0.3737759	0.3205443	**0.7138332**
Shannon Evenness (J)	0.3621692	0.6765604	0.1712976	0.1496251	0.6057625	**0.3590665**	0.9098327	0.8250623	0.7181664	0.3402255	0.291772	**0.649759**
Simpson's Index (1-Ds)	0.1947523	0.4208041	0.0741457	0.0679024	0.3582604	**0.1880693**	0.6042453	0.5331484	0.482537	0.1739318	0.142896	**0.3963162**
Berger-Parker Dominance (d)	0.8933225	0.7340909	0.9618395	0.9649596	0.7869822	**0.897878**	0.5131579	0.6298201	0.6590909	0.9066265	0.9243176	**0.7565084**
Dominant group	Rotifera	Rotifera	Rotifera	Rotifera	Rotifera	**Rotifera**	Rotifera	Rotifera	Rotifera	Rotifera	Rotifera	**Rotifera**

TABLE 6. JACCARD'S SIMILARITY OF ZOOPLANKTON COMMUNITIES, WARD AND WILD GOOSE LAKES, POLK CO. (WI) 2008. THE VALUE FOR THE WHOLE YEAR IS OVERALL SIMILARITY, NOT A MEAN OF MONTHLY SIMILARITIES.

Date	# Genera Ward	# Genera Wild	# Common	Jaccard's similarity
27-May-08	14	17	12	63.2
16-Jun-08	14	16	11	57.9
14-Jul-08	14	14	9	47.4
25-Aug-08	12	16	8	40.0
15-Sep-08	15	14	10	52.6
whole year	**28**	**24**	**19**	**57.6**

FIGURES

FIGURE 1. DENSITY OF THREE MAIN ZOOPLANKTON GROUPS IN WARD LAKE, POLK CO. (WI) OVER TIME IN 2008.

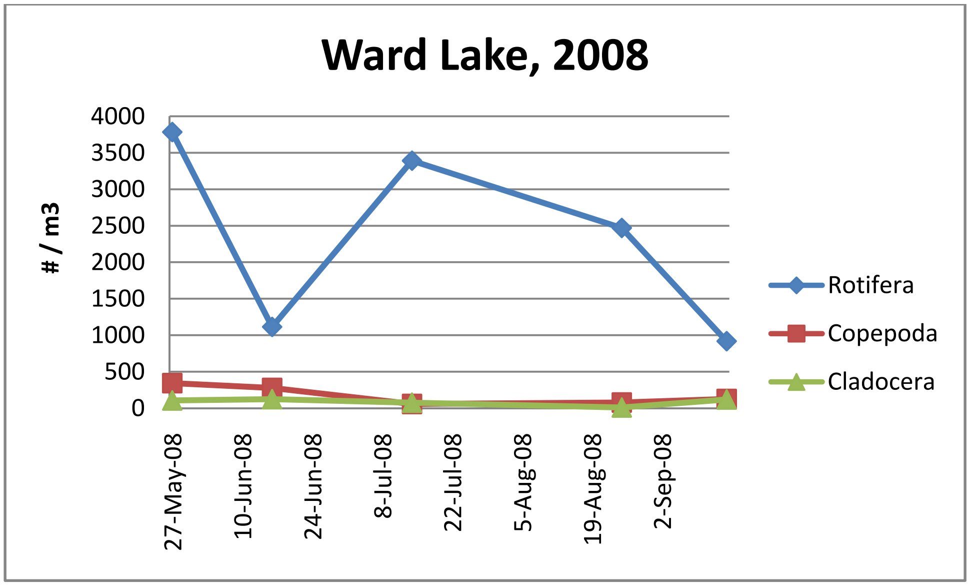

FIGURE 2. MEAN PROPORTION OF THREE MAIN ZOOPLANKTON GROUPS IN WARD LAKE, POLK CO. (WI) 2008 OVER 5 SAMPLING PERIODS.

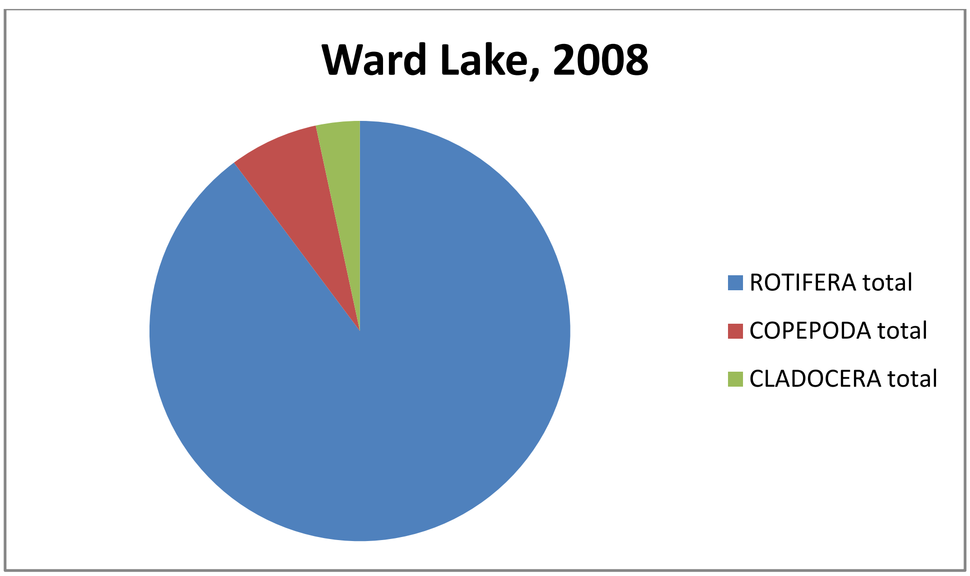

FIGURE 3. DENSITY OF THREE MAIN ZOOPLANKTON GROUPS IN WILD GOOSE LAKE, POLK CO. (WI) 2008 OVER FIVE SAMPLING PERIODS.

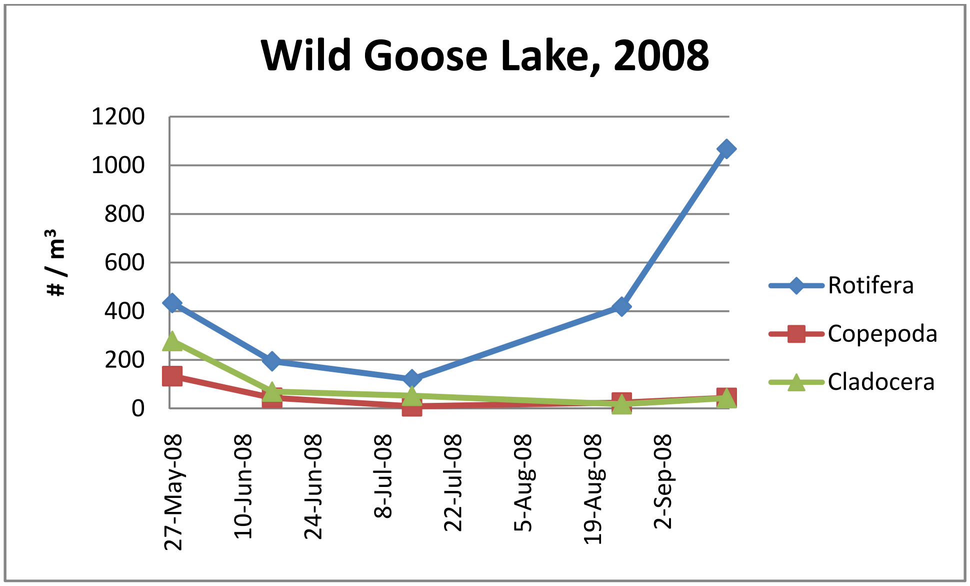

FIGURE 4. MEAN PROPORTION OF THE THREE MAIN ZOOPLANKTON GROUPS IN WILD GOOSE LAKE, POLK CO. (WI) 2008.

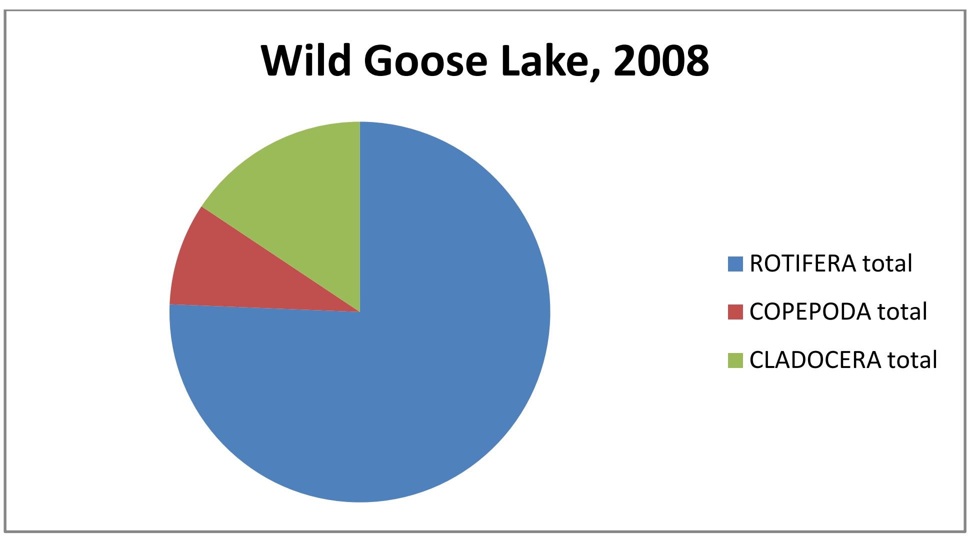

FIGURE 5. DIVERSITY OF GENERA OF THREE MAIN ZOOPLANKTON GROUPS IN WARD LAKE, POLK CO. (WI) OVER FIVE SAMPLING PERIODS.

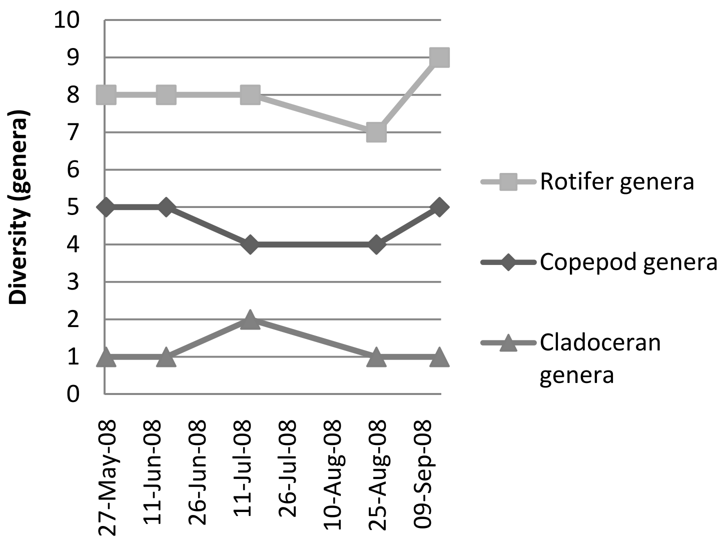

FIGURE 6. DIVERSITY OF GENERA OF THREE MAIN ZOOPLANKTON GROUPS IN WILD GOOSE LAKE, POLK CO. (WI) OVER FIVE SAMPLING PERIODS.

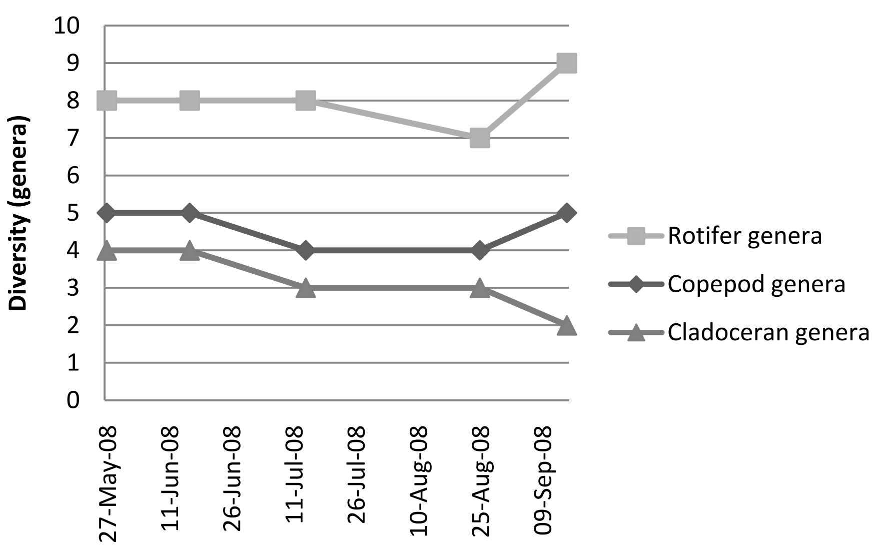

FIGURE 7. COMPARISON OF TOTAL ZOOPLANKTON DENSITY BETWEEN WARD AND WILD GOOSE LAKES IN POLK CO. (WI), 2008, OVER FIVE SAMPLING PERIODS.

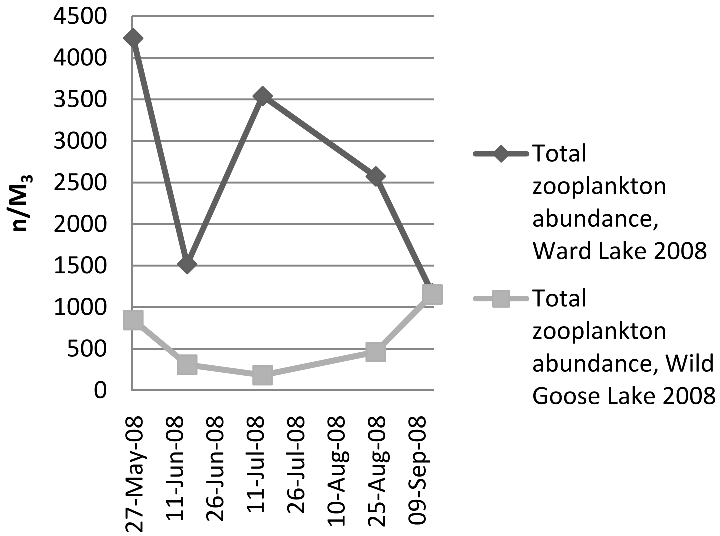

FIGURE 8. COMPARISON OF DOMINANCE (BERGER-PARKER, OR % OF TOTAL COMMUNITY COMPOSED BY MOST COMMON ORGANISM) BETWEEN WARD AND WILD GOOSE LAKES, POLK CO. (WI) 2008. IN BOTH CASES THE DOMINANT GENUS WAS *KERATELLA* SPP., PRIMARILY *K. COCHLEARIS COCHLEARIS* BUT INCLUDING *K. COCHLEARIS ROBUSTUS* AND *K. HIEMALIS.*

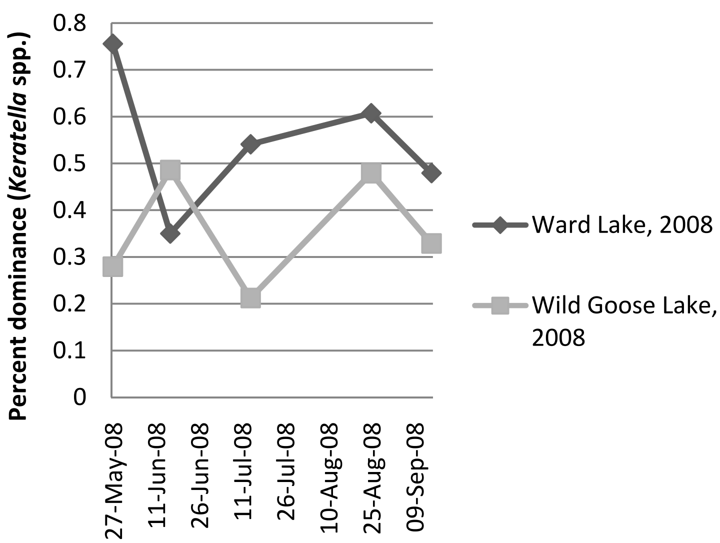

FIGURE 9. SIMPSON'S INDEX OF DIVERSITY (1 - DS OR 1 – SIMPSON'S DIVERSITY MEASURE) FOR GENERA IN WARD AND WILD GOOSE LAKES, POLK CO. (WI) 2008. THE SCALE FROM 0 TO 1 INDICATES THE PROBABILITY THAT GIVEN TWO RANDOM SAMPLES FROM THE TOTAL POPULATION, THE SECOND ORGANISM IS A DIFFERENT GENUS THAN THE FIRST.

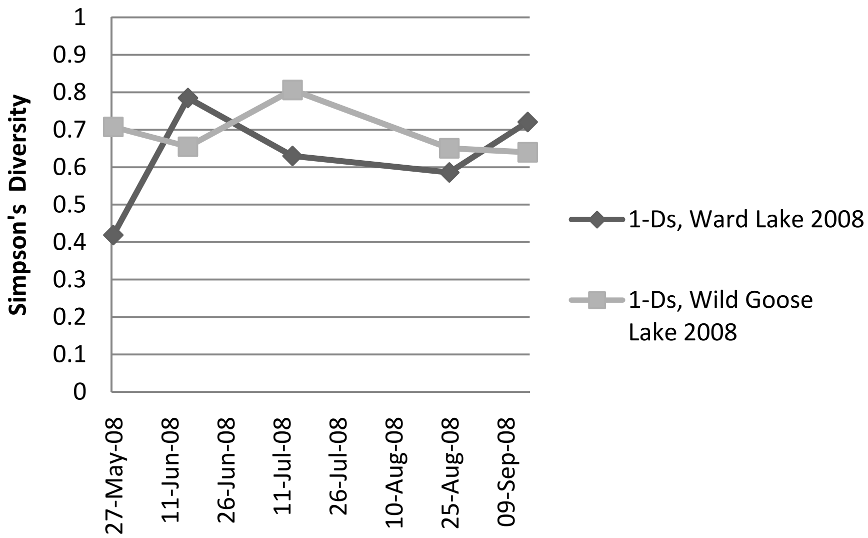

FIGURE 10. SIMPSON'S INDEX OF DIVERSITY FOR ROTIFERA, COPEPODA, AND CLADOCERA IN WARD AND WILD GOOSE LAKES, POLK CO. (WI) 2008. THE SCALE FROM 0 TO 1 INDICATES THE PROBABILITY GIVEN TWO RANDOM INDIVIDUALS THAT THE SECOND IS A DIFFERENT MAJOR GROUP THAN THE FIRST.

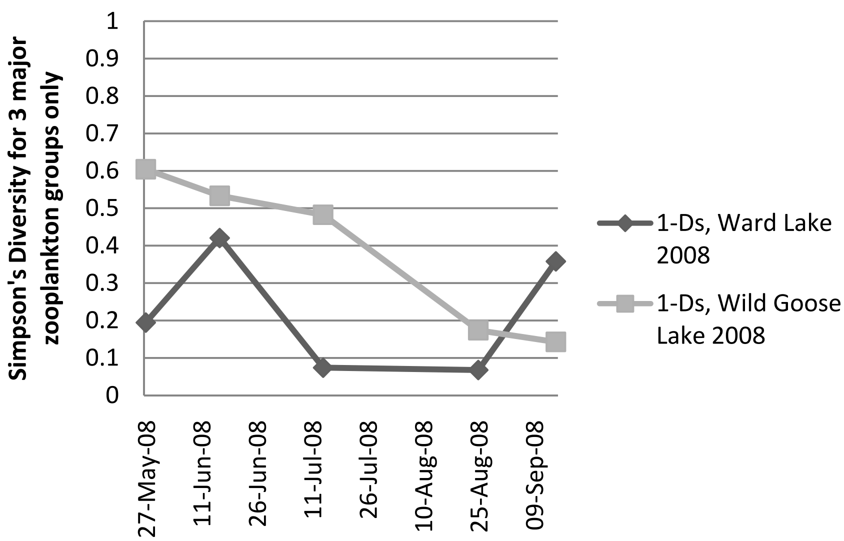

FIGURE 11. JACCARD'S SIMILARITY OF ZOOPLANKTON COMMUNITIES BETWEEN WARD AND WILD GOOSE LAKES, POLK CO. (WI) 2008. WHOLE YEAR IS THE OVERALL SIMILARITY, NOT A MEAN.