Gull Lake Watershed Monitoring Program 2011

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THE GULL LAKE WATERSHED MONITORING PROGRAM

The Gull Lake Quality Organization (GLQO) supports monitoring of Gull Lake and its inflow streams by researchers at the W.K. Kellogg Biological Station (KBS). In 2011 the Gull Lake Watershed Monitoring Program was expanded with funding for a summer graduate student fellowship at Michigan State University. The expanded 2011 monitoring program included Gull Lake, its inlet streams, and Little Long Lake. The sampling was designed to track the ecological condition of the lakes and how changing land use and cover in the watershed may affect water quality. Faculty at KBS/MSU, including Dr. Steve Hamilton, Dr. Gary Mittelbach, Dr. Elena Litchman, and Dr. Orlando Sarnelle, contribute to the monitoring program and provide in-kind support for laboratory analyses.

Jeffrey White performed the sampling and some of the lab analyses in summer 2011, and co-authored this year's report with Dr. Hamilton, whose lab also contributed to the chemical analyses. Jeff is a doctoral student in the Department of Fisheries and Wildlife, and he recently completed his Master's degree studying the relationship between *Microcystis*, an undesirable blue-green alga (cyanobacterium) that becomes common in Gull Lake in late summer, and zebra mussels that feed on algae in the lake. Previous research by Jeff's advisor, Dr. Orlando Sarnelle, and Dr. Hamilton has shown that zebra mussel invasions of Michigan lakes often lead to higher abundance of *Microcystis* through complex ecological interactions. Presently Jeff is conducting his doctoral research, and he is further pursuing these questions in Gull Lake and other lakes. Gull Lake was sampled more frequently and more variables were measured in 2011 than had been planned for the long-term monitoring program because the sampling coincided with the field work for Jeff's dissertation.

BACKGROUND ON GULL AND LITTLE LONG LAKES

Gull and Little Long lakes are located in Kalamazoo and Barry counties, Michigan (Figure 1). Gull Lake is one of the largest and deepest inland lakes in southern Michigan. Little Long Lake is much smaller and shallower. Two smaller lakes—Wintergreen and Miller lakes—also drain into Gull Lake.

Gull Lake

Gull Lake has a surface area of 2030 acres and a maximum depth of 110 feet. The KBS campus is situated along its eastern shore. This lake is unusual in southern Michigan because it supports a diverse fishery, including both warm- and coldwater species, and serves as an important recreational site for the region. Residential development lines the lakeshore; unlike most local lakes, there is no wetland along its shores and aquatic plant growth is sparse. The Gull Lake outflow, which flows year round, is regulated by a sluice-gate dam.

Fig. 1. Location of Gull Lake and Little Long Lake, Kalamazoo and Barry counties (courtesy Google Maps).

Observations in the 1970s suggested that Gull Lake was becoming increasingly eutrophic (i.e., supporting undesirably high algal growth), prompting studies of the linkage between nutrient loading and algal blooms. These studies established that phosphorus was the principal limiting nutrient for algal growth in Gull Lake (Tessier and Lauff 1992).

Citizen action, supported by state and federal grants, resulted in construction of a sanitary sewer around the perimeter of Gull Lake in 1984. This diversion of a significant source of phosphorus from Gull Lake resulted in a rapid reversal in eutrophication trends and marked improvement in water quality (Tessier and Lauff 1992).

Current water quality in Gull Lake is considered good, although late-summer blooms of the blue-green alga *Microcystis aeruginosa* cause some concern. This species produces microcystin, a toxin that is potentially harmful if water with abundant *Microcystis* cells is ingested directly without filtration or treatment. *Microcystis* blooms have developed since the invasion of zebra mussels, which as noted above seem to promote this particular species.

Little Long Lake

Little Long Lake is located close to the northwestern end of Gull Lake and is much smaller (169 acres) and shallower (maximum depth, 32 feet). Residential development lines the lake except for parts of its western edge where riparian wetlands occur. The lake receives groundwater inputs, some of which emerge in the wetlands along its western shore to form visible springs or very small streams, and it supports an outflow stream to Gull Lake. The water is alkaline, reflecting the importance of groundwater inputs. Water levels are very stable.

PREVIOUS AND EXISTING SAMPLING PROGRAMS

A number of ecological studies have been conducted on Gull Lake by KBS researchers, producing theses and peer-reviewed publications that are available in the KBS Library. Early work was summarized by Tessier and Lauff (1992) and Sippel and Hamilton (1998). Little Long Lake has not been studied except for occasional water sampling by KBS researchers.

David Tague estimated water and phosphorus budgets for Gull Lake in his 1977 master's thesis. A water budget for Gull Lake in 1974 revealed that the lake received 40% of its water from groundwater inflow, 25% from direct precipitation onto the lake surface, and 35% from stream inflows (Tague 1977; Figure 2). The water budget was combined with information on the phosphorus concentrations of these inputs to formulate a phosphorus budget for the lake (Tague 1977). The phosphorus budget demonstrated that septic systems and lawn fertilization comprised 76% of the annual phosphorus inputs at that time (Figure 3), and that most of the phosphorus input was ultimately retained within the lake by sedimentation.

In 1994-95, well after the sewer system was installed, the GLQO supported a reevaluation of the phosphorus budget of Gull Lake by Dr. Alan Tessier, with the objective of following up on Tague's study. That work included sampling of the stream inflows and precipitation over the year.

Tessier's study found that the total phosphorus loading to Gull Lake had been reduced considerably from ~2331 kg P/year in 1974 to ~517 kg P/year in 1994-95. The inputs from septic systems were presumed to account for most of this decrease (Figure 3). Phosphorus inputs originating from lawn fertilizers became the most important source of phosphorus to the lake following the construction of the sewer, although this input is not well quantified. Tributary inputs were dominated by Prairieville Creek (high discharge, low P concentrations) and the Wintergreen Lake outlet (low discharge, high P concentrations). Today's P inputs are not likely to differ greatly from those estimated by Tessier (1995).

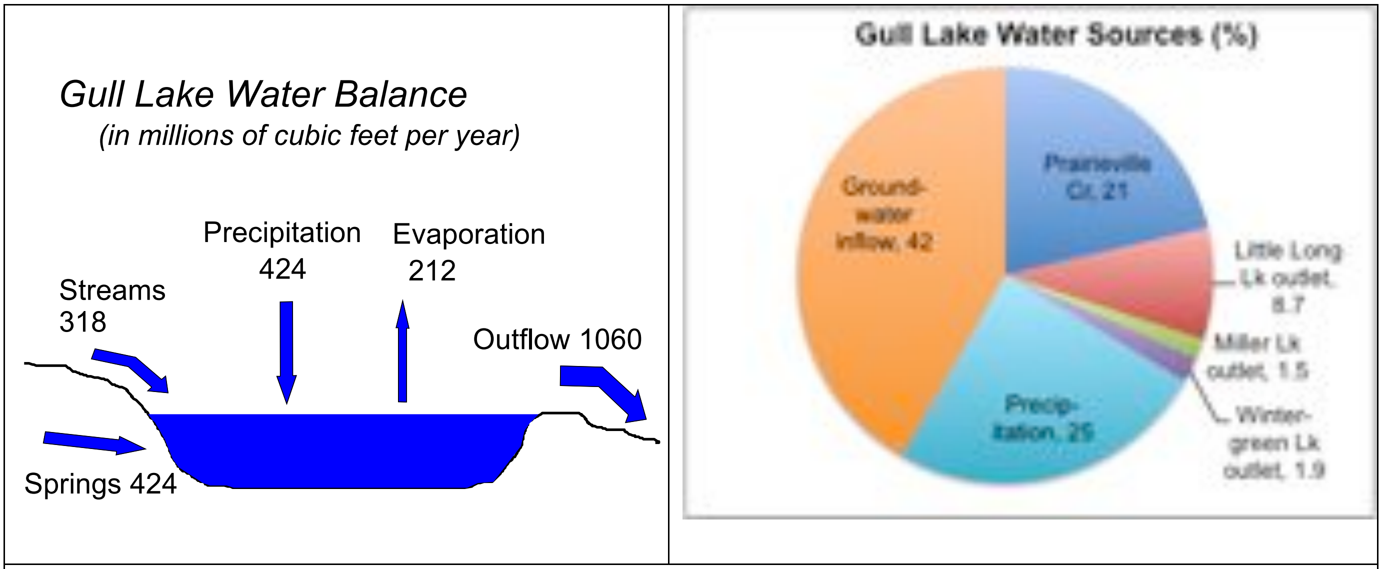


Fig. 2. Gull Lake water budget (left, from Tague 1977) and proportional contributions from tributary inflows, precipitation, and groundwater inflows (right, from Tessier 1995).

Although water sampling supported by research grants over the past three decades has contributed to our knowledge base, it has been sporadic and inconsistent in its coverage. Fortunately, during the past decade, KBS/MSU researchers have regularly sampled Gull Lake in conjunction with several specific research programs over the past decade. The main research activities have included studies of zebra mussel and *Microcystis* ecology by Drs. Orlando Sarnelle and Stephen Hamilton, with most activity between 2001-02 and 2005-present, and limnological research by Dr. Elena Litchman, which began in 2005 and continues to the present. This report includes data from the past decade where available.

Since 2005, the GLQO has provided funds for sampling and analysis of Gull Lake's inflow streams during summer, with water quality analyses conducted by Dr. Hamilton's lab at KBS. Sampling sites include Prairieville Creek, Little Long Lake outflow, Miller Lake outflow, and Wintergreen Lake outflow, as well as a ditch along the Gull Lake Country Club that carries water draining from its golf course. Prairieville Creek is also sampled several times per year as part of a broader stream monitoring program conducted by Dr. Hamilton in connection with the KBS Long-term Ecological Research site.

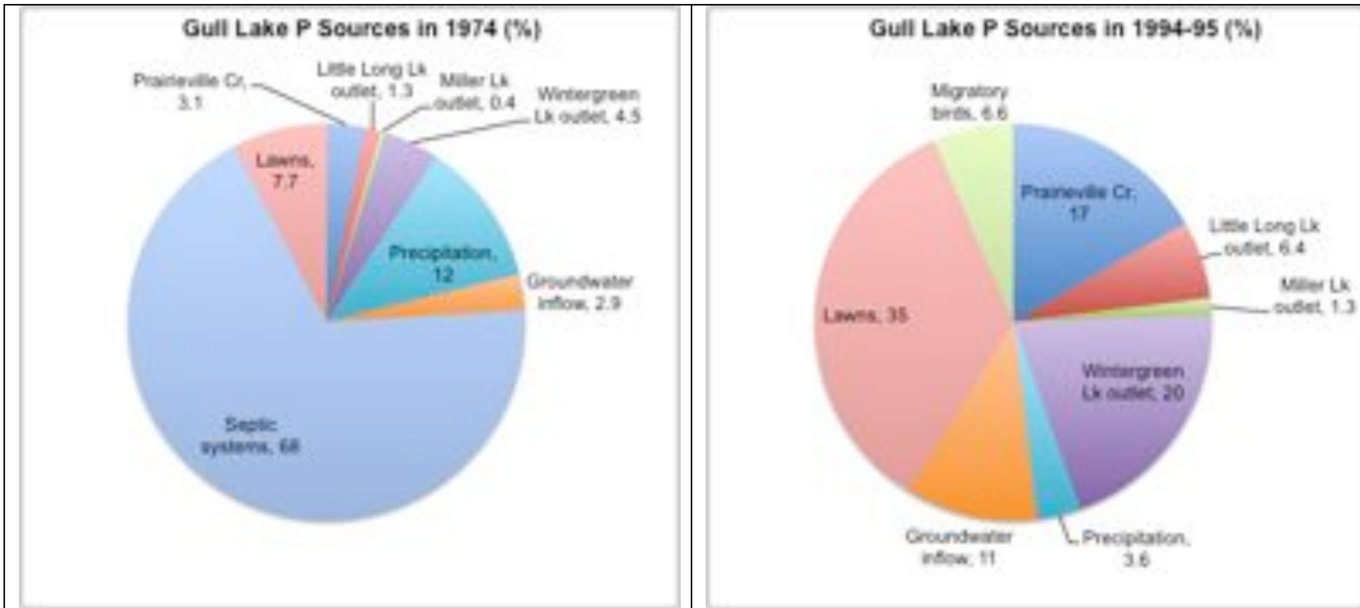


Fig. 3. Gull Lake phosphorus (P) budgets in 1974 (left, from Tague 1977) and 1994-95 (right, from Tessier 1995). The total loading of P to the lake in 1994-95 was estimated to be only 25% of the 1974 loading, mainly as a result of the sewer system installed in 1984, which essentially eliminated septic inputs.

Both Gull and Little Long Lake have been sampled since 2009 by GLQO volunteers as part of the Cooperative Lakes Monitoring Program (CLMP), following standardized protocols and contributing data to a statewide database. This program provides an opportunity to see how Gull Lake compares to other lakes across the state. Data for 2011 were not available at the time of this writing. More information is found at http://www.micorps.net/lakeoverview.html.

MONITORING UPDATE AS OF FALL 2011

The 2011 monitoring program called for biweekly sampling of the two lakes and monthly sampling of the five Gull Lake inflow sites from May-October. Variables of particular interest for understanding the ecological status of the lake are presented in the main body of this report. Additional data for 2011 are given in Appendix A. Various other water quality variables are measured in this monitoring program including major ions, pH, conductance, and silicate; the full water quality data are maintained in a database at KBS and are available from Dr. Hamilton. These data will eventually be used in scientific publications, and therefore the authors of this report request that the data not be used or distributed beyond the local community without permission.

Temperature, Dissolved Oxygen, and Transparency

Water temperature is an important variable that affects the strength and duration of summer stratification of the water column into a warmer upper layer (epilimnion) and a colder lower layer (hypolimnion) as well as the propensity for harmful algal blooms (e.g., *Microcystis*), which tend to be associated with warm temperatures in Gull Lake (Jeff White, unpublished data).

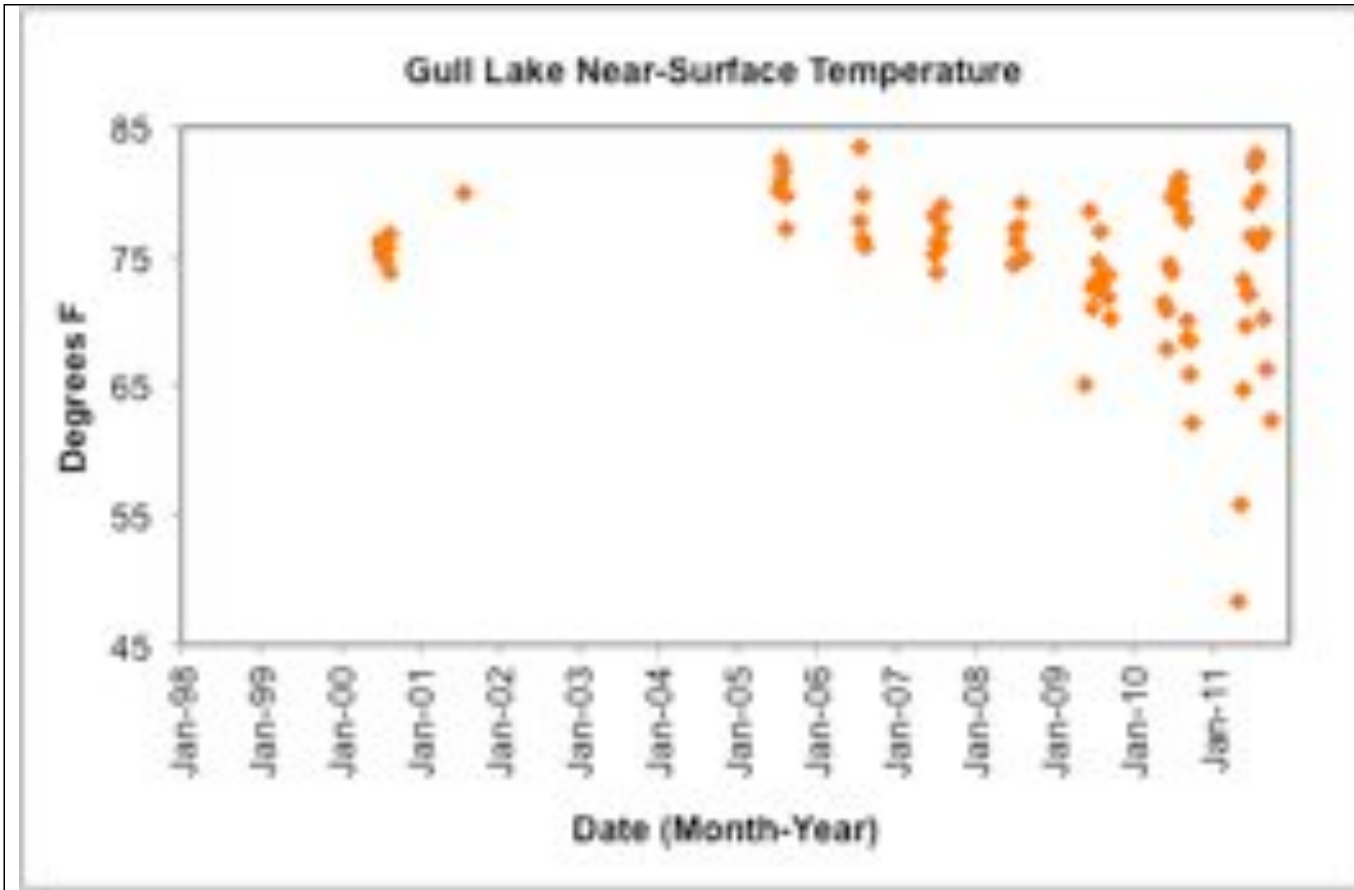


Fig. 4. Gull Lake water temperature from 2000-2011, measured just below the water surface. Sampling in 2010 and 2011 extended over a longer season than in preceding years, and hence more low temperatures were recorded, resulting in the appearance of greater temperature variability. Prior to 2011 data were collected in connection with the zebra mussel research of Drs. Sarnelle and Hamilton.

The available temperature data for Gull Lake surface water over the past decade are depicted in Figure 4. Trends cannot be ascertained in these data because measurements in some of these years did not cover the full range of summer temperatures, although the seasonal maximum of water temperature probably was observed in most years. Gull Lake water reached high temperatures in the past two summers (83-84°F), though similar maximum temperatures were recorded in 2005 and 2006. In contrast, Gull Lake water remained much cooler during the summers of 2007-2009.

During 2011 Little Long Lake also developed thermal stratification, and its surface layer reached a maximum temperature of 84°F. The only available thermal and oxygen data for past years is for a single date in summer 1998 (Sippel and Hamilton 1998), and the Cooperative Lakes Management Program sampling done since 2009.

Dissolved oxygen reflects the effects of biological activity (photosynthesis and respiration), and can become a limiting factor for aquatic life when it falls below a concentration of about 4 mg/L. Daytime oxygen concentrations in the surface water reflect the rate of photosynthesis by suspended algae (phytoplankton). Oxygen in the deeper waters of the lake (hypolimnion) declines progressively over the summer stratification period as bacteria decompose organic matter at depths that are too dark to support much photosynthesis.

Gull Lake surface waters showed a range of variation in dissolved oxygen concentrations in 2011 that was similar to that recorded in previous years, although monitoring was less frequent prior to 2009 (Figure 5). Notably, oxygen became completely depleted in the hypolimnion by late in the stratification season in each of the past three years, making the cold deep waters inhospitable for fish. Prior measurements over the past decade are insufficient to say whether this is normal. Researchers documented oxygen depletion in Gull Lake several decades ago, although that was before the sewer system was installed.

The bottom waters of Little Long Lake declined in dissolved oxygen during summer 2011, but concentrations remained above 5.4 mg/L and were thus favorable for aquatic life including fish.

Transparency (visibility) is determined by a combination of living and non-living particulate material in the water column, and dissolved organic matter sometimes can be important as well. In Gull and Little Long lakes, the major factors that reduce transparency are algae and a mineral known as calcium carbonate. Marl and chalk are examples of calcium carbonate. Calcium carbonate forms in the water column as a result of summer warming in combination with algal uptake of carbon dioxide during photosynthesis, and when abundant it is referred to as a “whiting” event. These factors vary seasonally and tend to reduce transparency the most during mid to late summer. Transparency in lakes is measured by lowering a black-and-white Secchi disk into the water column and determining the depth at which it disappears from view.

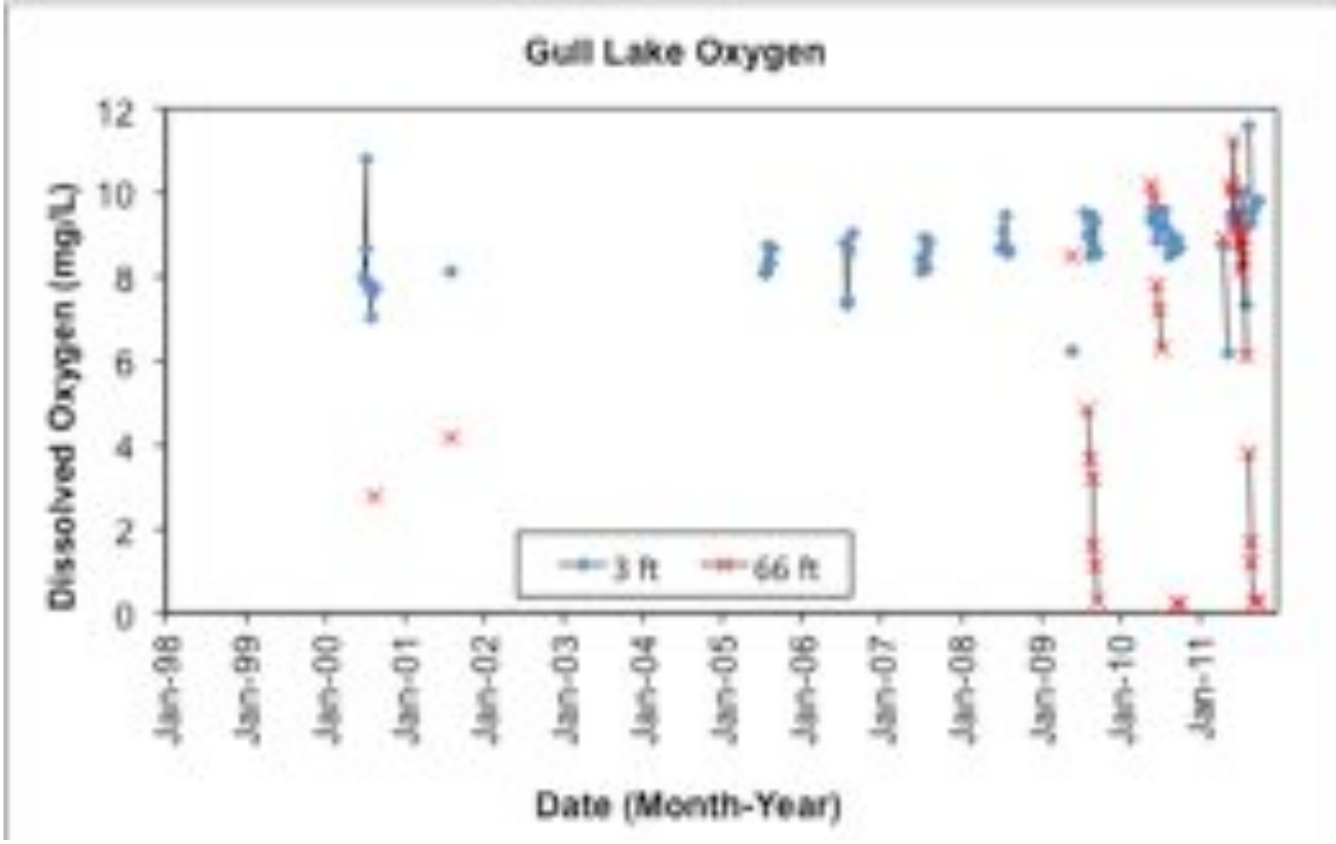


Fig. 5. Gull Lake dissolved oxygen from 2000-2011, measured just below the water surface (epilimnion) and at a depth of 66 feet (hypolimnion), well below the summer thermocline. Prior to 2009 sampling frequency was inadequate to show the full range of variation over the course of summer stratification. Prior to 2011 data were collected in connection with the zebra mussel research of Drs. Sarnelle and Hamilton.

Transparency (Secchi depth) data for Gull Lake show that 2011 was not unusual compared to the past decade (Figure 6), and the past decade shows values similar to those for 1989-1995 reported by Tessier (1995). Little Long Lake ranged in Secchi depth from 7.5-19.4 feet during summer 2011.

Nutrients

Total phosphorus is a key indicator of the potential for undesirably high algal growth in Gull and Little Long lakes because it is the limiting nutrient in these waters. Algae (phytoplankton) in the water column respond rapidly to added phosphorus, which occurs in very low concentrations in the lake water, whereas nitrogen is relatively more available.

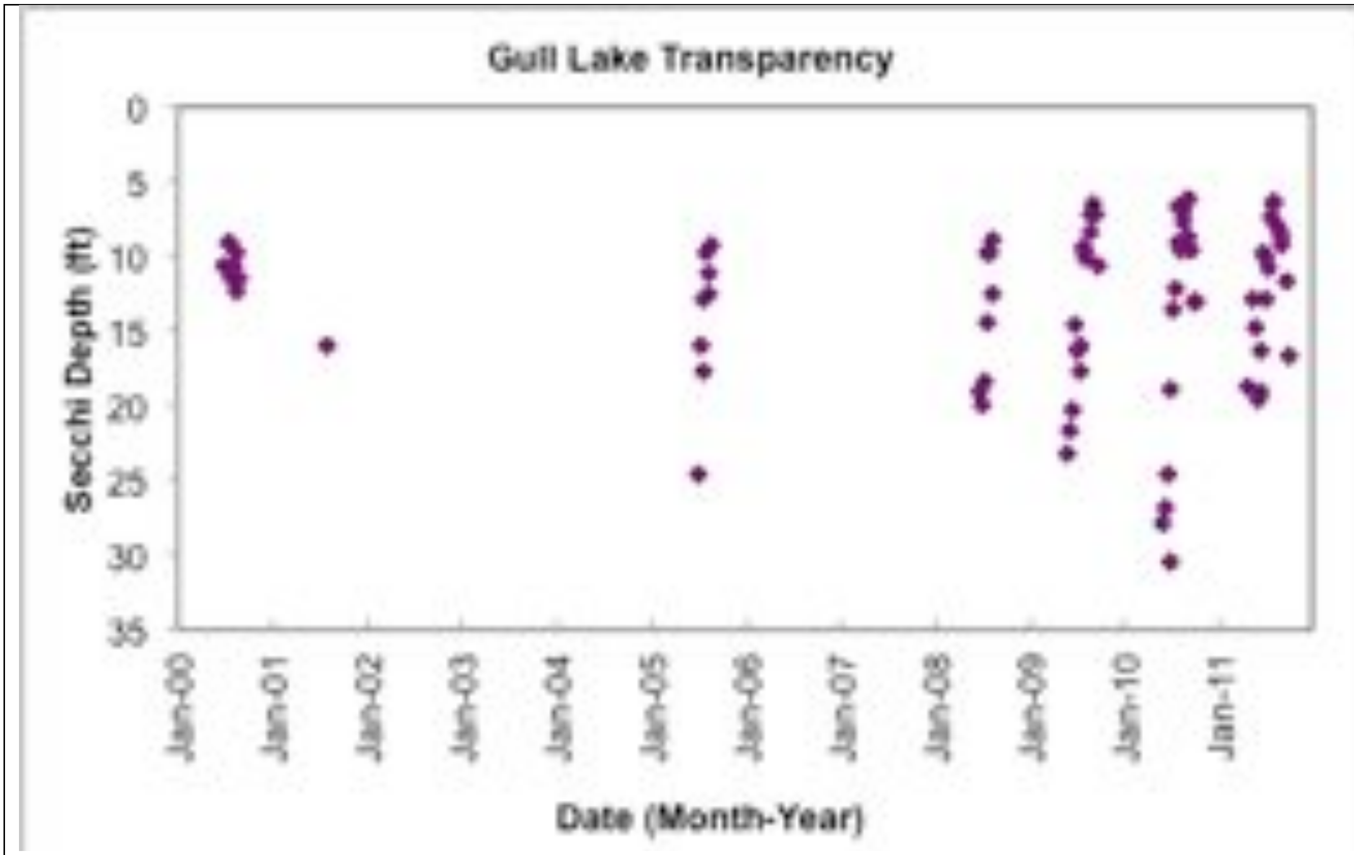


Fig. 6. Gull Lake transparency from 2000-2011, measured by the depth at which a black-and-white Secchi disk can be seen from a boat. Note that the numbers on the y-axis are in reverse order. Prior to 2011 data were collected in connection with the zebra mussel research of Drs. Sarnelle and Hamilton.

Total phosphorus concentrations in Gull Lake during summer 2011 varied over a range similar to that observed in the preceding 10 years (Figure 7). Summer phosphorus concentrations of ~5-10 ppb indicate that the lake is oligotrophic, though bordering on mesotrophic. These terms refer to the level of algal productivity in the open waters. An oligotrophic to mesotrophic state is highly desirable for recreation and fishing; less desirable is a eutrophic state (highly productive). No long-term trend in total phosphorus is evident in Figure 7.

Total phosphorus concentrations in the inflowing waters to Gull Lake are shown in Figure 8. Note that the importance of these inflows as sources of phosphorus to the lake is a function of both phosphorus concentrations (Figure 8) and water discharge (i.e., the volume of inflowing water over time), as is evident by comparing Figures 2 and 3. The Country Club Drain carries very high phosphorus concentrations, as is typical for water exiting fertilized turf grass, but the discharge at that site is small. Nonetheless, the high concentrations underscore the importance of not using phosphorus fertilizers on lakeside lawns, which typically do not need phosphorus because their soils are saturated with this nutrient from years of over-application.

For Little Long Lake, surface-water total phosphorus concentrations since 2005 are evident from the outflow stream data in Figure 8. Dr. Alan Tessier's 1994-95 sampling of the outflow stream yielded concentrations of total phosphorus ranging from 8-29 ppb. A few total phosphorus measurements of the lake's surface water have been made in the past in connection with research by Dr. Tessier and Dr. Carla Caceres (samplings in 1999, 2000, 2001, and 2007; range 2.8-10 ppb). Sippel and Hamilton (1998) reported 16 ppb for a summer 1998 sampling. There is no evidence for major changes over time, although the information base is limited.

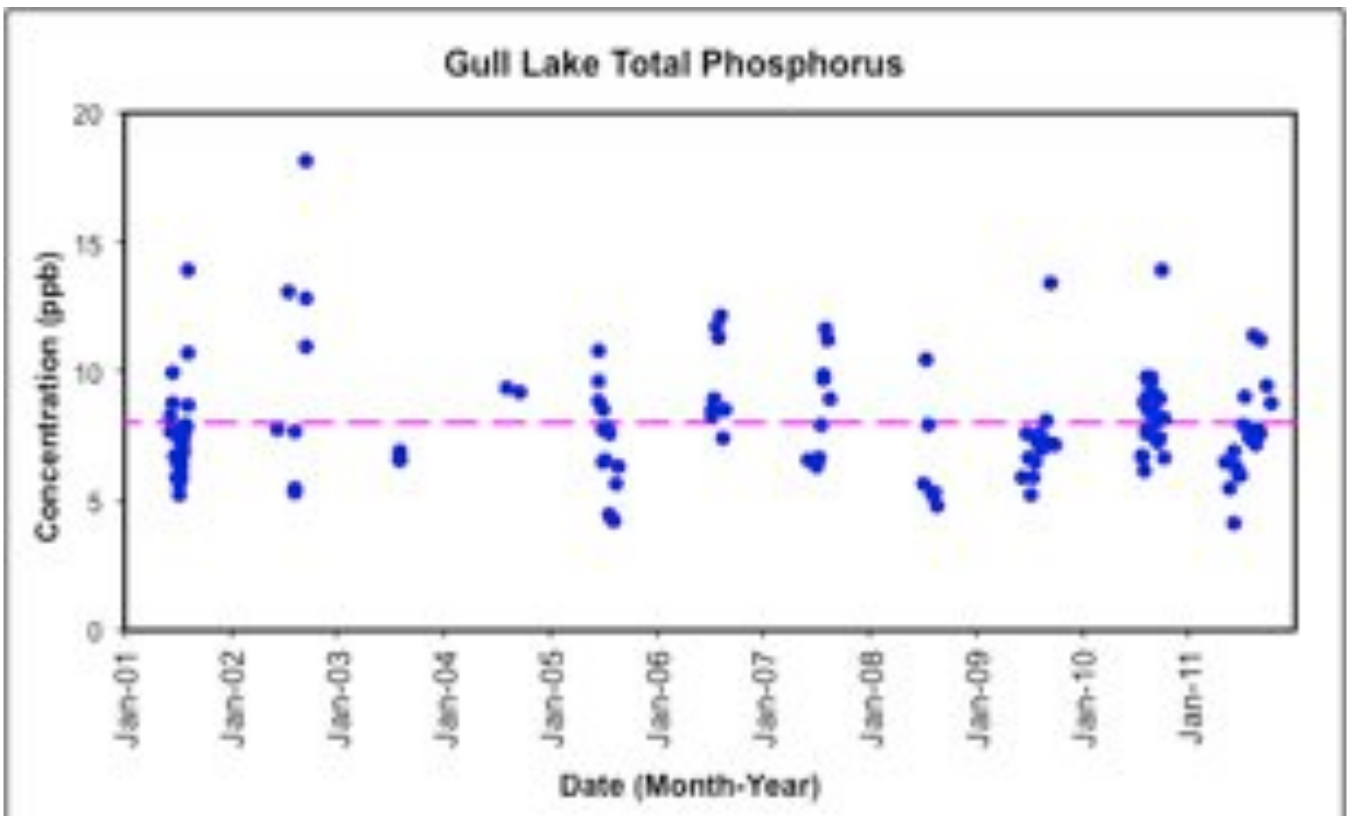
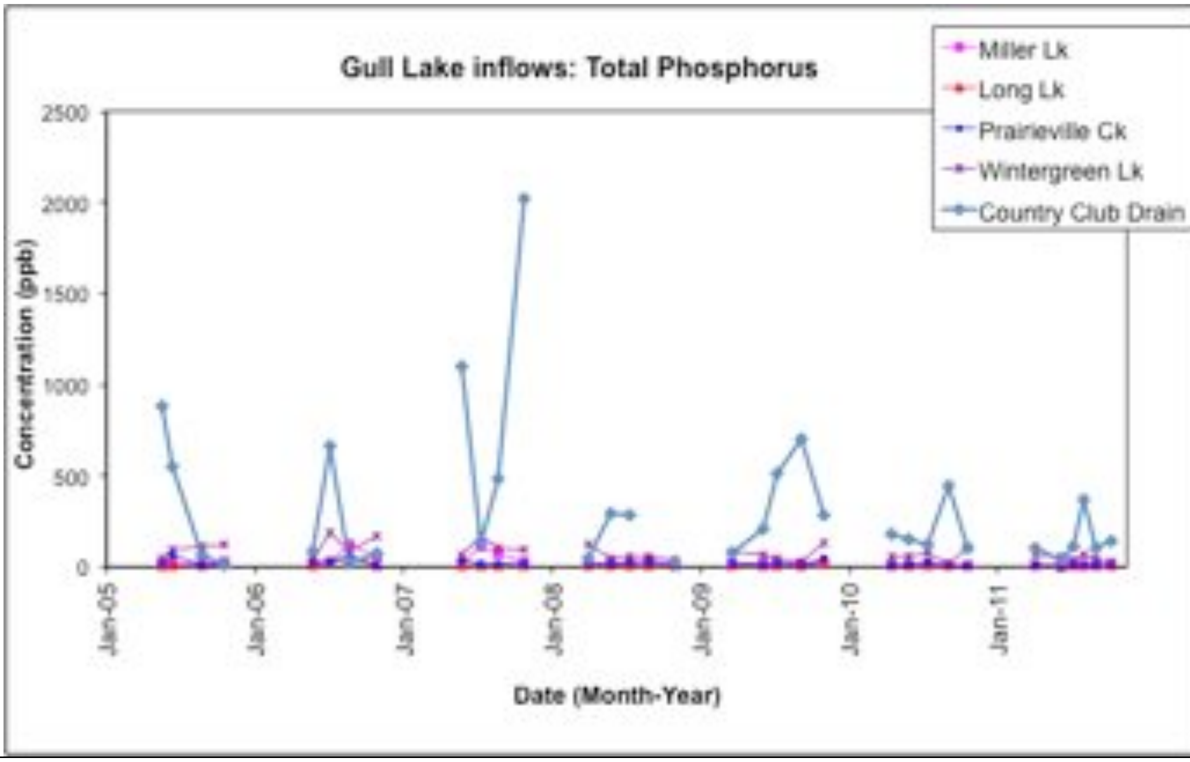


Figure 7. Total phosphorus concentrations in Gull Lake from 2001-2011. These measurements include phosphorus in algal biomass (phytoplankton). Prior to 2011 data were collected in connection with the zebra mussel research of Drs. Sarnelle and Hamilton. Dashed line shows the overall average.



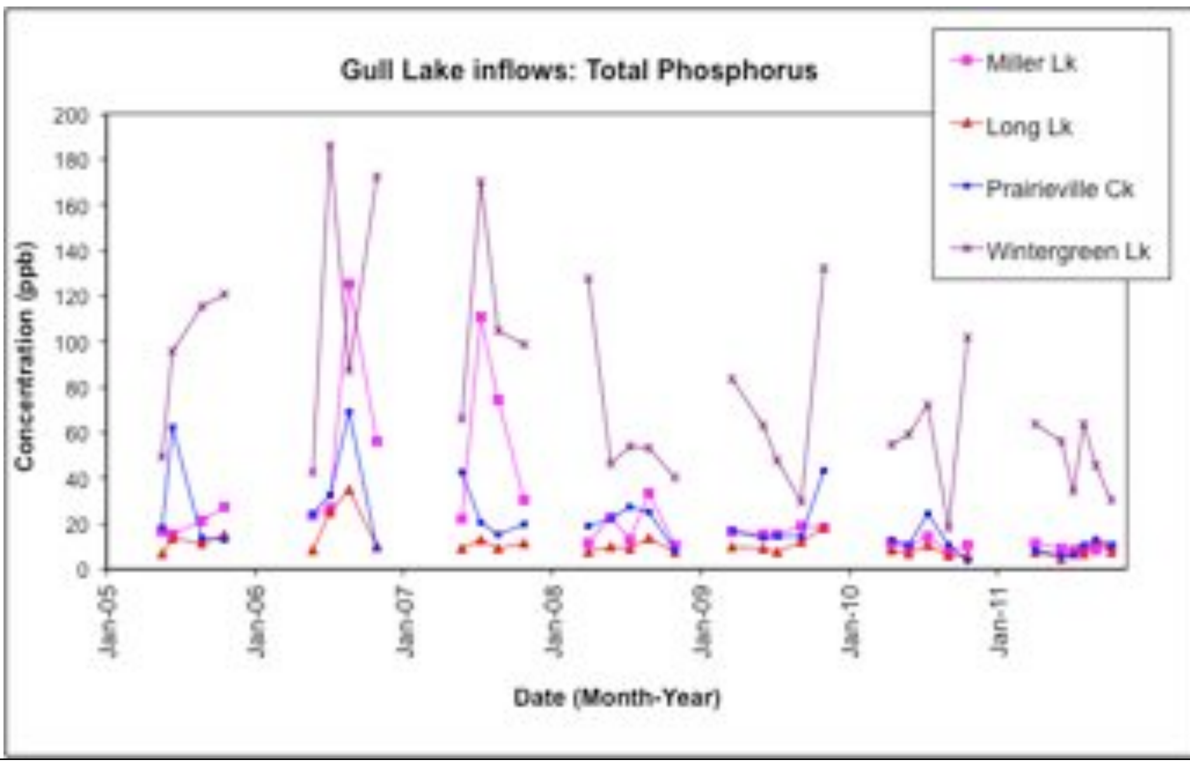


Figure 8. Total phosphorus concentrations in Gull Lake inflows from 2005-2011, shown with and without the Country Club Drain. Data collection was supported by the GLQO and measurements were made by Dr. Hamilton's lab.

Algae

The amount of algal biomass in lake water is often estimated by measuring the concentration of the main photosynthetic pigment, chlorophyll-*a*, which gives algae their green appearance. Water samples are filtered and chlorophyll is extracted from material retained on the filter, which includes algal cells. The trophic status, or level of productivity, of lakes is often ascertained from chlorophyll concentrations.

Chlorophyll concentrations show considerable year-to-year variation in Gull Lake (Figure 9). These concentrations span the range from oligotrophic to mesotrophic. Algal abundance tends to be lower in cool summers, although the controlling factors remain unclear and are the subject of ongoing research by Jeff White.

Little Long Lake chlorophyll concentrations have been sampled on multiple dates over the summer season only as part of the new 2011 monitoring (range, 2.3-8.1 ppb). A few chlorophyll measurements have been made in the past in connection with research by Dr. Alan Tessier and Dr. Carla Caceres (samplings in 1999, 2000, 2001, and 2007; range 1.1-5.1 ppb). Sippel and Hamilton (1998) reported 4.7 ppb for a summer 1998 sampling. As in the case of total phosphorus in Little Long Lake, there is no evidence for major changes over time, albeit the information base is limited.

Algal toxins can be a public health concern, particularly in lakes where blue-green algae (cyanobacteria) are abundant. The most important toxin produced in Gull Lake is probably microcystin, given the predominance of *Microcystis aeruginosa*. The dynamics of *Microcystis* and microcystin in Gull Lake are the principal focus of Jeff White's M.S. and ongoing doctoral research.

Concentrations of the microcystin toxin in Gull Lake have been measured in past years in connection with the zebra mussel research at KBS, and were measured there again in 2011. Microcystin is consistently found at measurable concentrations in the surface waters of Gull Lake during summer (Figure 10), and is generally proportional to the biomass of *Microcystis aeruginosa* (Jeff White, unpublished data). Concentrations were particularly low in 2011. The World Health Organization (WHO) has developed exposure guidelines for microcystin of 1 ppb for drinking water and 20 ppb for recreational usage (WHO 2003).

Lake users should bear in mind that *Microcystis aeruginosa* tends to form surface scums, in which case the toxin can accumulate to high levels. Therefore care should be taken to prevent people and pets from ingesting water with visible surface algal scums, which in the case of *Microcystis aeruginosa* often appear like pollen, yellow-green in color.

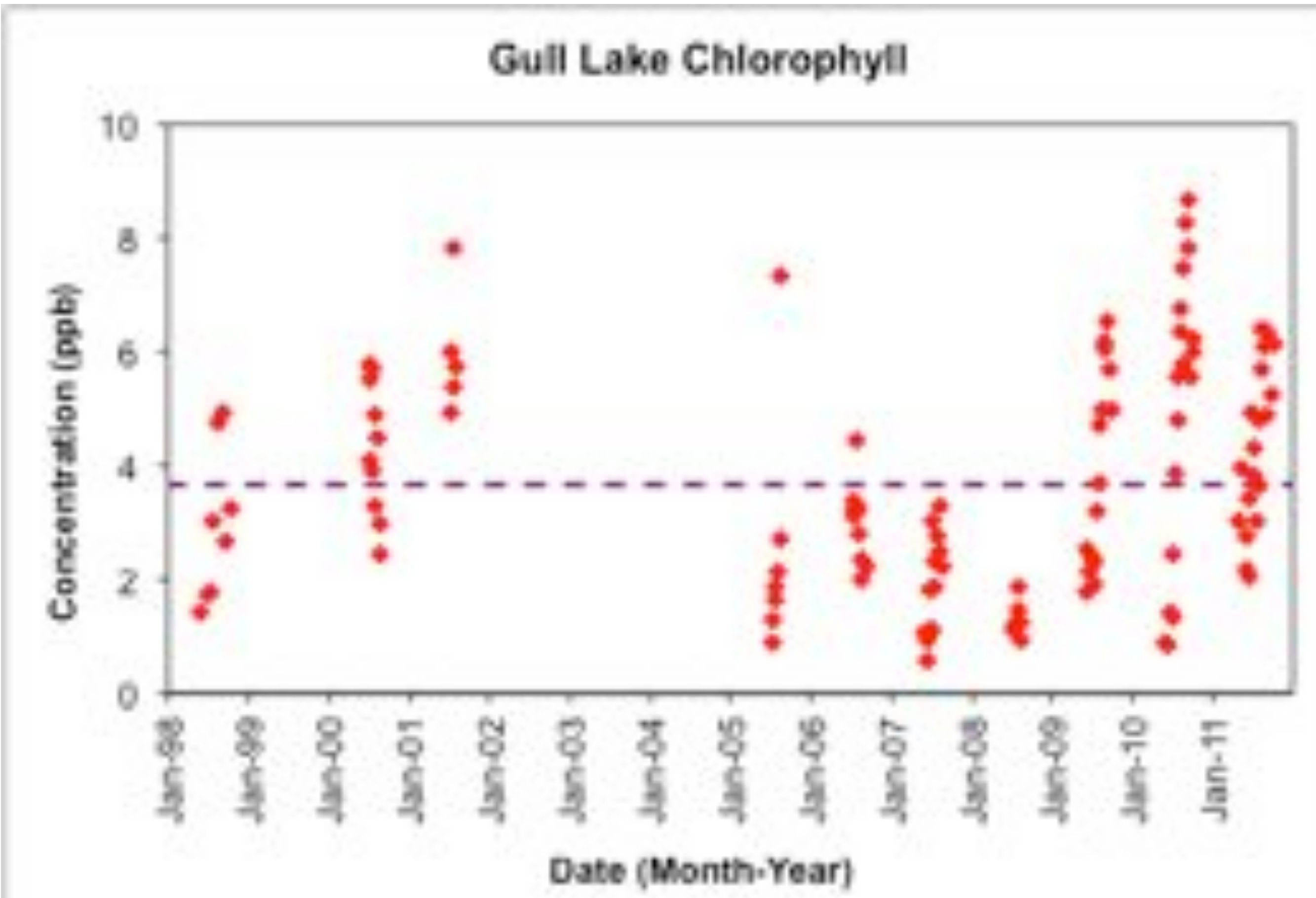


Fig. 9. Chlorophyll-a concentrations in Gull Lake from 1998-2011. These measurements are indicative of algal biomass (phytoplankton). Dashed line shows the overall average. Data from 1998-2010 were collected in connection with the zebra mussel research of Drs. Sarnelle and Hamilton.

Pesticides

Pesticide and PCB concentrations in water were measured as part of the Gull Lake Watershed Monitoring Program. Only a single sampling in late July was conducted because of the high expense of the measurements, which were made by the state MDEQ laboratory. Sampling was timed to coincide with heavy summer rainfall; 4.6 inches fell between 27-29 July. The Country Club Drain and Prairieville Creek were sampled on 28 July and Little Long Lake spring inflows were sampled on 31 July. All measurements showed undetectable concentrations. An example report (Prairieville Creek) is provided in Appendix D to show what compounds were tested for.

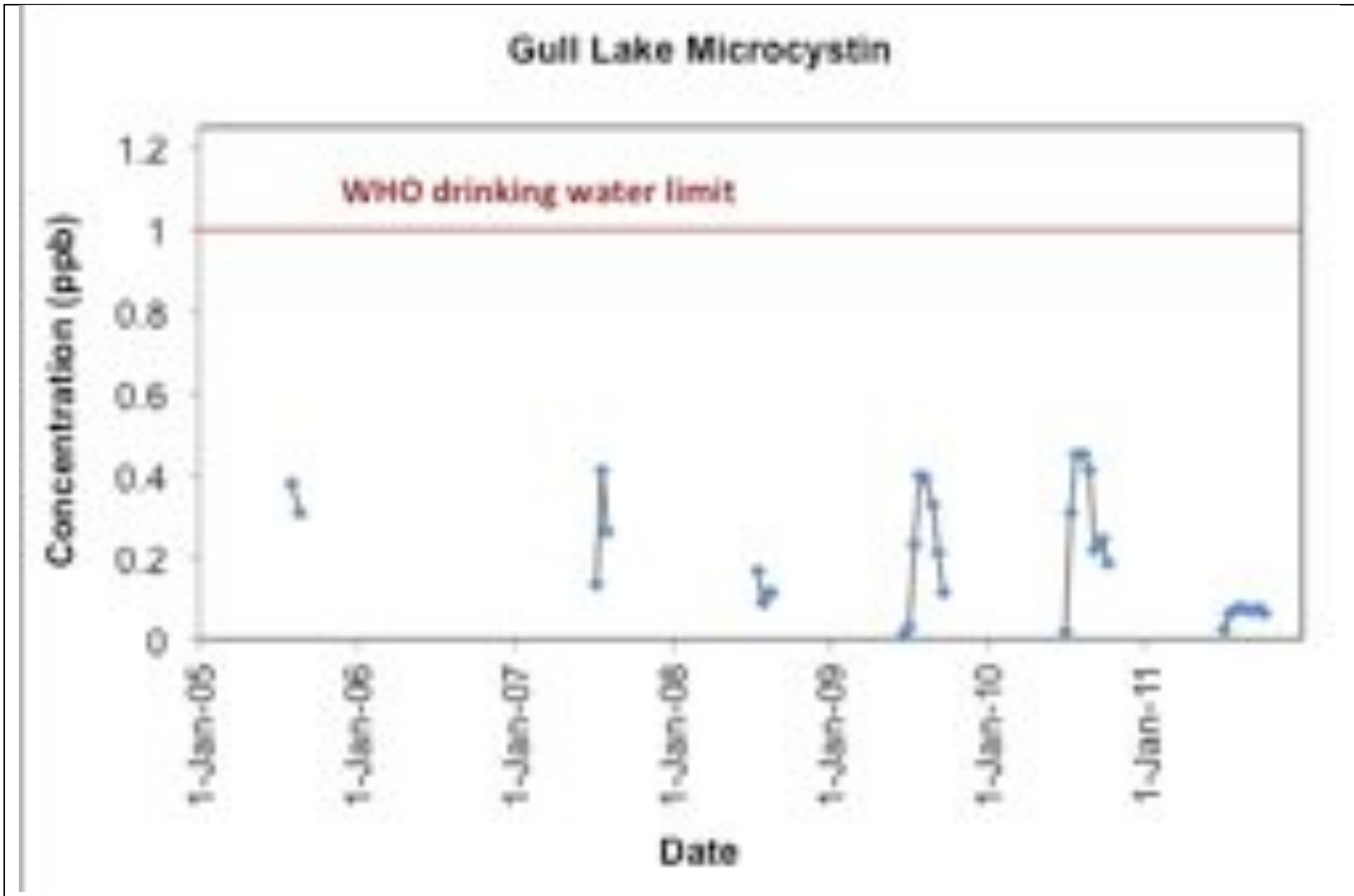


Fig. 10. Microcystin, an algal toxin, in Gull Lake surface waters. The Gull Lake measurements represent toxin collected on filters (i.e., contained in algal cells), whereas the World Health Organization limit for drinking water (1 ppb, red line) is for the total microcystin concentration (i.e., includes toxin "leaked" from cells into the water, though this dissolved fraction is probably small and of consequence only when blooms of Microcystis die back). Data were collected in connection with the zebra mussel research of Drs. Sarnelle and Hamilton.

Pathogens

E. coli bacteria have been monitored by Jeff Reicherts of Kalamazoo County Health & Community Services under a separate agreement with the GLQO, and the results are summarized in his reports to the GLQO. Sampling in 2011 included Prairieville Creek, the outflow as well as a spring-fed inflow to Little Long Lake on its southwest end, and several points along Augusta Creek, which drains the watershed to the east of the Gull Lake watershed. In addition, Gull Lake water along the Ross Township Park has been monitored as part of a longstanding bathing beach monitoring program run by Jeff Reicherts.

Stream water commonly shows high *E. coli* cell counts, sometimes exceeding standards for bathing, whereas the lake at the park has low counts.

A pilot study to examine microbial indicators of fecal pollution from humans and cattle was conducted in summer 2009 by Marc Verhougstraete and Dr. Joan Rose of MSU, and the results were recently provided as a technical report to the GLQO. Sampling was conducted at two locations (Prairieville and Augusta creeks) over two time periods. The July sampling represented relatively dry conditions and stable summer flow whereas a later sampling in October represented a period of higher and variable flow. A suite of indicators was examined, each with its advantages and disadvantages.

Culture-based assays provided estimates of the abundance of *E. coli*, Enterococci, *Clostridium perfringens,* and Coliphage (viruses that grow on bacteria). Both creeks carried concentrations of fecal bacteria that are high by public health standards. Notably, concentrations were high even in July when there had been no recent rain and runoff, and the Coliphage data suggested that this contamination had occurred in the recent past. Molecular analyses that provide highly sensitive markers for fecal bacteria originating from either humans or cattle showed no evidence for contamination from those sources.

Taken together, these source tracking results suggest that warm-blooded wildlife were the likely source of fecal bacteria in these streams. Deer, raccoons, geese, and other wildlife frequent the wetlands and riparian areas and they are much more likely to be the source of contamination in times when there is no runoff from more distant upland areas. These results must be considered preliminary given that the limited amount of sampling did not cover late winter and early spring, the most likely time for microbial contamination from upland sources to reach streams by surface runoff.

OTHER OBSERVATIONS

Zebra Mussel Die-offs in Gull Lake

Zebra mussels (*Dreissena polymorpha*) are an invasive aquatic mollusk from Asia that spread through the Great Lakes in the late 1980s and appeared in Gull Lake in the early 1990s. Since their establishment in Gull Lake they have maintained high densities wherever the sediments are not too soft. By 2007 the zebra mussels had established a population in Little Long Lake but did not reach such high densities there because of the prevalence of soft marl sediment.

A major die-off of Gull Lake zebra mussels was observed by KBS researchers in the first week of August 2010 (Figure 11). Along KBS there was near complete mortality down to around 10 feet of depth. This die-off coincided with very warm water temperatures, and these mussels are known to become stressed when water temperature exceeds about 80°F. Surprisingly, however, a similar die-off was not observed in the shallow waters of Little Long Lake, which reached similar maximum temperatures based on 2011 observations.

By autumn 2010 the zebra mussels had recolonized the shallow waters of Gull Lake as larvae, likely released by surviving mussels in cooler, deeper waters, settled and developed into small mussels. The summer of 2011 also brought high water temperatures (in excess of 85°F in the shallows), and high mussel mortality was again observed in these shallower waters. These events must have reduced the ecological impact of zebra mussels on the lake, including particularly their promotion of *Microcystis* and its associated toxin, microcystin (Figure 10). This is a topic of ongoing study by Jeff White that includes placing caged mussels at various depths along with temperature loggers; results from 2011 are shown in Figure 12.

Fig. 11. Recently expired zebra mussels from about 8 feet depth in Gull Lake following high summer temperatures. Photo taken on 17 Aug 2010.

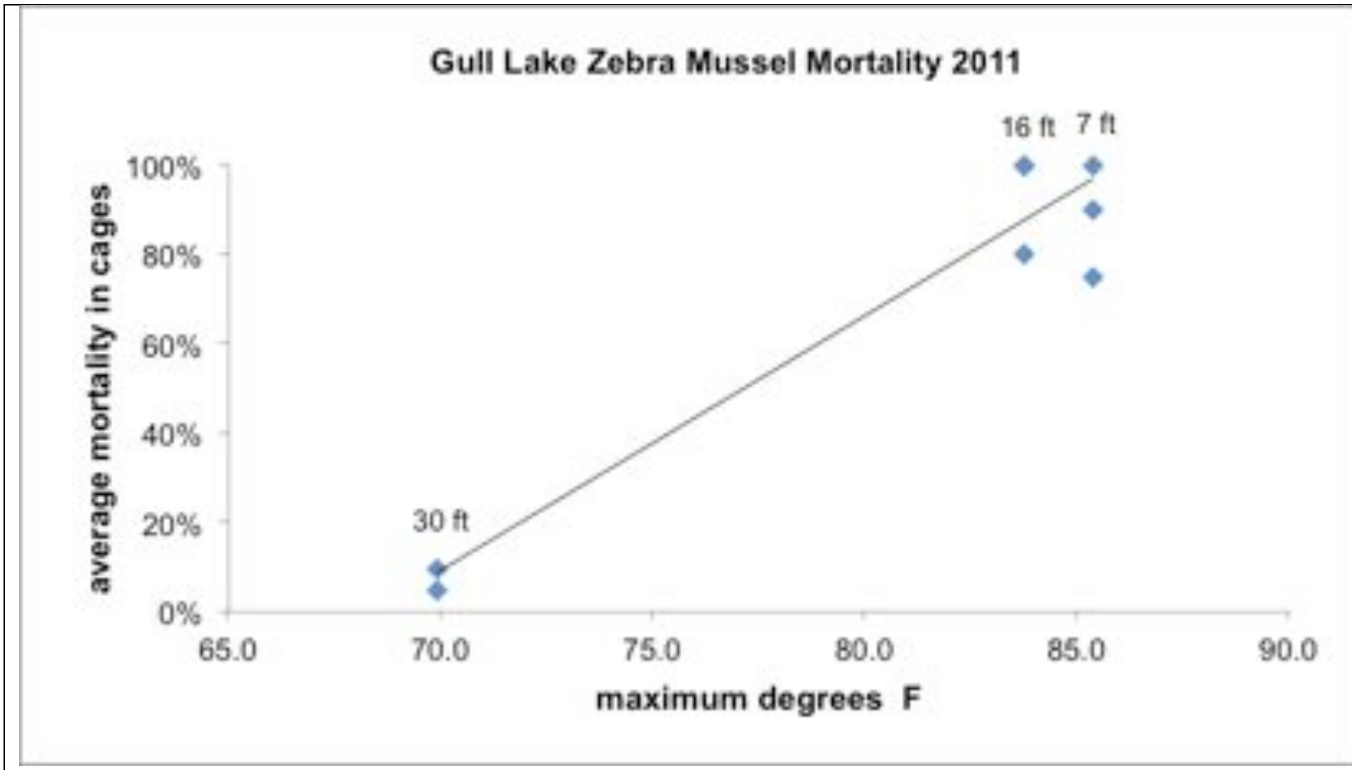


Fig. 12. Mortality results from a study of zebra mussel population dynamics in Gull Lake, 2011 (Jeff White, unpublished data). Cages containing mussels were placed at 3 depths: 7, 16, and 30 ft in June, along with continuous temperature loggers. Cages were retrieved in November. Survival, death, and reproduction were assessed. There was a highly significant relationship between mortality rate and maximum water temperature at depth.

Expanding Sedge in Little Long Lake

Residents on the west side of Little Long Lake reported that a new plant had appeared in the lake in recent years, producing nearly pure stands, and that the extent of those stands had been expanding to the point where they were becoming a nuisance. Dr. Stephen Hamilton visited the sites and determined that the plant is a native sedge known as the jointed spikesedge (*Eleocharis equisetoides*), which is considered uncommon in Michigan as well as in Wisconsin and Ontario. Dr. Hamilton submitted a report to the Michigan Natural Features Inventory (Appendix B) to document this occurrence, and he subsequently submitted another report of this plant for Otis Lake in Barry County. While uncommon, this plant probably occurs in more lakes than records suggest, and hence better documentation of its distribution is important.

The reason for its dramatic appearance—or perhaps resurgence—in Little Long Lake remains an enigma. The lake is hydrologically stable and no changes in nutrient availability or water chemistry are known to have taken place in recent years. Most of the new stands are found along the western edge of the lake, where groundwater inflows are high, but there is also a stand in the northeastern corner, where there may be less groundwater inflow.

Little Long Lake Springs

Little Long Lake has several groundwater springs entering along its western edge that are large enough to be sampled for water quality. The water flow of these springs is small (total ~ 5 liters/second) compared to that of the lake outflow (annual mean, 76 L/s: Tessier 1995 study), and given that the lake chemistry is indicative of groundwater dominance much more groundwater must enter directly through the lake bed. Nonetheless, the springs may represent the chemistry of groundwater entering the lake. The springs were sampled on 5 January, 5 July, and 31 July 2011 (the latter date followed several days of heavy rainfall). Results for total phosphorus and nitrate are compared with the lake average for 2011 (surface water) in the table below.

	Lake average summer 2011	**Southwest inflow spring**	**Spring near Locke Lane**	**Northwest Bay inflow spring**
Total Phosphorus* (ppb)	7.7	9.5, 10, 28	3.8, 2.4, 2.3	2.2, 9.2, 5.0
Nitrate (ppb as N)	660	1800, 1500, 1300	8700, 9100, 7000	1600, 400, 300
Ammonium (ppb as N)	85	50, 35, 40	3, 2.5, 5.6	140, 80, 78

* *Total phosphorus in the springs was measured on filtered water due to the difficulty of avoiding resuspended sediment during sampling of very shallow water.*

These data as well as other measurements not reported here show a typical chemical composition for local groundwater emanating from watersheds dominated by row-crop agriculture. The somewhat higher phosphorus concentration in the southwest inflow could explain the localized abundance of filamentous algae around the inflow point. Pesticides were also measured in the Southwest Inflow and Locke Lane springs on the 31 July sampling; none were detected (see above).

Gull Lake Ice Cover

Gull Lake has one of the longest ice cover observation records for Michigan lakes. Over the past 60 years the duration of ice cover has been decreasing in many inland lakes throughout the Northern Hemisphere, and this is thought to reflect a warming climate. The Gull Lake ice record shown in Figure 13 shows this long-term decrease since 1955. . The declining trend for the entire time series (1920s to present) is not statistically significant due to minimal ice cover during the early 1930s (the Dust Bowl). The ecological implications of diminished ice cover duration are uncertain.

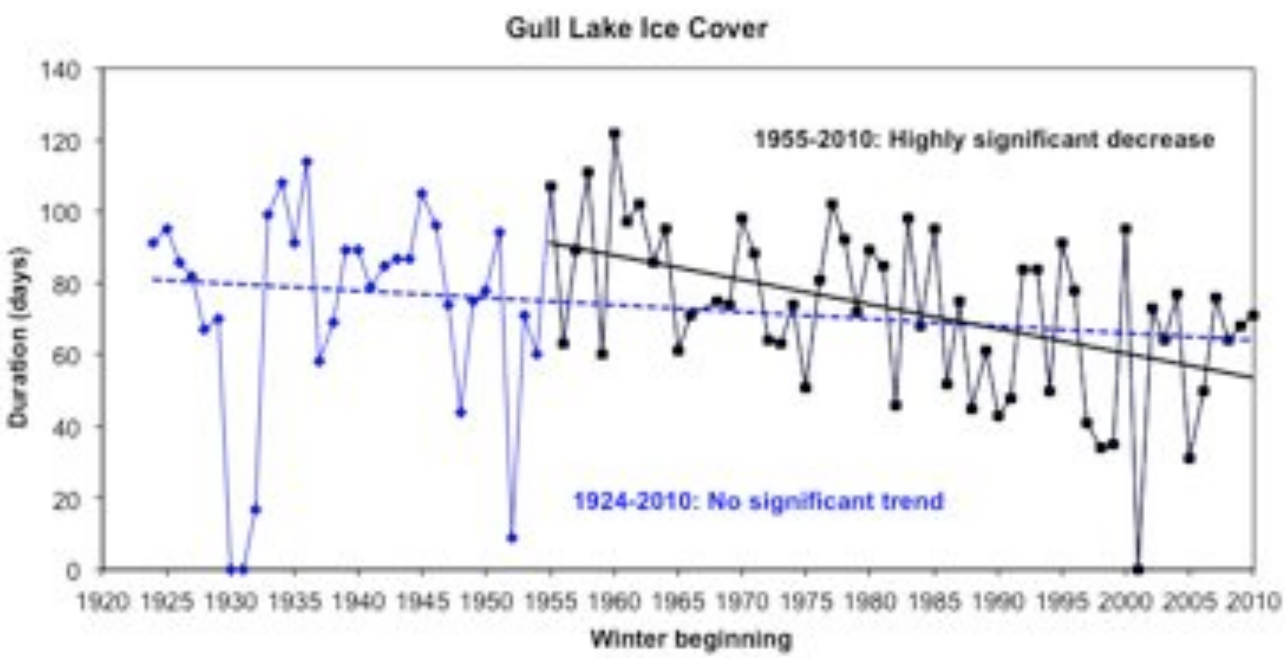


Fig. 13. Duration of ice cover in Gull Lake since the winter of 1924-25. Data collected by the GLQO and its predecessor organizations, and by Dr. Stephen Hamilton since 1995. Trend lines were estimated by linear regression. The x-axis labels represent the year beginning each winter (e.g., 1975 = Winter 1975-76).

SUMMARY

The summer of 2011 was not particularly unusual for Gull Lake in comparison to available information for the preceding decade. High water temperatures coincided with reduced transparency and high peak chlorophyll concentrations, as has been observed in some other warm summers. High water temperatures also appear to have caused mortality of zebra mussels in shallow waters, something that has only been observed before in one other summer (2010). The algal toxin microcystin was present in lower concentrations in 2011 than usual, possibly related to the decline in zebra mussel activity. The nutrient content of Gull Lake inflows varied over a range similar to what has been observed in recent years. A number of pesticides were measured in inflowing waters to Gull and Little Long lakes once after summer rains but none was found to be detectable.

Little Long Lake has much less information available from previous years, and 2011 marks the start of an improved information base on this lake. Its outflow stream has been sampled since 2005, and measurements from 2011 did not look unusual. An expanding population of an evidently uncommon sedge was investigated and documented, yet its cause remains a mystery.

Lakeside landowners can help protect the good water quality of Gull and Little Long lakes. Most important is to be careful with fertilizer and other nutrient sources in close proximity to the lakes and inflow streams. These particular lakes would respond strongly to any increase in phosphorus inputs. Lawn and garden fertilizers should be used sparingly and those used near water should not contain phosphorus, which is often not needed anyway. Eroded soil, pet waste, ashes from leaf burning, and piled leaves or grass clippings can also be sources of phosphorus and would best be avoided in areas close to the water's edge, or where storm drains conduct water from impervious surfaces and ditches into the nearest water body. Geese and ducks can deposit nutrient-rich excrement in and along the water as well as contribute to pathogen problems, so feeding or otherwise encouraging their congregation on a shoreline is not recommended.

Wetlands and natural vegetation provide excellent buffers to filter out sediments and nutrients from water heading towards lakes and streams. Lakeside landscaping can provide a buffer between turf grass and other nutrient sources and the water's edge, and it discourages geese and ducks from loitering there while promoting more diverse native plants and wildlife. Demonstration projects are in place along the Gull Lake shoreline at Kellogg Biological Station, and information is available at http://www.shoreline.msu.edu/.

Agricultural best management practices should be strictly adhered to, and land disposal of manure should be done carefully in the vicinity of water bodies. Conservation easements in the Prairieville Creek watershed, established recently with involvement of the Southwest Michigan Land Conservancy and the Four Township Water Resources Council, help guard against unwise new development that could negatively impact water quality.

A Watershed Management Plan for Gull Lake and nearby watersheds, developed in 2010 by the Four Township Water Resources Council, contains an abundance of information as well as maps and proposed riparian buffer zones where protection of water quality should be a priority (http://www.ftwrc.org/).

ACKNOWLEDGEMENTS

We are grateful to the Gull Lake Quality Organization for supporting the stream sampling since 2005 and the lake sampling in 2011. Many people contributed to the collection of data depicted in this report from before 2011, including students and technicians at KBS and MSU, and we particularly thank David Weed of KBS for lab work. Research grant funding was provided by the Michigan Sea Grant, the U.S. Environmental Protection Agency, the National Science Foundation (Long-term Ecological Research program), and the Kalamazoo Community Foundation. Drs. Gary Mittelbach of KBS and Orlando Sarnelle of MSU provided helpful suggestions.

REFERENCES

Sippel, S.J. and S.K. Hamilton. 1998. Four-township water atlas: A guide to the water resources in the townships of Barry and Prairieville (Barry County) and Richland and Ross (Kalamazoo County). Four-Township Water Resources Council, Inc. 58 pp.

Tague, D.T. 1977. The hydrologic and total phosphorus budgets of Gull Lake, Michigan. Master of Science thesis, Dept. of Fisheries and Wildlife, Michigan State University.

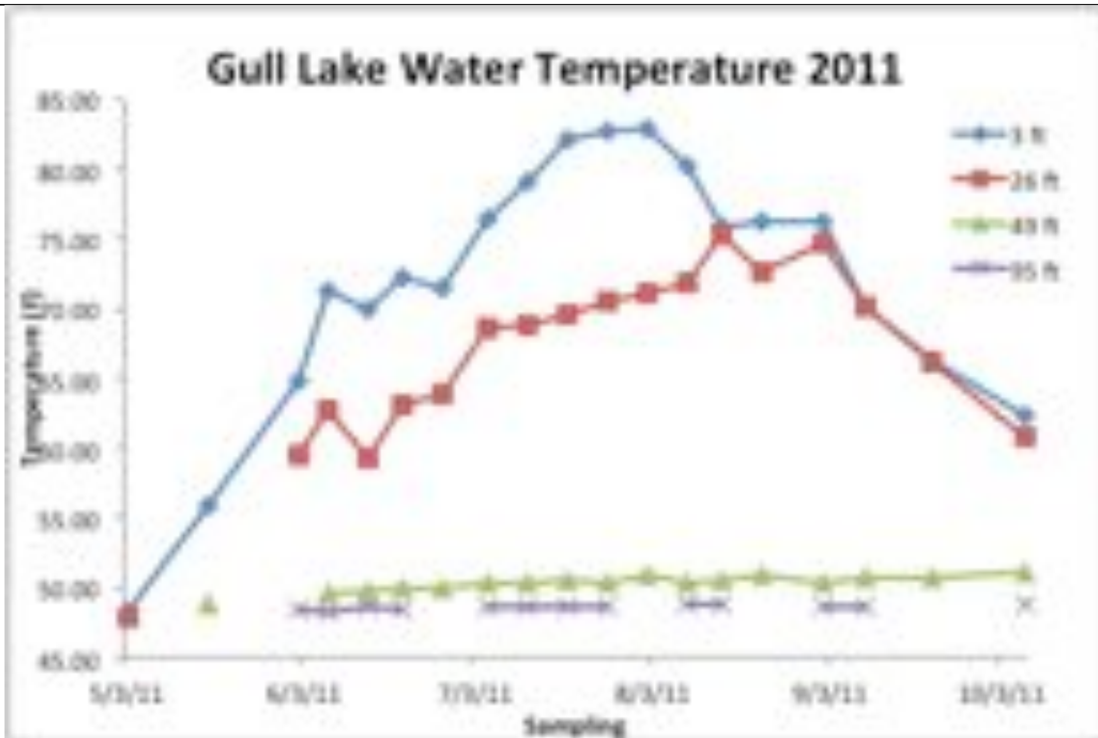
Tessier, A.J. and G.H. Lauff. 1992. The Gull Lake story. The Michigan Riparian, February 1992.

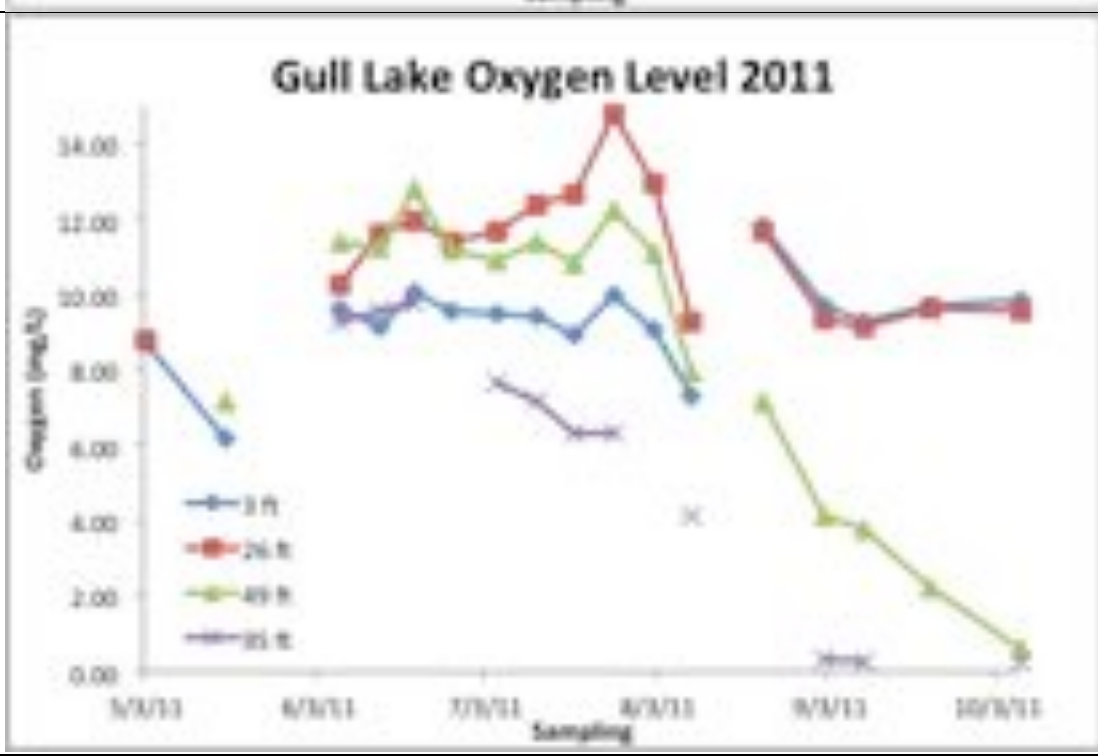
Tessier, A.J. 1995. Gull Lake Phosphorus Study. Unpublished report available in the KBS library.

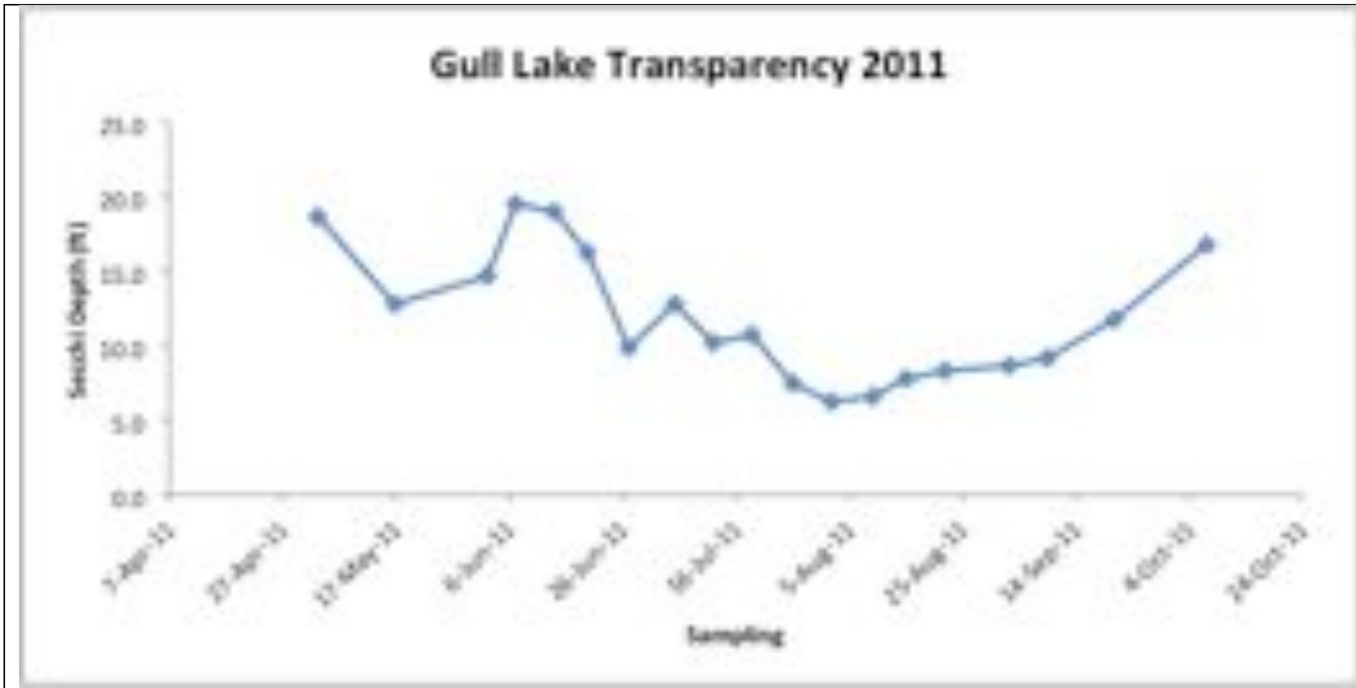
WHO. 2003. Ch. 8: Algae and cyanobacteria in fresh water, *in* Guidelines for safe recreational water environments: coastal and fresh waters, vol. 1. Report available at: http://whqlibdoc.who.int/publications/2003/9241545801.pdf

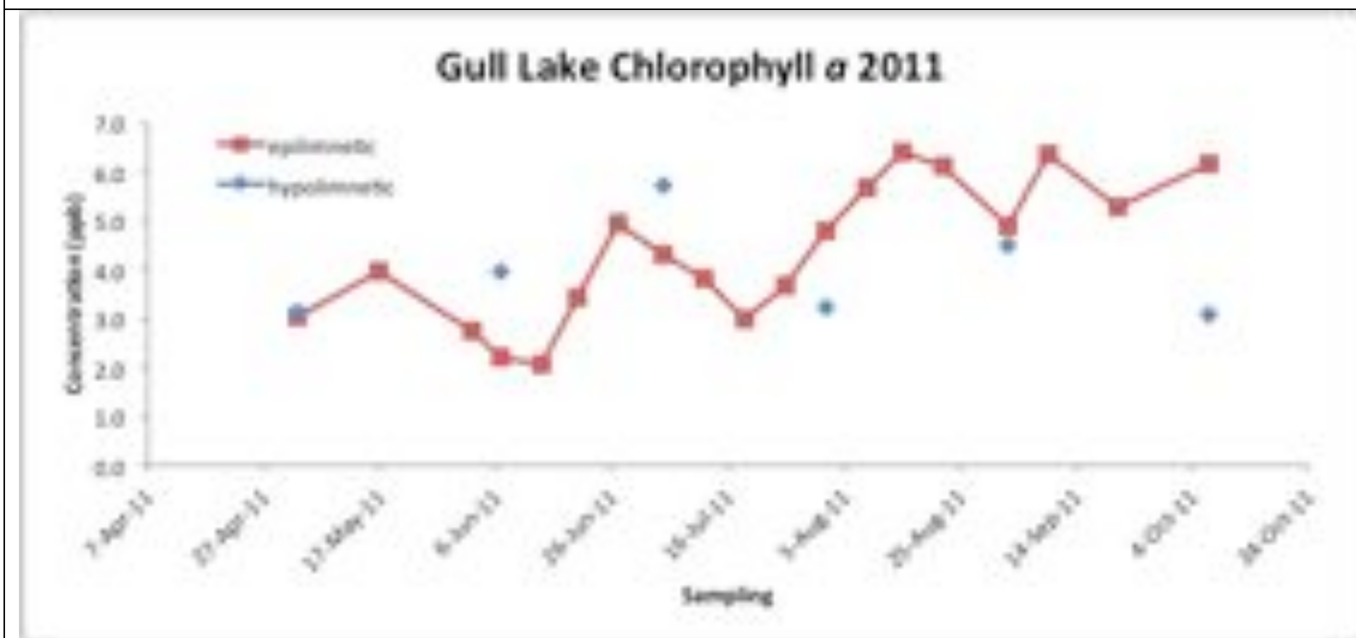
APPENDIX A: DETAILED DATA FROM 2011

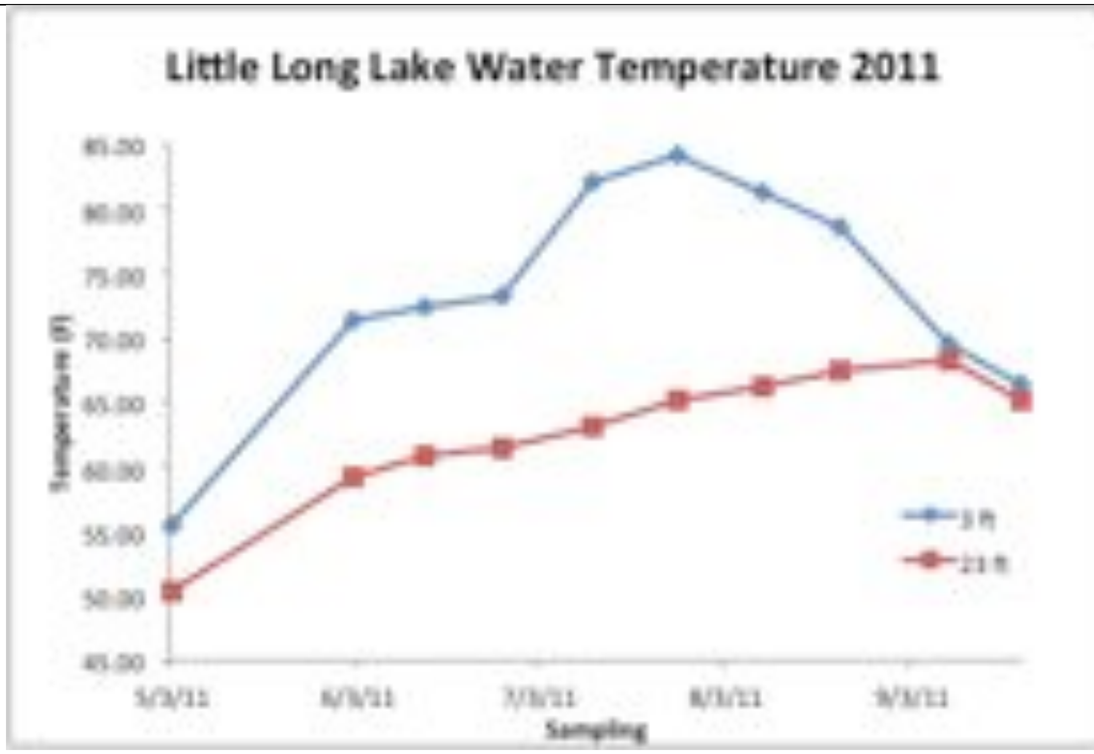
Selected variables measured during the 2011 sampling season are depicted here to better visualize the seasonal changes.

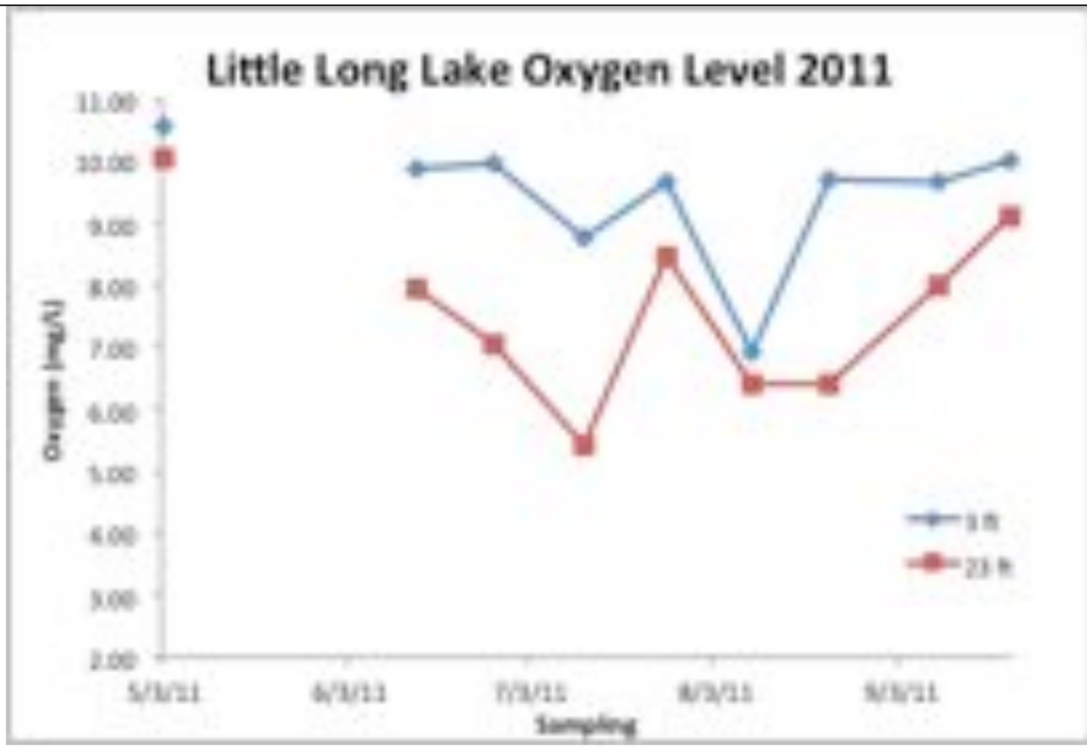


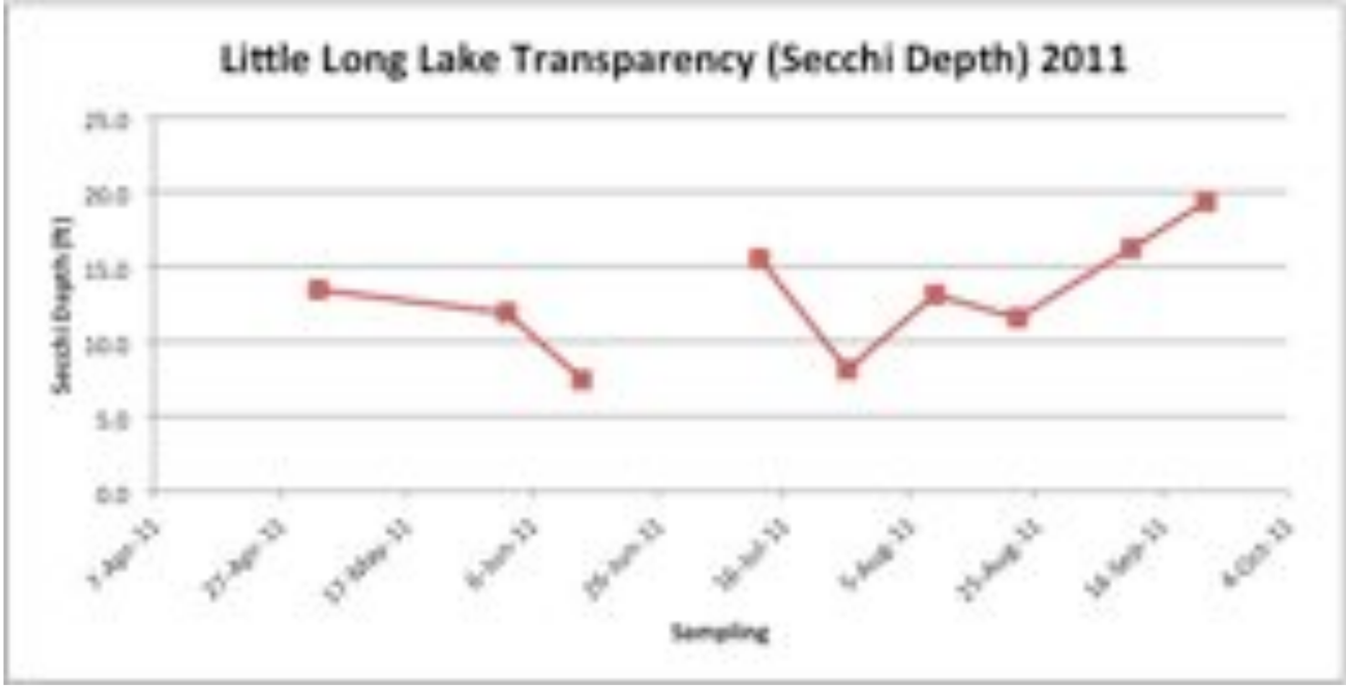


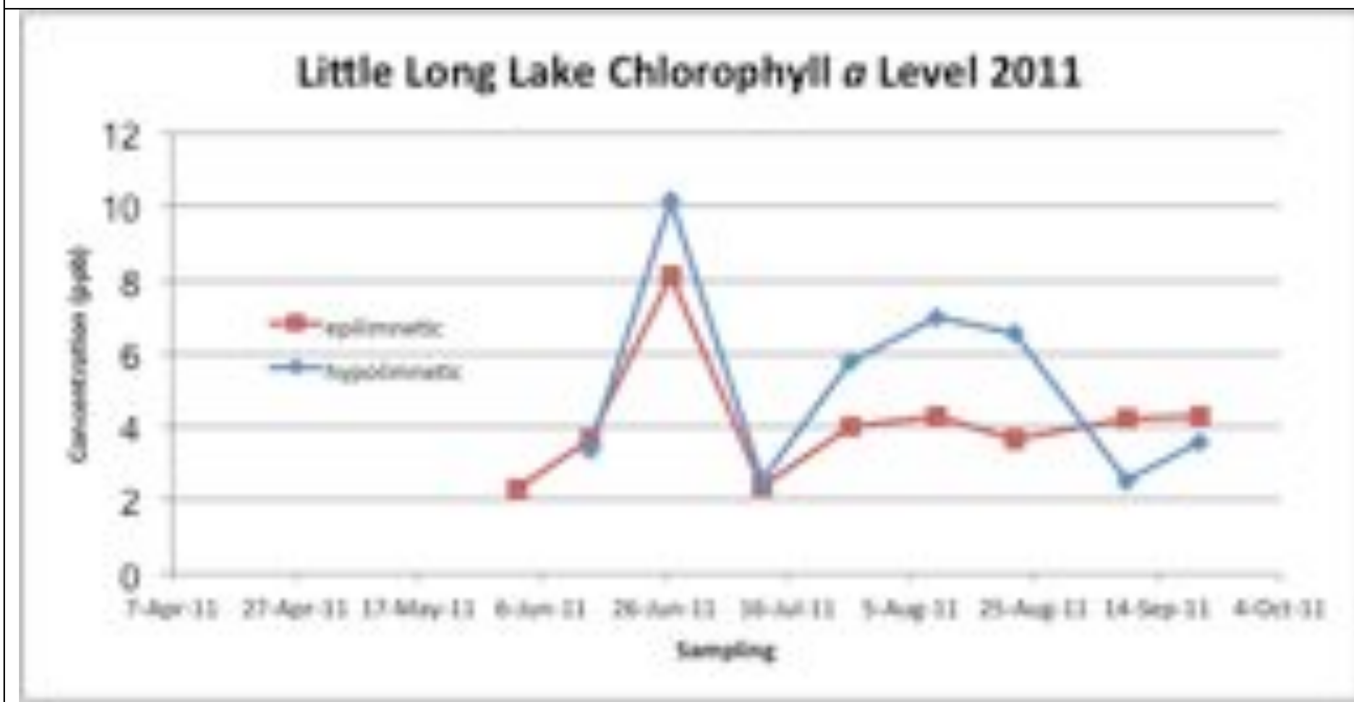

Gull Lake Transparency 2011
Sampling


Gull Lake Chlorophyll *a* 2011
Sampling


Little Long Lake Water Temperature 2011
Temperature (F)
Sampling


Little Long Lake Oxygen Level 2011
Oxygen (mg/L)
Sampling


Little Long Lake Transparency (Secchi Depth) 2011
Secchi Depth (ft)
25.0
20.0
15.0
10.0
5.0
0.0
Sampling


Little Long Lake Chlorophyll a Level 2011
Concentration (ppb)
12
10
8
6
4
2
0
epilimnetic
hypolimnetic
7-Apr-11
27-Apr-11
17-May-11
6-Jun-11
26-Jun-11
16-Jul-11
5-Aug-11
25-Aug-11
14-Sep-11
4-Oct-11
Sampling

APPENDIX B: NEW PLANT OBSERVATION FOR LITTLE LONG LAKE

Dr. Stephen Hamilton investigated a new and expanding plant population in Little Long Lake and filed the report below to the Michigan Natural Features Inventory. Subsequently he located another population in Otis Lake (Barry County). It is important to document such occurrences because apparently uncommon plants may be underreported.

Michigan Natural Features Inventory

MNFI Special Species Form

MICHIGAN STATE UNIVERSITY EXTENSION

SURVEY INFORMATION

Species identified: **Eleocharis equisetoides (Elliot) Torr. jointed spikesedge** Phone or e-mail: hamilton@kbs.msu.edu Survey date: 31 Oct 2010

Surveyors (principal surveyor first, include first & last name):
Stephen Hamilton

Voucher/Collection#:
(permit required)

LOCATIONAL INFORMATION

County: Kalamazoo + Barry Township/Range/Section: T.1S and T.1N, R.10W USGS Topo Quad: Delton

Latitude: 42º 25' 21" N Longitude: 85º 26' 52" W

DIRECTIONS: Provide detailed directions to the observation (rather than the survey site). Include landmarks, roads, towns, distances, compass directions.

Several discrete stands have become conspicuous in past 5-10 years along the west-central edge of the lake, and in the far northeast end. Also there is a sparse stand on a shallow bar in the center of the northern part of the lake.

HABITAT DATA:
List associated species. For plants, please list at least 6 species in order of dominance, beginning with overstory if present. Restrict associates to immediate habitat.

Only associated emergent plant is bulrush (probably Schoenoplectus acutus). Sparse submersed vegetation includes Potamogeton spp. and patches of Chara sp.

Describe microhabitat. Focus on exactly where species occurs and apparent favoring/limiting factors. Include relevant info. on soils, micro-topography, moisture conditions, etc.

Growing among bulrushes or in pure stands. Sediments are fine and marly and there are indications of groundwater emergence in the vicinity. Depth range within stands is 70-105 cm and the lake has a very stable water level (it supports an outflow stream all year). Lakeside vegetation is fen wetland in low areas although much is covered with glossy buckthorn (Frangula alnus). Residential development lines more than half of the lakeshore and most has been present for many years.

Estimate of habitat extent: 1,000? per area unit: ☒ meters^2 ☐ kilometers^2 ☐ feet^2 ☐ acres

POPULATION SIZE, EXTENT AND CONDITION: Total # of individuals: Countless shoo ☒ estimate ☐ actual count

Phenology (plants): % flowering: 0 % fruiting: 10 Apparent vigor (plants): Already undergoing autumn senescence at time of observation.

Population Age Structure (animals): # adults ____ # juveniles ____

Evidence of reproduction: Seeds still present on plants but most spread looks likely to be via rhizomes.

CONSERVATION DATA

Overall Site Quality: ◉ Excellent ○ Good ○ Fair ○ Poor

Disturbance to organisms or habitat:
Some powerboat use occurs on this lake but no evidence of damage to stands, which appear to be robust.

Threats or need for protection (immediate? long term?):
Lakeside residents likely will need to clear some areas to maintain access.

Other information needs (survey, monitoring, etc):
Stands appear to be expanding and may come to dominate the shallow areas of the lake.

Other comments related to observation:
Michael Penskar of DNRE agreed with Hamilton's identification.

Michigan Natural Features Inventory, P.O.Box 30444, Lansing, MI 48909-7944 PHONE: (517) 373-1552

NOTE: All images and maps uploaded and submitted help expedite transcription of this information into the Natural Heritage Database. This type of information allows MNFI staff to verify species and locations to ensure accurate information is entered at all times. Please call us if you have any questions on how to complete this form.

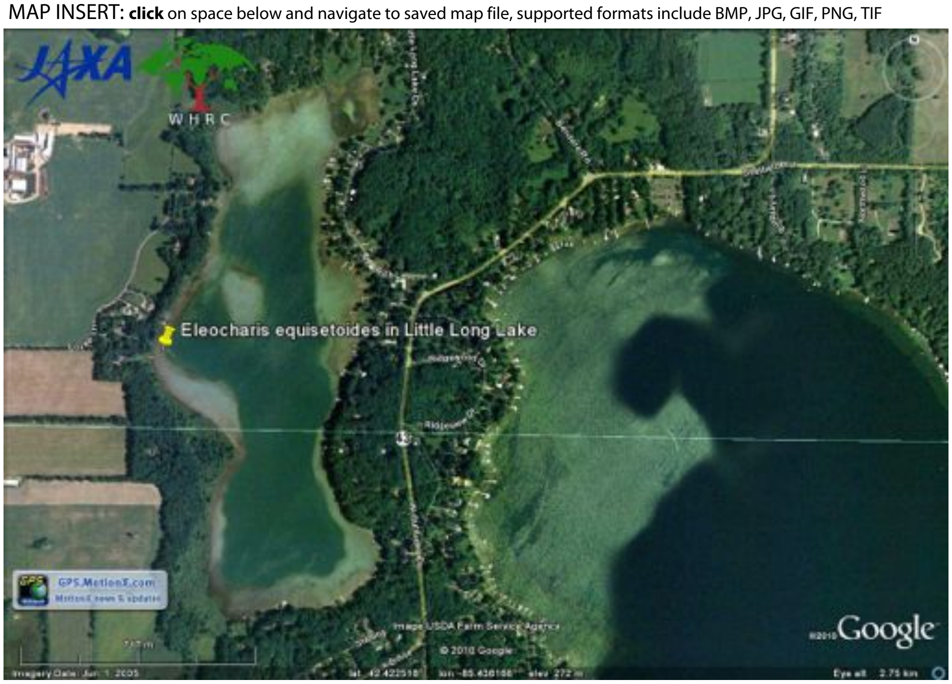
IMAGE INSERT: **click** on space below and navigate to saved photo, supported formats include BMP, JPG, GIF, PNG, TIF

IMAGE INSERT: **click** on space below and navigate to saved photo, supported formats include BMP, JPG, GIF, PNG, TIF

IMAGE INSERT: **click** on space below and navigate to saved photo, supported formats include BMP, JPG, GIF, PNG, TIF

IMAGE INSERT: **click** on space below and navigate to saved photo, supported formats include BMP, JPG, GIF, PNG, TIF

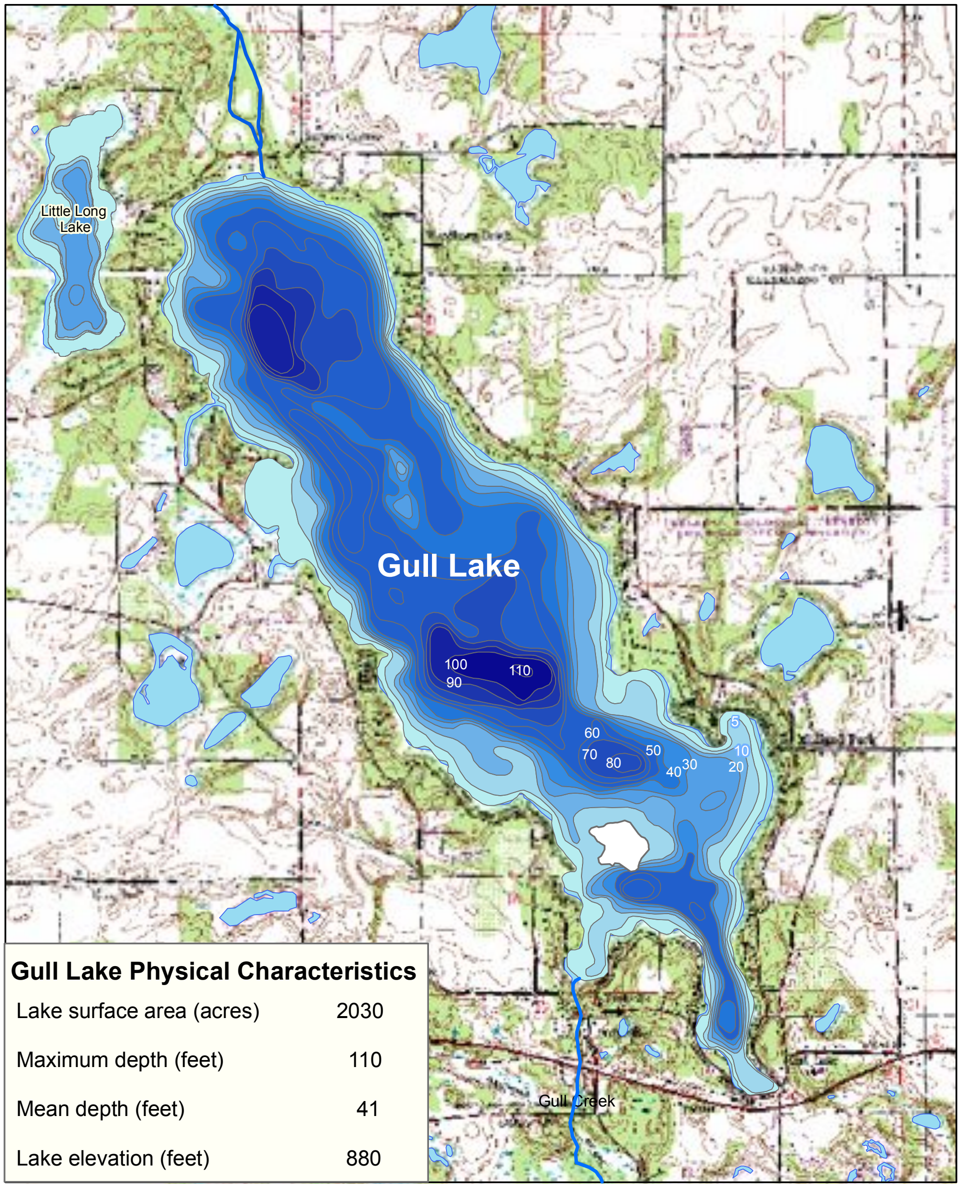
MAP INSERT: **click** on space below and navigate to saved map file, supported formats include BMP, JPG, GIF, PNG, TIF



APPENDIX C: BATHYMETRIC MAPS

Maps of bathymetry (depths in feet).

Gull Lake Depth Contour Map



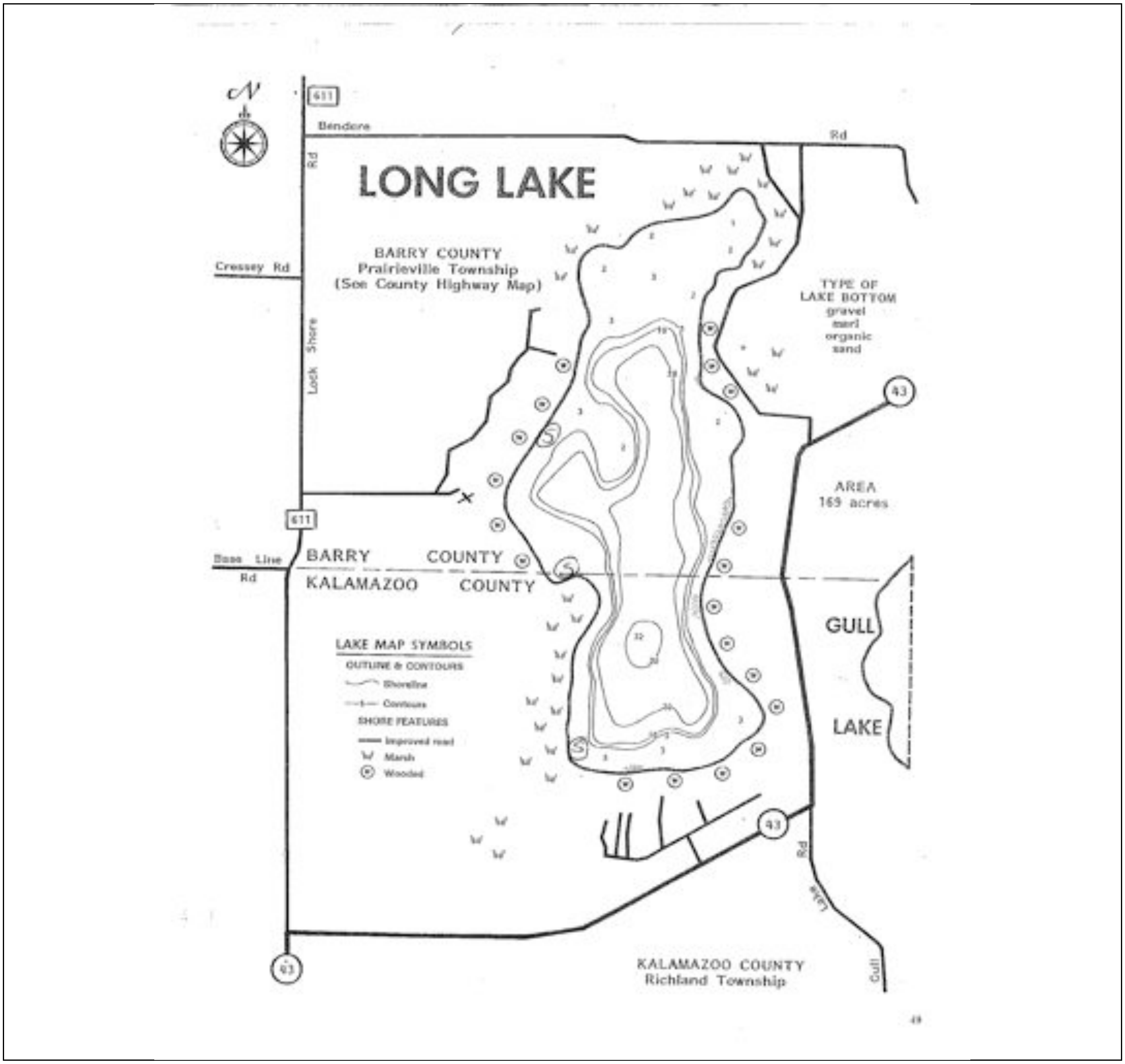
Gull Lake Physical Characteristics

Lake surface area (acres)	2030
Maximum depth (feet)	110
Mean depth (feet)	41
Lake elevation (feet)	880

0 0.5 1 Miles

Four Township Water Resources Council
Prairievile and Barry Townships, Barry County
Richland and Ross Townships, Kalamazoo County

Map prepared by Kellogg Biological Station,
Michigan State University, GIS Lab, June 2007


LONG LAKE
N
611
Bendore
Rd
Rd
Cressey Rd
Lock Shore
BARRY COUNTY
Prairieville Township
(See County Highway Map)
TYPE OF
LAKE BOTTOM
gravel
marl
organic
sand
43
AREA
169 acres
611
Base Line
Rd
BARRY COUNTY
KALAMAZOO COUNTY
GULL
LAKE
LAKE MAP SYMBOLS
OUTLINE & CONTOURS
Shoreline
Contours
SHORE FEATURES
Improved road
Marsh
Wooded
43
Rd
Lake
43
KALAMAZOO COUNTY
Richland Township
Gull

APPENDIX D: PESTICIDE MEASUREMENTS

The MDEQ lab report for Prairieville Creek is provided here as an example to show what pesticide and PCB compounds were analyzed in the 2011 water samples. None of these was detectable in the water samples collected from Prairieville Creek, Little Long Lake inflow springs, and the Country Club Drain.

MICHIGAN DEPARTMENT OF ENVIRONMENTAL QUALITY
DRINKING WATER LABORATORY
USEPA Region V Drinking Water Cert. No. MI00003
P.O. Box 30270
Lansing, MI 48909
TEL: (517) 335-8184
FAX: (517) 335-8562

Sample Number
LD93520

Official Laboratory Report

Report To: JEFFREY WHITE
13 NATURAL RESOURCES BLDG MSU
EAST LANSING MI 48824

System Name/Owner:		WSSN/Pool ID:	
Collection Address:	PRAIRIEVILLE CREEK,	Source:	Surface Water
Collected By:	STEVE HAMILTON	Site Code:	
Township/Well#/Section:	PRAIRIEVILLE//	Collector:	Other
County:	Kalamazoo	Date Collected:	07/28/2011 10:00
Sample Point:	AT M-43	Date Received:	08/03/2011 14:24
Water System:	Other	Purpose:	Routine Monitoring

TESTING INFORMATION			REGULATORY INFORMATION			
Analyte Name	Result (mg/L)	Date Tested	RL (mg/L)	MCL/AL (mg/L)	Method	CAS #
Chlorinated Acid Herbicides						
2,4,5-T	Not Detected	08/05/2011	0.002		EPA 515.4	93-76-5
2,4,5-TP (silvex)	Not Detected	08/05/2011	0.0003	0.05	EPA 515.4	93-72-1
2,4-D	Not Detected	08/05/2011	0.002	0.07	EPA 515.4	94-75-7
Acifluorfen	Not Detected	08/05/2011	0.004		EPA 515.4	50594-66-6
Bentazon	Not Detected	08/05/2011	0.002		EPA 515.4	25057-89-0
Dicamba	Not Detected	08/05/2011	0.002		EPA 515.4	1918-00-9
Dinoseb	Not Detected	08/05/2011	0.0003	0.007	EPA 515.4	88-85-7
Pentachlorophenol	Not Detected	08/05/2011	0.00006	0.001	EPA 515.4	87-86-5
Picloram	Not Detected	08/05/2011	0.001	0.5	EPA 515.4	1918-02-1
Total DCPA degradates, mono- and di-acid	Not Detected	08/05/2011	0.001		EPA 515.4	1861-32-1
Pesticides Analysis by GC/MS						
4,4'-DDD	Not Detected	08/05/2011	0.001		EPA 525.2	72-54-8
4,4'-DDE	Not Detected	08/05/2011	0.001		EPA 525.2	72-55-9
4,4'-DDT	Not Detected	08/05/2011	0.001		EPA 525.2	50-29-3
Acetochlor	Not Detected	08/05/2011	0.001		EPA 525.2	34256-82-1
Alachlor	Not Detected	08/05/2011	0.0002	0.002	EPA 525.2	15972-60-8
Aldrin	Not Detected	08/05/2011	0.0004		EPA 525.2	309-00-2
alpha-Chlordane	Not Detected	08/05/2011	0.0002	0.002	EPA 525.2	5103-71-9
Atrazine	Not Detected	08/05/2011	0.0002	0.003	EPA 525.2	1912-24-9
Dieldrin	Not Detected	08/05/2011	0.0005		EPA 525.2	60-57-1
Endrin	Not Detected	08/05/2011	0.00005	0.002	EPA 525.2	72-20-8
Endrin aldehyde	Not Detected	08/05/2011	0.002		EPA 525.2	7421-93-4

CAS# : Chemical Abstract Service Registry Number
MCL : Maximum Contaminant Level
AL : Action Level
RL : Reporting Limit

mg/L : milligrams / Liter (ppm)
ppm : parts per million
MPN : Most Probable Number
CFU : Colony Forming Unit

Laboratory Contacts
Drinking Water Unit Mgr: Julia Pieper
Systems Mgmt. Unit Mgr: George Krisztian

By authority of PA 368 of 1978 as amended **Work Order 10800733_04** Report Created on: 8/10/2011 3:58:29PM Page 1 of 2

MICHIGAN DEPARTMENT OF ENVIRONMENTAL QUALITY
DRINKING WATER LABORATORY
USEPA Region V Drinking Water Cert. No. MI00003
P.O. Box 30270
Lansing, MI 48909
TEL: (517) 335-8184
FAX: (517) 335-8562

Sample Number
LD93520

TESTING INFORMATION			REGULATORY INFORMATION			
Analyte Name	Result (mg/L)	Date Tested	RL (mg/L)	MCL/AL (mg/L)	Method	CAS #
Pesticides Analysis by GC/MS						
gamma-Chlordane	Not Detected	08/05/2011	0.0002	0.002	EPA 525.2	5103-74-2
Heptachlor	Not Detected	08/05/2011	0.00008	0.0004	EPA 525.2	76-44-8
Heptachlor epoxide	Not Detected	08/05/2011	0.00004	0.0002	EPA 525.2	1024-57-3
Hexachlorobenzene	Not Detected	08/05/2011	0.0001	0.001	EPA 525.2	118-74-1
Hexachlorocyclohexane (alpha-BHC)	Not Detected	08/05/2011	0.001		EPA 525.2	319-84-6
Hexachlorocyclohexane (beta-BHC)	Not Detected	08/05/2011	0.001		EPA 525.2	319-85-7
Hexachlorocyclohexane (delta-BHC)	Not Detected	08/05/2011	0.001		EPA 525.2	319-86-8
Hexachlorocyclopentadiene	Not Detected	08/05/2011	0.0002	0.05	EPA 525.2	77-47-4
Lindane (gamma-BHC)	Not Detected	08/05/2011	0.00004	0.0002	EPA 525.2	58-89-9
Methoxychlor	Not Detected	08/05/2011	0.0001	0.04	EPA 525.2	72-43-5
Metolachlor	Not Detected	08/05/2011	0.001		EPA 525.2	51218-45-2
Metribuzin	Not Detected	08/05/2011	0.001		EPA 525.2	21087-64-9
Molinate	Not Detected	08/05/2011	0.002		EPA 525.2	2212-67-1
PCB (aroclor 1016)	Not Detected	08/05/2011	0.0001	0.0005	EPA 525.2	12674-11-2
PCB (aroclor 1221)	Not Detected	08/05/2011	0.0001	0.0005	EPA 525.2	11104-28-2
PCB (aroclor 1232)	Not Detected	08/05/2011	0.0001	0.0005	EPA 525.2	11141-16-5
PCB (aroclor 1242)	Not Detected	08/05/2011	0.0001	0.0005	EPA 525.2	53469-21-9
PCB (aroclor 1248)	Not Detected	08/05/2011	0.0001	0.0005	EPA 525.2	12672-29-6
PCB (aroclor 1254)	Not Detected	08/05/2011	0.0001	0.0005	EPA 525.2	11097-69-1
PCB (aroclor 1260)	Not Detected	08/05/2011	0.0001	0.0005	EPA 525.2	11096-82-5
Polybrominated biphenyls	Not Detected	08/05/2011	0.001		EPA 525.2	59536-65-1
Simazine	Not Detected	08/05/2011	0.0002	0.004	EPA 525.2	122-34-9
Toxaphene	Not Detected	08/05/2011	0.001	0.003	EPA 525.2	8001-35-2

The analyses performed by the MDEQ Drinking Water Laboratory were conducted using methods approved by the U.S. Environmental Protection Agency in accordance with the Safe Drinking Water Act, 40 CFR parts 141-143, and other regulatory agencies as appropriate.

Your local health department has detailed information about the quality of drinking water in your area. If you have concerns about the health risks related to the test results of your sample, please contact the Environmental Health Section through the address and telephone number listed below:

Kalamazoo County Human Services Dept.
3299 Gull Rd.
Nazareth, MI 49048
269 373-5200

CAS# : Chemical Abstract Service Registry Number
MCL : Maximum Contaminant Level
AL : Action Level
RL : Reporting Limit

mg/L : milligrams / Liter (ppm)
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MPN : Most Probable Number
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