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An Environmental Assessment of Little Black Lake

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Submitted by the Annis Water Resources Institute
Grand Valley State University

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Executive Summary

A limnological survey was conducted of Little Black Lake and its tributaries during summer 2007 by researchers at the Annis Water Resources Institute of Grand Valley State University. Water quality, sediment composition, and phytoplankton, macrophyte, and fish abundance and composition were analyzed. In general, the water quality of both the inflows to, and Little Black Lake itself, was good. Nutrient concentrations occasionally exceeded existing guidelines, but no systemic problems were detected. Phosphorus concentrations did increase during stormflow conditions, but this is typical and concentrations were not considered excessive. One site in the lake had very high sediment phosphorus concentrations. Because our water quality results are based on a 1-time sampling, we cannot address if concentrations vary across seasons or if these concentrations are representative of typical conditions in Little Black Lake.

Macrophyte growth was extensive throughout most parts of the lake, but the plant composition was generally indicative of good water quality conditions. The clear water column and adequate concentrations of nutrients in the sediment provide excellent conditions for macrophyte growth in Little Black Lake. This may cause water quality problems in future years, however, as continual accumulation of organic matter may result in muck sediments and reduced oxygen levels. Phytoplankton abundance was low relative to other lakes in the region, and composition was indicative of good water quality. Little Black Lake has a healthy fish community, dominated by bluegill and pumpkinseed, with no invasive species being observed. The healthy fish community is likely a function of good habitat and good water quality.

Despite the current healthy conditions, there are some indications the lake is starting to experience ecological pressures. As a consequence, it is important that the City and lakefront homeowners become active stewards of the lake and its watershed to maintain the lake's condition. A number of recommendations are provided in this report, including the development of a watershed management plan and the implementation of best management practices to limit nonpoint source loading to Little Black Lake.

Introduction

Little Black Lake is a 95-ha lake located in Norton Shores, Michigan (43°07'20"N, 86°14'47"W) directly east of P.J. Hoffmaster State Park (Figure 1). It is a shallow lake located in a rapidly urbanizing region. Local residents have expressed concerns over excessive aquatic plant growth during summer months, thereby impacting their recreational and aesthetic enjoyment of the lake. The Annis Water Resources Institute (AWRI) of Grand Valley State University was contracted by the City of Norton Shores to conduct a general assessment of water quality conditions in Little Black Lake and its connecting waterways. The information generated from this project provides the City of Norton Shores with a snapshot of the lake's current condition, which can serve as a basis for future decision-making.

Methods

Tributaries:

Six tributary sites were sampled for nutrient concentrations (Fig. 1). Baseflow conditions were sampled on July 19, 2007. One of the tributaries that normally flows into the south end of Little Black Lake (South trib.; Fig. 1) was dry and therefore not sampled. Tributary water samples were collected in 1-L bottles, kept on ice, and returned to the laboratory for measurement of total phosphorus (TP), soluble reactive phosphorus (SRP), nitrate-nitrogen (NO_3-N), and ammonia-nitrogen (NH_3-N). Water for the SRP and NO_3-N analyses were syringe-filtered immediately upon collection through 0.45-μm membrane filters into scintillation vials; samples for NH_3-N were preserved with sulfuric acid. Flow and depth also were measured using a Marsh-McBirney flow meter (Flow-Mate Model 2000) along transects established at these sites. The Microsoft Windows-based hydrologic software, HYDROL-INF (Chu and Mariño 2006) was used for processing the measured stream data and computing stream discharge and other hydraulic parameters. In addition, a YSI 6600 multi-parameter datasonde was used to measure stream water dissolved oxygen, pH, temperature, specific conductance, total dissolved solids, turbidity, and chlorophyll *a*.

The six tributaries were resampled for nutrient concentrations during a storm event on August 20, 2007. Nutrient concentrations can show very different patterns during storm events compared to baseflow, so it is critical to measure nutrients under both low and high flow conditions.

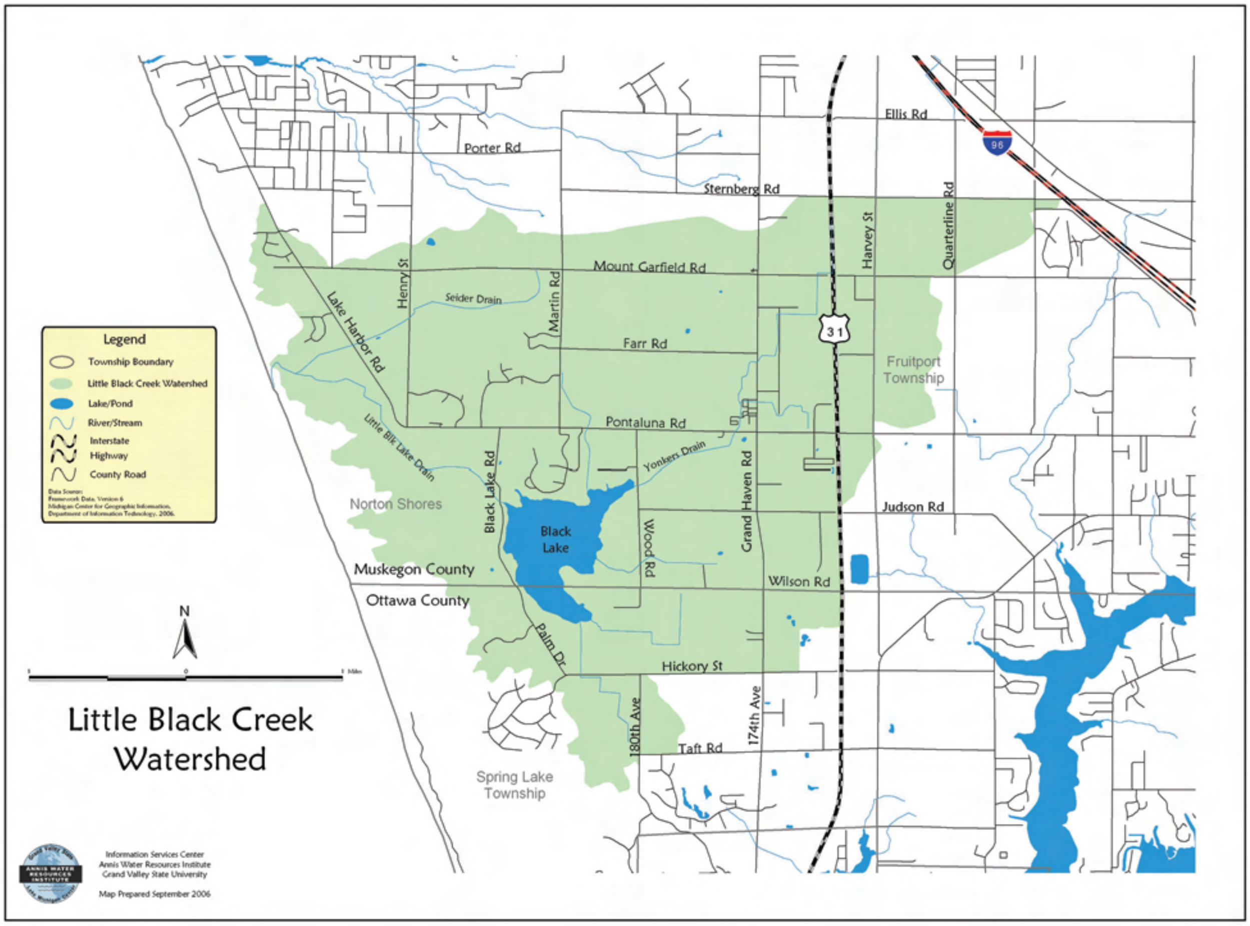

Figure 1. Map of Little Black watershed (green shading).

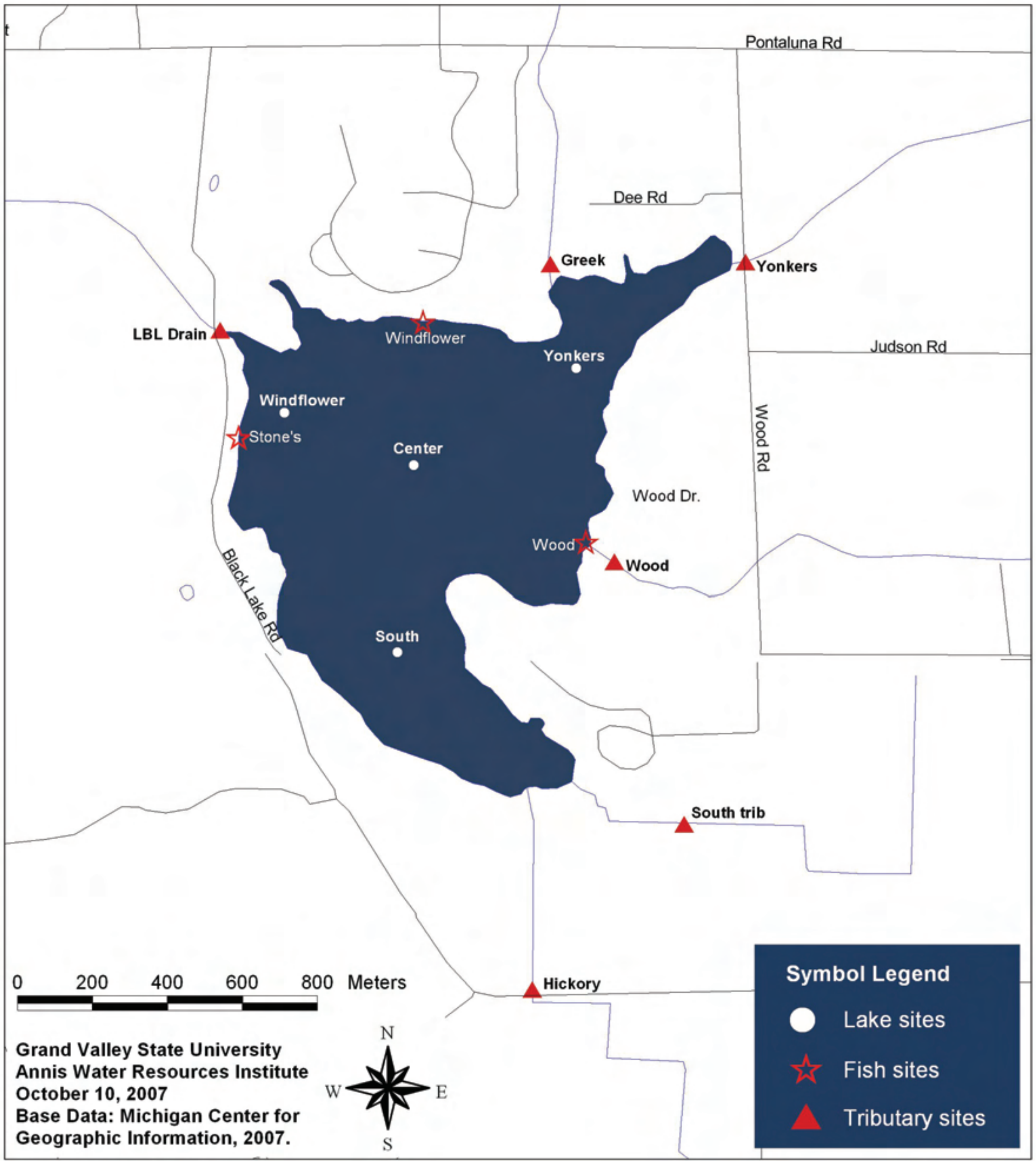

Figure 2: Location of sampling points for assessment of Little Black Lake.

Little Black Lake:

Water quality was sampled at four sites in Little Black Lake on August 1, 2007 (Fig. 2). A YSI 6600 multi-parameter datasonde was used to measure lake water dissolved oxygen, pH, temperature, specific conductance, total dissolved solids, turbidity, and chlorophyll *a* at the middle of the water column. Water clarity was measured using a Secchi disk. Water samples were collected with a Van Dorn bottle for measurement of TP, SRP, NO_3-N, and NH_3-N. In addition, a water column composite sample was collected for characterization of the phytoplankton community. One sediment core was collected from each site for analysis of TP and SRP in the sediment. One sediment core was collected from each site for analysis of TP and SRP in the sediment. In the lab, the sediment cores were extruded and divided into two depth fractions: 1) 0-5 cm depth (top) and 2) 5-10 cm depth (bottom). Each depth fraction was homogenized and subsampled for TP and SRP analysis.

On August 1 and 2, 2007, an aquatic macrophyte survey was conducted. The lake was overlain with a grid network with grid cells measuring 100 m × 100 m. Sample points were located at each of the line intercepts on the grid, resulting in a total of 108 sample points. Along the shoreline, where macrophyte vegetation was dense, every sample point was visited. In the middle of the lake, where macrophyte growth was less dense, every other point was sampled, resulting in a total of 74 locations visited. At each sample point, water depth was measured and aquatic macrophyte composition and density visually estimated using a modified ranking system.

Fish were sampled on August 8, 2007 at three nearshore sites (Fig. 2). We deployed three 4' x 3' fyke net and two minnow traps at each site. Gears were deployed between 9:00 and 11:30 AM the previous day to allow the gears to fish for about 24.6 h. All fish captured were identified and measured (total length) to the nearest 1 mm. Most fish were identified and released in the field; however, a few specimens were euthanized and transported to the laboratory for further examination.

Results

<u>Tributary Conditions:</u>

Flow was barely detectable during base flow conditions in most tributaries (Table 1). This is a reflection of the flat grade in the surrounding watershed. During storm sampling, flow increased 19-fold in Wood, 21-fold in Yonkers, 9.5-fold in Greek, and 5-fold in the outflow (Table 2). Storm flow in Hickory was similar to that in Wood and Greek, but was not measurable during base flow. The South tributary held water during storm sampling, but was not flowing. Yonkers Drain contributes the most flow to Little Black Lake; it contributed ~84% of the total measured flow to the lake during both base flow and storm event sampling.

Dissolved Oxygen (DO) is often used as an indicator of water quality, with higher absolute values and percent saturation reflecting better water quality conditions. Values less than 5 ppm (mg/L) are indicative of impaired water quality. No tributaries had DO levels < 5 ppm, under either base flow or storm flow conditions (Table 1). The South tributary had the lowest DO values measured—5.68 ppm—under storm flow conditions, but this tributary was dry when we sampled under base flow conditions, so it is unlikely that it is important as permanent habitat for aquatic life.

pH is an indicator of the hydrogen ion content in water. Water with a pH of 7.0 indicates a neutral solution. pH values less than 7.0 indicate acidic conditions, while pH values above 7.0 indicate alkaline conditions. The USEPA drinking water standard for pH is 6.5 to 8.5. pH values were circumneutral in all tributaries measured, ranging from 6.87 in South tributary to 8.16 in LBL out (Table 1). There is no indication that pH is causing stress in this system.

Specific Conductance (or conductivity) reflects the amount of ionized salts in solution. As chloride is often one of the most common salts, there is usually a strong positive relationship between specific conductance and chloride. Conductivity is also used as an indicator of human disturbance in aquatic systems, as it tends to increase with increasing amount of urban development. In west Michigan, specific conductance generally ranges from 0.100 (precipitation and surface water-driven) to 0.600 mS/cm (more groundwater-dominated systems), with values > 0.600 suggesting human-induced stress to aquatic systems. Most values were less than 0.600 mS/cm in the Little Black Lake system, although Yonkers Drain and LBL out were > 0.600 mS/cm during baseflow conditions (Table 1). Note that in each tributary, specific conductance declined during storm flow conditions indicating that the runoff diluted the salts that are present during base flow. This dilution factor will vary among seasons. It is likely, based on studies on inflows to Mona Lake (Steinman et al. 2006), that specific conductance during storm flow would *increase* if we measured this during winter and early spring, when road salt mixtures are being applied to road surfaces.

Total Dissolved Solids (TDS) is the portion of solids in water that can pass through a 2-μm filter. The more minerals dissolved in the water, the higher the total dissolved solids. TDS is generally not considered a primary pollutant (i.e., it is not associated with health effects), but rather is used as an indication of aesthetic characteristics of drinking water and as an indicator of the presence of a broad array of chemical contaminants. Waters with high TDS levels are generally of inferior quality. In drinking water, a limit of 0.5 g/L is desirable; Illinois has set a general water quality standard of 1.0 g/L for TDS. All samples in the Little Black Lake tributaries had TDS concentrations less than 1.0 g/L (Tables 1 and 2).

Chloride (Cl) is often used as an indicator of human disturbance to freshwaters; industrial sources, road salting, and municipal wastewater operations all contribute chloride to waters. An approximate average concentration of chloride in pristine fresh water is 8.3 mg/L (from Wetzel 2001). The USEPA drinking water standard for chloride is 250 mg/L, whereas Illinois sets a general water quality standard of 500 mg/L for Cl. None of the values measured in the Little Black Lake tributaries approached those thresholds (Tables 1 and 2), but as noted for specific conductance, concentrations may be higher during different times of the year.

Sulfate (SO_4) has many sources, including weathering from rocks, and pollution from fertilizers, wastes, mining activities, and burning of fossil fuels. Illinois sets a general water quality standard of 500 mg/L for sulfate; all of the concentrations measured in the Little Black Lake tributary samples were far less than this threshold (Tables 1 and 2).

Nitrate (NO_3) is created by bacterial action on ammonia, by lightning, or through artificial processes involving extreme heat and pressure. Nitrate can be found in fertilizers, such as potassium nitrate or sodium nitrate. In appropriate amounts, nitrates are beneficial but excessive concentrations in water can cause health problems. Excess nitrates can cause hypoxia (low levels of dissolved oxygen) and can become toxic to warm-blooded animals at higher concentrations (10 mg/L) under certain conditions. The natural level of nitrate in surface water is typically low (less than 1 mg/L); however, in the effluent of wastewater treatment plants, it can range up to 30 mg/L. The USEPA safe drinking water standard is 10 mg/L of NO_3-N. In general, nitrate concentrations were low in the tributary samples (Tables 1 and 2). All tributaries, except Hickory under storm flow conditions, were < 1 mg/L of nitrate. Nitrate concentrations in all tributaries except Yonkers increased significantly during storm flow conditions, suggesting that external nitrate sources are entering most of Little Black Lake's tributaries during rain events. Although the storm event concentrations we measured were still generally low, the increases are cause for potential concern and suggest a need for best management practices to control this nonpoint source pollution.

Ammonia (NH_3) is a byproduct of decaying plant tissue and decomposition of animal waste. Because ammonia is rich in nitrogen, it is also used as fertilizer. Ammonia levels at 0.1 mg/L usually indicate polluted surface waters, whereas concentrations > 0.2 mg/L can be toxic for some aquatic animals (Cech 2003). High levels of ammonia are typically found downstream of wastewater treatment plants and near water bodies that harbor large populations of waterfowl, which produce large amounts of waste. Ammonia levels in all tributaries were <0.1 mg/L under base flow conditions, although the 0.09 mg/L level in Greek is of potential concern (Table 1). Under storm flow conditions, ammonia concentrations reached or exceeded 0.1 mg/L in Hickory and Yonkers drains (Table 2), suggesting (similar to nitrate) that external sources of nitrogen are entering these systems, and likely reaching Little Black Lake.

Soluble reactive phosphorus (SRP) is a measurement of the bioavailable phosphorus in water. Although a high concentration is indicative of enrichment, a low concentration may be because the SRP is being actively taken up by the plants and algae in the water body. Therefore, caution must be used when evaluating the significance of SRP levels. SRP concentrations were either below detection (0.005 mg/L) or relatively low in all tributaries, regardless of flow conditions (Tables 1 and 2). This likely reflects the active uptake of phosphorus by submersed vegetation in these tributaries.

Total phosphorus (TP) is a measurement of all the various forms of phosphorus (inorganic, organic, dissolved, and particulate) in the water. TP standards have been established for some running waters, as filamentous green algae become abundant at TP concentrations of 0.01-0.02 mg/L (USEPA 2000). The TP concentrations in most tributaries to Little Black Creek were between 0.01 and 0.03 mg/L (Tables 1 and 2), which is about half of the TP concentrations measured in inflows to Mona Lake (Steinman et al. 2006). In all tributaries except Wood, the TP concentrations increased under storm flow conditions (Tables 1 and 2). This is to be expected, as much of the TP is adsorbed to particles, and these P-rich particles are carried by storm flow into tributaries through storm drains, surface runoff, and erosion. Relatively high TP concentrations were measured in Yonkers Drain and in South Tributary during the storm event (Table 2), suggesting these areas should be targeted for nutrient reduction strategies.

Table 1. Water quality parameters measured in 4 inflows and 1 outflow (LBL) of Little Black Lake during base flow conditions (July 19, 2007).

Site	Discharge (cms)	Temp °C	DO mg/L	DO%	pH	SpCond mS/cm	TDS g/L	Cl mg/L	SO_4 mg/L	NO_3-N mg/L	NH_3-N mg/L	SRP-P mg/L	TP-P mg/L
Hickory	N/A	19.74	7.34	80.4	7.49	0.358	0.233	29	7	0.02	0.04	< 0.005	0.02
Wood	0.002	23.41	6.44	75.7	7.66	0.55	0.358	34	40	<0.01	0.03	< 0.005	0.02
Yonkers	0.031	18.68	9.51	102.1	7.86	0.872	0.567	154	33	0.27	0.04	0.007	0.02
Greek	0.004	19.88	7.07	77.7	7.38	0.387	0.251	37	15	0.10	0.09	< 0.005	0.02
LBL out	0.044	26.19	6.38	79	7.85	0.629	0.409	125	20	<0.01	0.03	< 0.005	< 0.01

Table 2. Water quality parameters measured in 4 inflows and 1 outflow (LBL) of Little Black Lake during storm flow conditions (August 20, 2007).

Site	Discharge (cms)	Temp °C	DO mg/L	DO%	pH	SpCond mS/cm	TDS g/L	Cl mg/L	SO_4 mg/L	NO_3-N mg/L	NH_3-N mg/L	SRP-P mg/L	TP-P mg/L
Hickory	0.046	15.82	6.47	65.4	7.02	0.244	0.159	21	31	1.00	0.13	0.007	0.03
Wood	0.038	16.9	6.64	68.7	7.64	0.419	0.272	30	49	0.12	0.04	<0.005	<0.01
Yonkers	0.647	16.44	8.32	85.1	7.54	0.221	0.144	35	7	0.20	0.10	0.006	0.06
Greek	0.038	16.04	7.34	74.5	7.18	0.292	0.190	30	20	0.70	0.08	0.01	0.03
LBL out	0.219	18.05	8.34	88.3	8.16	0.574	0.373	95	14	<0.01	0.03	<0.005	0.01
S. Trib	0	16.22	5.68	57.9	6.87	0.520	0.338	99	61	0.04	0.04	0.015	0.07

<u>In-Lake Conditions:</u>

Depth at the four in-lake sampling sites varied from 0.156 m (South site) to 0.996 m (Yonkers site) (Fig. 1; Table 3). In general, the deepest part of Little Black Lake is in the north-east corner and the shallowest regions are along the immediate shorelines and the southern half of the lake (see Fig. 4).

Secchi disk depth is an indicator of water clarity. At all sites, we were able to see to the lake bottom, indicating the water clarity in Little Black Lake is good (Table 3).

The **DO** concentration at all sites was > 6.7 mg/L, with percent saturation of DO ranging from ~85 to 110% (Table 3). These data indicate that for at least the period of time when we sampled, the aquatic biota in Little Black Lake are not being stressed by a lack of dissolved oxygen.

pH concentrations were alkaline at all sites (Table 3). The concentrations, on average, were ~1 unit greater (i.e., 10X) than the pH values in the tributaries (Tables 1 and 3). This may reflect active photosynthesis in Little Black Lake, as the day-time removal of carbon dioxide by photosynthesis results in an increase in alkalinity.

Specific conductance at all sites exceeded 0.600 mS/cm, suggesting that human influences are impacting this lake. Specific conductance values were similar throughout the lake (Table 3), and were lower in the lake than under base flow conditions in Yonkers Drain, which may be because the larger volume of lake water dilutes the concentration of salts in the drain. We suspect the high conductivity in the lake is associated, at least in part, with human activities and development around the lake.

TDS values, similar to specific conductance, were similar at all 4 sites (Table 3), and all were less than the 1.0 g/L threshold suggested by the State of Illinois.

Chlorophyll *a* is the principal pigment used by plants and algae to absorb sunlight in the process of photosynthesis. As a consequence, chlorophyll *a* is often used as a proxy for algal biomass. Chlorophyll *a* values were very low throughout Little Black Lake (Table 3), and much lower than the eutrophic threshold of 10 μg/L; chl a concentrations in Mona Lake during August average ~15 μg/L (Steinman et al. 2006). Algal blooms can present a major ecological and human health problem in west Michigan lakes, so the low chlorophyll concentration is an indicator of good water quality in this system.

Both **chloride (Cl) and sulfate** concentrations in Little Black Lake were similar throughout the lake (Table 3). The high Cl levels entering from Yonkers Drain clearly influence Cl levels throughout the lake, but the concentrations of both ions were well below the water quality guidelines established by the State of Illinois.

Nutrient concentrations for **nitrate, ammonia, SRP, and TP** all were either very low or below detection (Table 3). The low levels for nitrate, ammonia, and SRP likely reflect the high uptake of dissolved nutrients by the dense macrophyte beds in Little Black Lake. The low TP concentration is consistent with the low chlorophyll *a* concentrations—the nutrients being taken up are not going to phytoplankton but instead likely are going to the benthic vegetation. These concentrations are again indicative of good water quality conditions in the lake.

Table 3. Select limnological parameters measured at 4 sites within Little Black Lake on August 1, 2007.

Site	Bottom m	Secchi m	Temp °C	DO mg/L	DO%	pH	Sp Cond mS/cm	TDS g/L	Chl μg/L
Windflower	1.00	bottom	27.19	7.25	91.4	8.23	0.638	0.415	*
Yonkers	2.20	bottom	27.31	8.72	110.2	8.65	0.669	0.435	1.87
Center	1.45	bottom	26.99	8.00	100.5	8.60	0.643	0.418	2.12
South	0.63	bottom	26.88	6.76	84.8	8.26	0.655	0.425	1.18

Site	Cl mg/L	SO_4 mg/L	NO_3-N mg/L	NH_3-N mg/L	SRP-P mg/L	TP-P mg/L
Windflower	*	*	*	*	*	*
Yonkers	105	19	<0.01	0.02	< 0.005	0.01
Center	105	18	<0.01	0.03	< 0.005	0.01
South	113	17	<0.01	0.03	0.006	< 0.01

*Samples not collected at this site

Sediment Chemistry

The sediments in Little Black Lake were largely organic and muck in the northern part of the lake and transitioned to mostly sand in the southern part of the lake (Table 4). The sediment data show several patterns:

1) the bioavailable phosphorus (SRP) in the sediment is below detection at all our sampling sites (Table 4); this is consistent with the low SRP concentrations measured in the water column (Table 3), and suggests that the sediments, at least during the time period when we sampled, are not a major source of bioavailable P to the lake;

2) there is considerable spatial variability in sediment TP throughout the lake (Table 4)—sediment TP was very high at the center site, moderate at the Yonkers site, and low at the south site. Low TP concentrations are expected at sand-dominated sites, as P-rich organic material is sparse under these conditions (note high % of solids in Table 4 at this site);

3) the TP concentrations in the top portions of the core were greater than in the bottom portions at the Center and South sites, and similar at the Yonkers site (Table 4). Caution must be exercised in the interpretation of these data, because it is unknown how often and to what degree these sediments get mixed throughout the year (which invalidates comparison of top vs bottom fractions of cores). If the sediments stay relatively stable over time, the data suggest that there has been an increase in P being deposited into certain regions of Little Black Lake. This could be related to decomposition of macrophytes; as the plants senesce and decompose, the phosphorus that was tied up in their plant tissue is released into the sediments. Of course, given the relatively good water quality conditions in the lake, these putative increases in sediment P are not causing current problems although they may be indicators of future problems; and

4) the average TP concentration in Little Black Lake sediment is similar to average TP sediment concentrations that we have measured in other lakes in this region (Fig. 3). However, the very high TP concentration at the Center site is one of the highest we have measured in the region (only one site in Mona Lake was greater), and suggests this is a potential concern for the future.

Table 4. Chemical parameters from sediment cores collected at 3 sites within Little Black Lake on August 1, 2007. Sediment cores were not collected at the Windflower site.

SEDIMENT CHEMISTRY	Porewater SRP-P mg/L	Sediment TP-P (dry) mg/kg	% solids	Substrate type
Windflower	*	*	*	organic/muck
Yonkers Sed top	< 0.01	823	23.07%	organic/muck
Yonkers Sed bot	< 0.01	884	23.76%	"
Center Sed top	< 0.01	3195	10.97%	organic/muck
Center Sed bot	< 0.01	2404	11.84%	"
South Sed top	< 0.01	196	60.82%	mostly sand/some muck
South Sed bot	< 0.01	46	77.21%	"

*Sediment cores not collected at this site

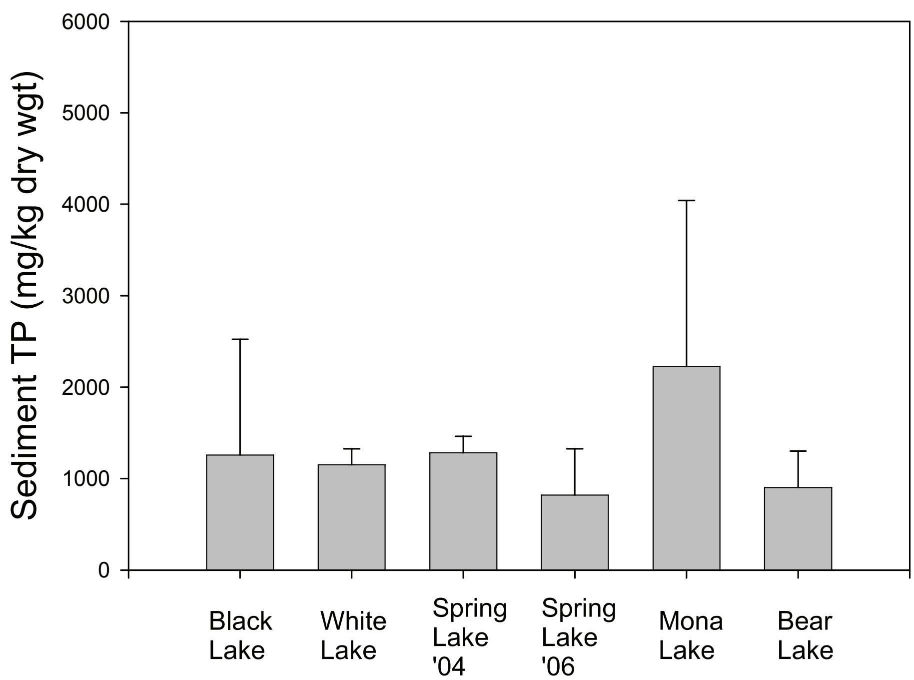

Figure 3. Mean (± SE) sediment TP concentrations (mg/kg) from Little Black Lake (2007), White Lake (2006), Spring Lake (2004 and 2006), Mona Lake (2005), and Bear Lake (2007).

Comparison to other lakes in the region

An alternative way to assess the ecological status of Little Black Lake is to compare key water quality parameters in the lake with other lakes in the region. We compared water transparency (Secchi disk depth as % of maximum depth), TP, SRP, and chlorophyll *a* concentrations in Little Black Lake with mid-summer values that we measured over the past few years in Mona Lake, Muskegon Lake, and Spring Lake.

The data show that the mid-summer water quality in Little Black Lake is good overall compared to other lakes in the region (Table 5)—the transparency is greater in Little Black Lake than any of the other lakes, the TP and SRP concentrations are lower than or equal to the lowest concentrations in the other lakes, and the algal biomass, as measured by chl *a*, is lower than the other lakes. It should be noted that the other lakes in Table 5 are all drowned river-mouth lakes, receiving most of their inflow (and nutrient loads) from a single major upstream river, often with high amounts of agricultural land use, and therefore are more eutrophic than might be expected for Little Black Lake. As a consequence, the comparison is not totally equitable; however, all lakes are located in the same region, and therefore are exposed to the same general climate, soils, and atmospheric inputs.

Table 5. Mean mid-summer values (averaged across all sites in each lake) of secchi disk depth (calculated as % of maximum lake depth), TP, SRP, and chl *a*. For TP, SRP, and chl *a*, separate mean values are given for top and bottom samples if there was sufficient depth to allow water to be collected from both the top and bottom of the water column.

Lake	Date	Secchi Depth (% of max depth)	Total P (µg/L) (top/bottom)	SRP (µg/L) (top/bottom)	Chl *a* (µg/L) (top/bottom)
Little Black	Aug 1, 2007	100%	10	BD*	1.7
Mona	Aug 19, 2003	9.2%	(90/208)	(5/151)	(10.0/4.0)
Muskegon	July 21, 2005	28.0%	(30/20)	(BD/BD)	(12.4/4.8)
Spring	June 10/11 and July 16, 2003**	13.8%	(98/70)	(20/28)	(13.6/4.6)
Spring	Aug 1, 2006***	7.1%	(30/40)	(BD/BD)	(17.3/14.4)

*BD = below detection (< 5µg/L)
**Prior to alum treatment
***Post-alum treatment

Macrophytes:

A total of 74 different sites were sampled for aquatic macrophytes (i.e., aquatic plants and macroscopic algae) in Little Black Lake (Fig. 4). Macrophyte coverage was high throughout the lake—the few sites that did not have >75% coverage were in the northeast corner of the lake and in the very shallow section where the SE peninsula juts out into the lake (Fig. 5). We observed 29 different macrophyte taxa in Little Black Lake (Table 6). The taxon that we found most often was the macroalga *Chara* (44.6% of sites), followed by two *Potamogeton* species.

The species composition varied with depth: at the shallowest sites (< 0.5 m depth; n = 24), *Schoenplectus* (formerly *Scirpus*) *pungens* (67% of sites) and *Chara* (54%) occurred most frequently. However, at the 0.5 – 1.0 m depths (n = 29), the most common taxa were *Brasenia* (52%), *Chara* (48%), *Utricularia* (48%), and *Myriophyllum heterophyllum* (45%). At the 1.0-1.5 m depth (n = 13), the macrophytes observed most frequently were *Potamogeton amplifolius* (92%), *Vallisneria americana* (62%), and *Potamogeton robbinsii* (54%). Finally, at the deepest water depths (> 1.5 m; n = 8), the most common taxa were *Potamogeton zosteriformis* (100%) and *Vallisneria americana* (88%). Overall, macrophyte community composition was variable throughout the lake. There was no evidence of dense plant monocultures, which is usually indicative of a high degree of disturbance.

Both the physical and chemical characteristics of Little Black Lake are contributing to the abundant macrophyte growth in the lake. The shallow depth, combined with good water clarity of the lake, allows sufficient light for plant growth over the entire area of the lake. Thus, the entirety of Little Black Lake is functioning as highly productive, littoral (nearshore) zone habitat. Further, the TP-rich sediments help support dense beds of rooted macrophytes. Two of the most abundant macrophytes found in Little Black Lake, *Chara* sp. and *Myriophyllum heterophyllum*, are characteristic of hardwater, alkaline lakes. *Myriophyllum heterophyllum*, or twoleaf watermilfoil, is closely related to *Myriophyllum spicatum* (eurasian watermilfoil), which is a highly aggressive invasive aquatic plant. The watermilfoil species found in Little Black Lake is known as a nuisance species in acid lakes in the northeast U.S., but in Michigan it grows in alkaline lakes and is less weedy (Crow and Hellquist 2000). *Utricularia* sp., or bladderwort, is a carnivorous plant that is free-floating; because it has no roots to utilize nutrients from the sediments, it generally grows in water with high concentrations of dissolved nutrients (Wetzel 2001). Another chemical factor that may be positively influencing macrophyte growth is the ability for some species to take advantage of alkaline conditions by utilizing bicarbonate when free carbon dioxide is in low supply (Wetzel 2001).

In developing a floristic quality assessment, the State of Michigan assigned a coefficient of conservativism (C) to each Michigan plant species. These values range from 0-10 and represent the probability that a species will occur within an undisturbed landscape. Therefore, a species with a C-value of 0 can be found in highly degraded areas and a species with a C-value of 10 is usually found in high quality areas (Herman et al. 2001). The species found in Little Black Lake had C-values that ranged from 1-10, with an average C-value of 5.65. Two macrophytes, *Utricularia* sp. (bladderwort) and *Potamogeton robbinsii* (Robbins' pondweed), have C-values of 10, indicating that Little Black Lake is capable of supporting species that are highly sensitive to environmental degradation. *Pontederia cordata* (pickerelweed) and *Eriocaulon aquaticum* (pipewort) have C-values of 8 and 9, respectively, further indicating that Little Black Lake has good water quality.

Although dense macrophyte growth can be a hindrance to recreational enjoyment of a lake, the macrophyte community provides many important ecosystem functions. In small, shallow lakes, macrophytes contribute significantly to lake productivity and often dominate and control the metabolism of the lake (Wetzel 2001). By incorporating nutrients into their biomass, the macrophyte community serves as a sink for nutrients entering the lake from the surrounding land. In this way, they make nutrients unavailable to phytoplankton and often help to prevent algal blooms. Macrophytes also provide exceptional wildlife habitat, as a source of cover, structure, refuge, and food for nearly all components of the food web.

Table 6. Species composition of the aquatic macrophytes observed in Little Black Lake, along with the number of sites where they were found (out of 74 total), the corresponding percentage, and the coefficient of conservatism (C) (Herman et al. 2001).

Species:	#	%	C
Chara sp.	33	44.6	--
Potamogeton amplifolius	28	37.8	6
Potamogeton gramineus	23	31.1	5
Brasenia sp.	21	28.4	6
Myriophyllum heterophyllum	21	28.4	6
Vallisneria americana	21	28.4	7
Potamogeton zosteriformis	20	27.0	5
Utricularia sp.	19	25.7	10
Nymphaea	19	25.7	6
Najas sp.	19	25.7	5
Schoenplectus pungens	17	23.0	5
Potamogeton robbinsii	14	18.9	10
Elodea sp.	12	16.2	1
Unidentified Submerged	9	12.2	--
Unidentified Emergent 1	8	10.8	--
Potamogeton natans	8	10.8	5
Schoenplectus acutus	8	10.8	5
Nuphar	7	9.5	7
Pontederia cordata	6	8.1	8
Potamogeton pusillis	5	6.8	4
Eleocharis vivipara	4	5.4	--
Sparganium americanum	3	4.1	6
Sagittaria latifolia	2	2.7	1
Zosterella dubia	2	2.7	6
Peltandra virginica	2	2.7	6
Eriocaulon aquaticum	1	1.4	9
Unidentified Emergent 2	1	1.4	--
Ceratophyllum demersum	1	1.4	1
Juncus sp.	1	1.4	--

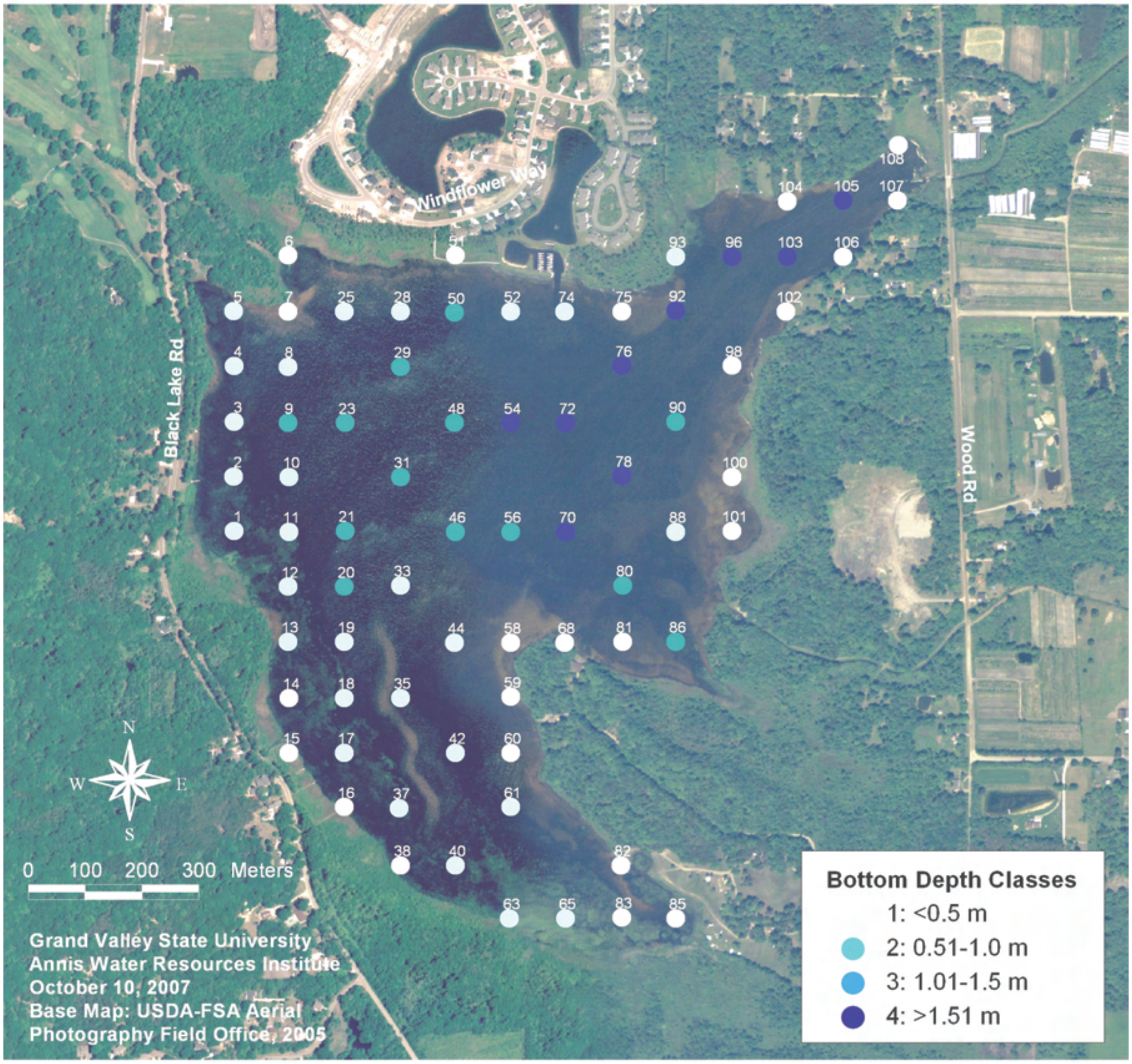

Figure 4. Water depth at the macrophyte sampling sites in Little Black Lake. Depths are color-coded, with station number located above each dot.

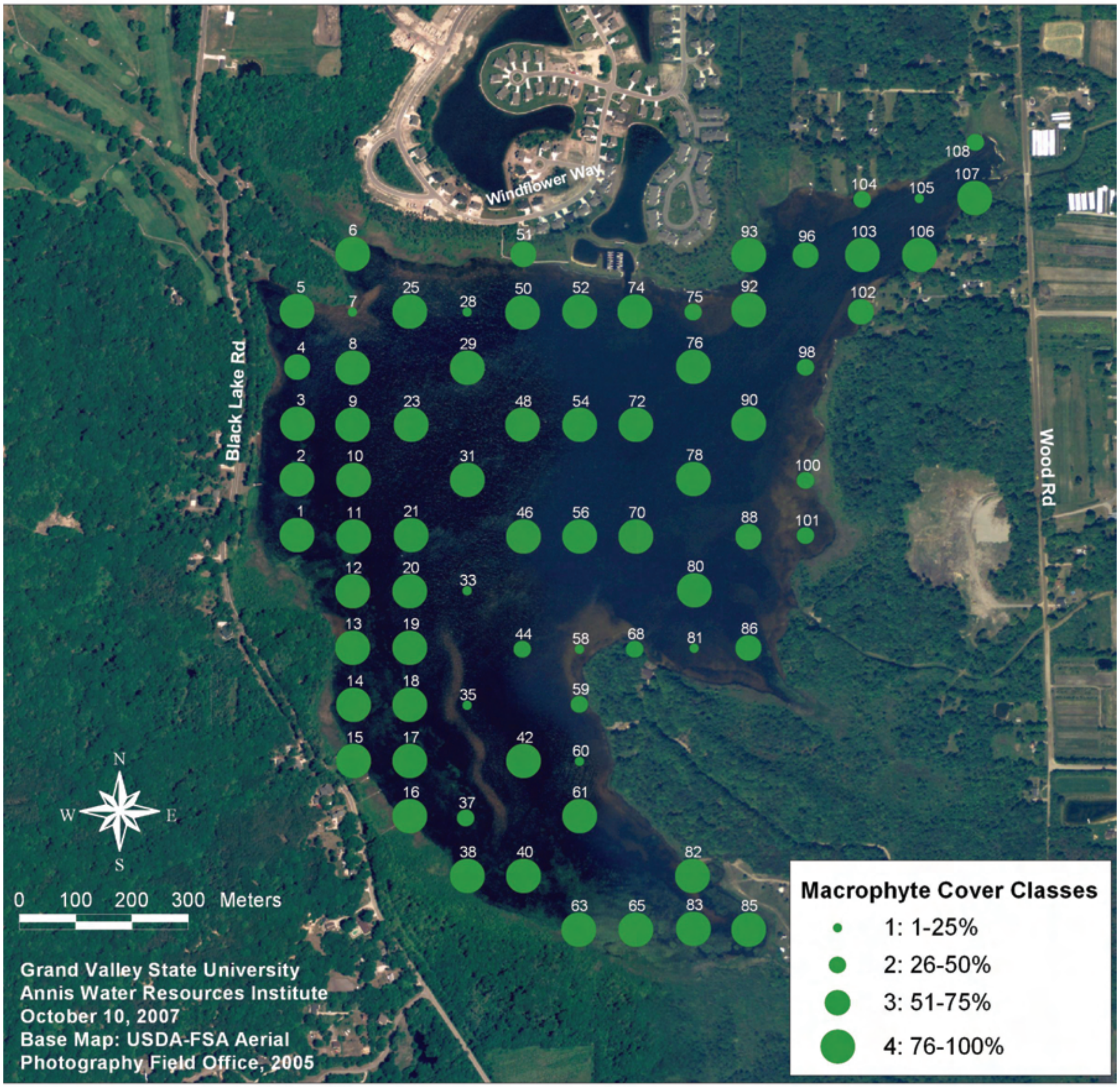

Figure 5. Macrophyte cover at each of the sampling sites in Little Black Lake. The larger the circle, the greater the coverage (see legend).

Phytoplankton

Phytoplankton are algal (photosynthetic) cells growing suspended in the water column. The major algal division observed overall in Little Black Lake was Cryptophyta (Fig. 6). These organisms are small (3 – 50 µm) and free-swimming, usually found in low-nutrient waters. They were most abundant at the Yonkers and Center sites (Fig. 6). The second most abundant overall division was Cyanobacteria, or the blue-green algae; they were most abundant at the South site (Fig. 5). Several cyanobacteria species are capable of releasing toxins, and therefore, present a potential human and ecological health concern. Of particular concern are the species *Microcystis aeruginosa* and *Cylindrospermopsis raciborskii*, which release the toxins microcystin and cylindrospermopsin, respectively.

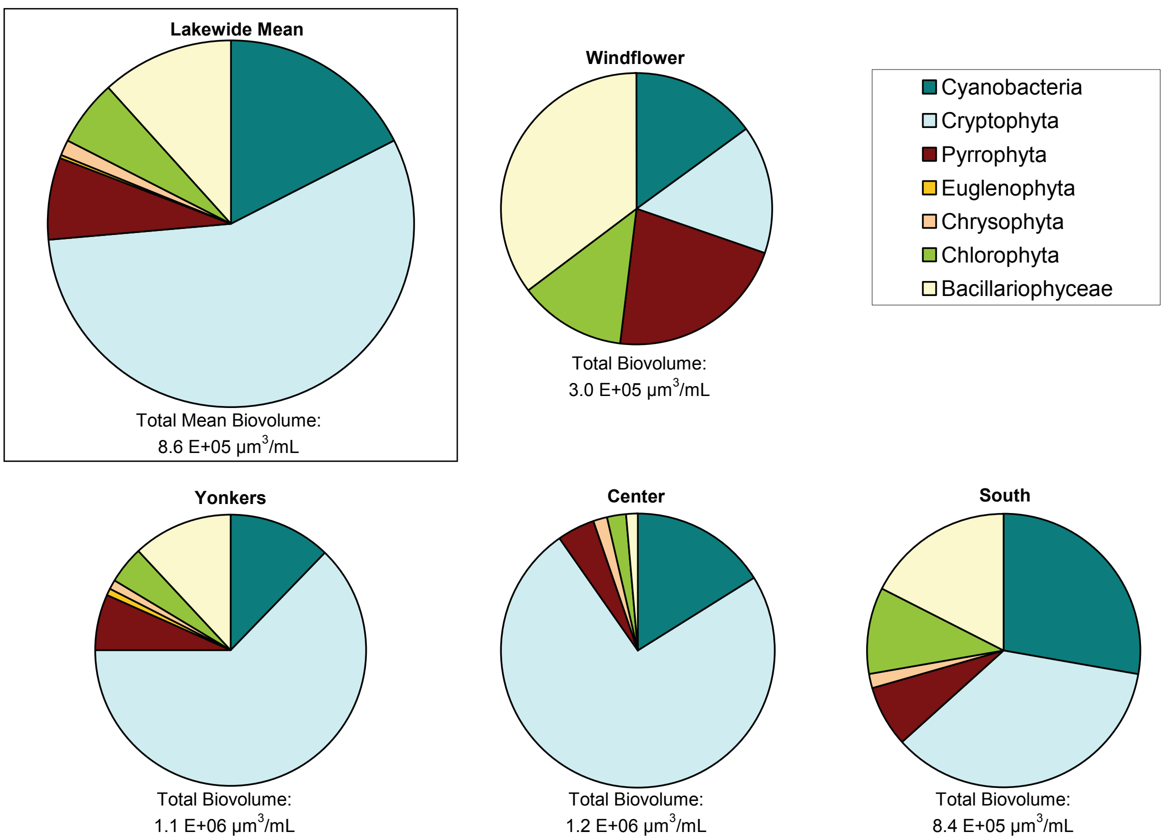

Figure 6. Phytoplankton composition based on major algal divisions. The enclosed pie chart shows the lakewide mean (from all 4 sites). The other pie charts show the algal divisions at each site (site name on top). Below each pie chart is the total algal biovolume calculated at each site.

Microcystis aeruginosa was present at all sites in the lake, ranging from 12% (South) to 40% (Central) of the cyanobacteria population at any site (Table 7). However, when compared to all the algae in Black Lake, *Microcystis* composed only 3-7% of total algal biovolume. *Cylindrospermopsis* was not found at all in Little Black Lake. Samples were not assayed for algal toxins, so it is impossible to know if the presence of cyanobacteria is creating a health hazard in Little Black Lake; however, the relatively low biovolume of these taxa suggests they are not a major health hazard in the lake. The World Health Organization has suggested that recreational use of waters has a moderate risk of cyanotoxin exposure when cyanobacteria biovolume exceeds 1 x 10^5 μm^3/mL. Only the Windflower site was below this threshold, although the other three sites just exceeded the WHO guideline (Table 7).

Table 7. Cyanobacteria taxa biovolume (μm^3/mL) measured at the four sampling sites in Little Black Lake on August 1, 2007.

	Central	South	Windflower	Yonkers
Cyanobacteria	biovolum/ml	biovolum/ml	biovolum/ml	biovolum/ml
Anabeana flos-aquae	6.26E+04	0.00E+00	0.00E+00	3.66E+03
Anabaena planktonica /affinis	3.05E+04	0.00E+00	0.00E+00	0.00E+00
Aphanocapsa delicatissima	0.00E+00	4.63E+03	0.00E+00	9.64E+02
Chroococcus dispersus	0.00E+00	2.93E+03	4.15E+03	0.00E+00
Chroococcus limneticus	4.59E+03	6.43E+03	0.00E+00	0.00E+00
Gloeotheca ruppstris	0.00E+00	0.00E+00	0.00E+00	2.12E+02
Merismopedia tenuissima	7.11E+02	2.67E+02	2.85E+03	0.00E+00
Microcystis aeruginosa	7.67E+04	2.70E+04	1.33E+04	3.33E+04
Limnothrix sp.	0.00E+00	0.00E+00	2.14E+04	3.21E+03
Phormidium tenue (f)	9.26E+03	1.32E+03	0.00E+00	0.00E+00
Woronichinia naegelianum	0.00E+00	1.89E+05	0.00E+00	9.45E+04
Snowell sp.	2.26E+03	0.00E+00	3.02E+03	7.55E+02
Planktothrix	6.59E+03	0.00E+00	0.00E+00	0.00E+00
SITE TOTAL	1.93E+05	2.32E+05	4.47E+04	1.37E+05
MEAN	1.52E+05			
SE	4.06E+04			

The phytoplankton taxonomic composition in Little Black Lake is considerably different from that in other lakes surveyed in Ottawa and Muskegon Counties. In summer 2006, phytoplankton was sampled in Lake Macatawa, Spring Lake, Mona Lake, Muskegon Lake, Bear Lake, Duck

Lake, and White Lake (Rediske et al. 2007). In all these systems, the dominant phytoplankton group was cyanobacteria, and cryptophytes were a very minor component. The phytoplankton taxonomic composition in Little Black Lake is further indication of good water quality in this system.

Fish

Fish are often good indicators of the ecological health of lakes. Fyke netting was more effective than minnow trapping for capturing fish. We captured 13 species in fyke nets and 6 species in minnow trips (Table 8). All but one of the species collected in minnow traps also were collected in fyke nets (Table 8). Therefore, we focused our assessment on the fyke net sampling. The sampling did have some limitations, which are common to almost all fisheries assessments. First, we used gear that is likely favors the capture of small fish relative to large individuals (Ruetz et al. 2007), and not all species are equally likely to be captured in our gear (Breen and Ruetz 2006).

The most abundant fishes captured in fyke nets were the bluegill and pumpkinseed (44% of total catch), yellow, brown, and black bullheads (14%), yellow perch (14%), blacknose shiner (12%), and largemouth bass (9%), which accounted for more than 94% of the fish captured (Table 8, Fig. 7). Species that rarely were captured were the black crappie, warmouth, johnny darter, brook silverside, and pugnose minnow (Table 8). Catch was greatest at the Wood site and lowest at the Stones site (Fig. 7). All sites tended to be dominated by bluegill and pumpkinseed, although bullheads were a larger percentage of the catch at the Stones site than the Wood or Windflower sites (Fig. 7).

The fishes captured in Little Black Lake were all native species, and many of the most abundant fishes—bluegill, pumpkinseed, yellow perch, and largemouth bass—are considered game species that are often associated with moderate to high water quality. Many of these game species were small (e.g., < 8 cm), which is partially a function of the gear we used to sample fishes. However, in our opinion, the abundance of small game fishes is likely indicative of good recruitment and not a stunted population (a condition when fish become highly abundant and the average size of adults declines, often to the point that anglers are uninterested in harvesting them). The two species of shiner we collected are indicative of a good water quality and a healthy fish community. Blacknose shiners generally require clear, vegetated water and often disappear when turbidity increases (Becker 1983). Similarly, the pugnose shiner is extremely intolerant to turbid conditions (Becker 1983) and is considered a species of special concern by the Michigan Department of Natural Resources.

Nevertheless, bullheads also were abundant in Little Black Lake, and they are adapted to lakes with low oxygen concentrations, abundant vegetation, and low transparency (Becker 1983). In lakes with high densities of vegetation, bullhead populations can explode and dominate the fish community. Little Black Lake could be a candidate for winter kills (i.e., oxygen concentrations plummet during periods when the lake is completely frozen and covered with snow, resulting in catastrophic kills of game species) if plant growth and nutrient inputs increase past some unknown threshold. Overall, we characterize Little Black Lake as having a healthy fish community.

Table 8. Number and size (total length; TL) of fish captured by fyke netting (n = 9 nets) and minnow trapping (n = 5 traps) at the three sites in Little Black Lake on August 8, 2007.

		Total	Fyke netting		Minnow trapping	
Common name	Scientific name	catch	Catch	TL (cm)	Catch	TL (cm)
yellow perch	*Perca flavescens*	42	21	6.2 (5.1-13.9)	21	8.8 (5.6-11.1)
unknown sunfish[1]	*Lepomis spp.*	41	33	3.8 (2.6-4.3)	8	3.6 (3.1-4.1)
bluegill	*Lepomis macrochirus*	34	27	6.4 (2.3-19.3)	7	4.3 (3.3-7.1)
blacknose shiner	*Notropis heterolepis*	19	19	4.5 (3.8-5.1)	0	--
pumpkinseed	*Lepomis gibbosus*	18	7	12.0 (4.3-22.6)	11	5.3 (3.9-7.4)
largemouth bass	*Micropterus salmoides*	16	14	6.2 (4.8-8.1)	2	5.8 (5.3-6.3)
yellow bullhead	*Ameiurus natalis*	10	10	27.7 (13.5-31.8)	0	--
black bullhead	*Ameiurus melas*	7	7	29.2 (13.5-33.8)	0	--
warmouth	*Lepomis gulosus*	7	3	14.8 (13.8-15.9)	4	6.3 (4.6-7.1)
brown bullhead	*Ameiurus nebulosus*	5	5	30.8 (29.0-32.0)	0	--
black crappie	*Pomoxis nigromaculatus*	3	3	10.4 (6.4-18.3)	0	--
grass pickerel	*Esox americanus*	2	0	--	2	17.6 (17.6-17.7)
johnny darter	*Etheostoma nigrum*	1	1	5.0	0	--
brook silverside	*Labidesthes sicculus*	1	1	6.3	0	--
pugnose shiner	*Notropis anogenus*	1	1	5.9	0	--
	Total	**207**	**152**		**55**	

[1] Unknow sunfish were either bluegill or pumpkinseed.

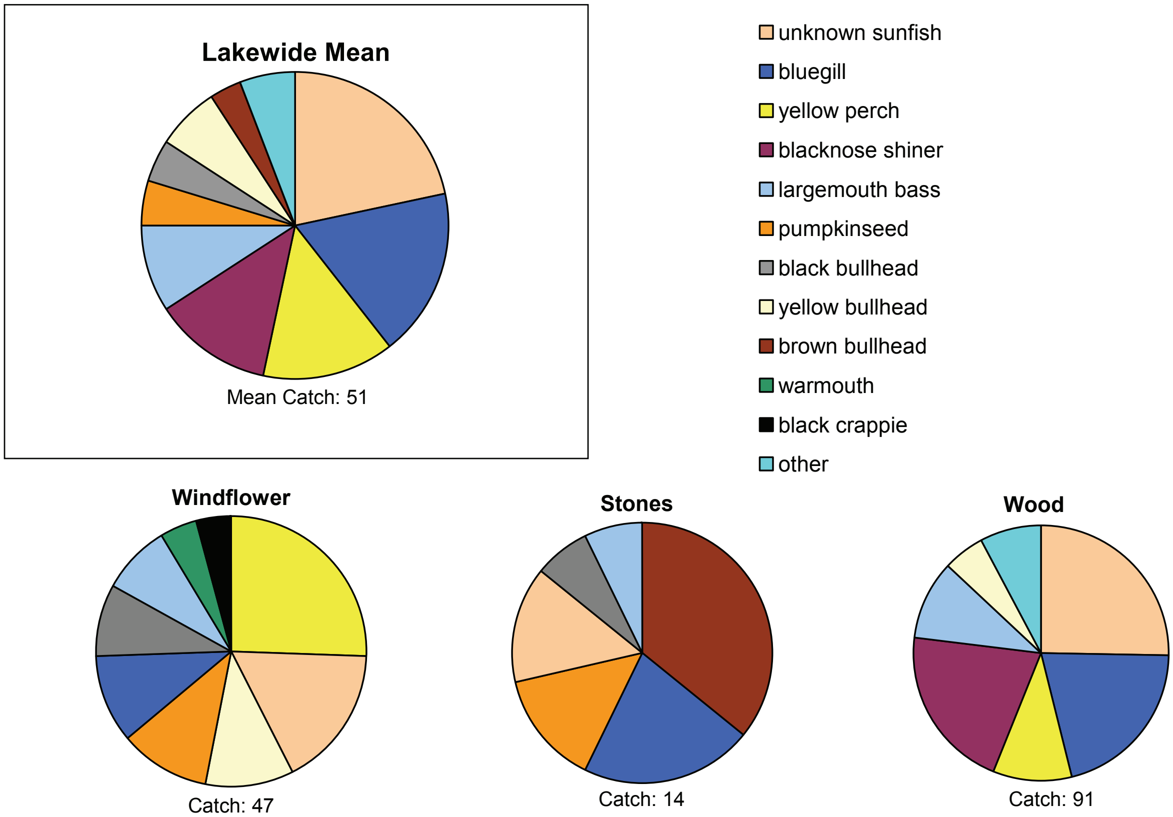

Figure 7. Fish community composition based on fyke netting. The enclosed pie chart shows the lakewide mean (from all 3 sites). The other pie charts show the community at each site (site name on top). Below each pie chart is catch (i.e., number of fish captured in three fyke nets). Unknown sunfishes were either bluegill or pumpkinseed.

Summary/Recommendations

Overall, the water quality and biotic data suggest that the ecological health of Little Black Lake is good. Nutrient levels at the time of our sampling were relatively low, water clarity was excellent, and both the phytoplankton and fish community structure were representative of a healthy lake. Although there was abundant macrophyte growth, the community composition and spatial variation was indicative of good lake condition.

However, the following observations suggest that environmental stress is being placed on Little Black Lake:

- The phosphorus concentration in the sediment at the Center site was extremely high. This suggests that organic matter is either entering the lake from inflows or is being produced within the lake, and is being focused to this location. An expansion of nutrient-rich, organic sediment will ultimately change the ecology of Little Black Lake.
- Nutrient concentrations of some elements increased in tributaries during storm flow. This suggests there are upstream nutrient sources potentially impacting Little Black Lake.
- The dense macrophyte beds, while providing good fish habitat, also can deplete dissolved oxygen levels at night and in early light hours because of excessive respiration. This can potentially stress aquatic organisms. Perhaps more importantly, as these macrophytes die off each autumn and decompose, the nutrients return to the sediments and create a feedback loop that stimulates their growth the following year.
- Increased development around the lake will create added stress to the lake, especially in the form of nonpoint source pollution (i.e., diffuse inputs of fertilizers, pesticides, greases, oils, pathogens, etc. from lawns, road runoff, and streambank erosion).

<u>Recommendation #1:</u>

Develop Watershed Management Plan: The assessment conducted in the present study provided baseline information on the ecological status of Little Black Lake. However, the study was a snapshot of conditions, and does not provide any seasonal or interannual information. The City of Norton Shores and the lakefront homeowners may want to consider developing a comprehensive watershed management plan for the watershed of Little Black Lake. One of the key elements that this plan should address is changing land use patterns in the watershed, since land use/land cover has such broad implications for water quality, water quantity, terrestrial and aquatic habitat, and sustainable economic development. This type of plan is especially important for a lake with good water quality, such as Little Black Lake, to protect the resource and ensure that future decisions in the watershed do not negatively impact the lake. The plan also should identify the sub-basins in the watershed, and which sub-basins are contributing the most pollutants to the lake during different times of the year.

Recommendation #2

Control Nonpoint Source Loads: Based on our preliminary data, the Yonkers Drain sub-basin is the dominant source of nonpoint source pollution to Little Black Lake. Assuming these data are confirmed with more extensive sampling, pollutant reduction activities focused in this sub-basin will have the greatest impact per unit dollar expended. This does not mean that other inflows should be ignored, simply that the Yonkers Drain sub-basin should have the highest priority for external pollutant load reduction activities.

- A thorough assessment of the upper reaches of the Yonker Drain sub-basin is needed. This inventory should identify potential source areas, with a focus on both highly erodable lands and impervious surfaces that may be directing stormwater to the drain. This drain includes the rapidly developing region along Sternberg and Harvey (Fig. 1), so it is anticipated that stormwater pollutants will continue to grow as a major issue for Little Black Lake. Locations for the implementation of best management practices (BMPs), including bank stabilization projects, passive infiltration areas, and planting of riparian vegetation, should be identified and prioritized. Although this watershed is outside the geographic boundaries of the Mona Lake Watershed Council, homeowners and the City of Norton Shores should consider working with this group, as well as the Muskegon Conservation District, to adopt and install these BMPs.
- Although Yonkers Drain accounts for most of the nutrient loads to Little Black Lake, other inflows also can account for high concentrations of contaminants at certain times of the year. Because the flows at these sites are low relative to Yonkers, their overall contribution of load is small, but they may represent localized “hot spots” of biological

impairment. Again, appropriate BMPs should be designed and installed along these tributaries to minimize impacts to Little Black Lake.

Recommendation #3:

Internal Loading: Unlike other lakes in the region, it does not appear that internal loading (nutrient release from the sediments) is a major problem in Little Black Lake. In most cases, internal loading reflects years of external nutrient loading to a lake; these nutrients accumulate in the sediments, and become a reservoir for release to the water column under the appropriate environmental conditions. Therefore, the more that external nutrient loading to Little Black Lake can be controlled, the greater the likelihood that internal nutrient loading will not become a major issue in this system. Implementing the BMPs in Recommendation #2 will help prevent internal loading from becoming a major issue in Little Black Lake.

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