Ecological Characterization of Long Lake, Porter and Lake Counties, Indiana

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Cover photograph: The west section of Long Lake, illustrating the dominance of white water lilies in the open water section and the surrounding cattail monoculture.

1. Study Purpose

Long Lake, prior to its partial development, once extended eight miles along the southern shore of Lake Michigan and was habitat for diverse populations of invertebrates, fish, plants, herpetofauna, birds and mammals (Whitman et al. 2002). Since the construction of railroads and roads on all sides and the splitting of the lake by County Line Road, subsequent changes in drainage have caused Long Lake to decrease in size and depth. The west side of the lake is primarily a monoculture of cattails surrounding a wetland that sometimes has standing water. The east side of the lake is now being encroached by vegetation and is becoming shallower due to the abundance of organic material settling in the lake. A ditch along the southern side of US route 12 has often been cited as a factor in diminishing natural water flow into Long Lake, particularly the western portion, and it might be possible to rehabilitate Long Lake to some degree by restoring natural drainage.

The purpose of this report is to characterize the west side of Long Lake. Because very little data is available on this section of Long Lake, data from the east section of Long Lake, as well as from other similar water bodies, will be used to extrapolate what possible conditions exist in the west section. This information is presented to offer an information base upon which to make decisions related to future hydrologic management decisions. This survey will characterize the physical, chemical, and biological characteristics of Long Lake and will attempt to compare differences between the basins east and west of County Line Road, Lake and Porter Counties, Indiana. Historical descriptions of the lake and its natural history will be presented to provide background of the area and evidence of the lake's significance to the ecosystem.

2. Background

In 1966, the Indiana Dunes National Lakeshore was established as part of the National Park system (Whitman et al. 2002). The Indiana Dunes National Lakeshore extends from Michigan City to Gary, Indiana, but it is not a continuous swath of land. For years, encroaching industrial and residential development in the area threatened the rare dune ecosystem. Even today, development around the protected dunes impacts the various ecosystems of the park. Heavy industry, residential communities, and municipalities are scattered along the southern shore of Lake Michigan, forcing the park's boundaries to bend around them. With the close proximity of developed areas, water resources in the park experience contamination from aerial inputs, runoff, and sewage systems. Many of the wetlands have been drained or ditched in order to protect residences from flooding, thereby sacrificing their natural filtration qualities.

3. History

When the Wisconsin Glacier retreated 14,000 years ago, Lake Michigan went through a series of lake fluctuations. The receding water exposed land areas marked by sand dunes, relict beaches, sandbars, and spits (Chrzastowski et al. 1994). Long Lake developed as a result of winds moving sand out of an expanse of swale area, and when this “blowout” dipped below the groundwater surface, water gradually filtered in and an interdunal lake formed. Long Lake is one of the larger of these interdunal ponds, and many similar ponds can be found nearby in the Miller Woods section of the Indiana Dunes National Lakeshore.

At the beginning of the 1900’s, railroads were built on the north and south sides of the lake. This increased the threat of contamination and added to the impacts the lake was already experiencing from the highway south of the railroads. In the mid-1920’s a major road was constructed through the lake, and it effectively cut Long Lake into two separate parts. Eventually, the railroad on the north side was abandoned and was submerged by rising lake levels.

Long Lake has had a history of severe degradation. Despite the presumed degradation of Long Lake, the amount of available information is limited. There are brief mentions of the lake in historical documents and maps, but most data is limited to that collected after the area was incorporated into the Indiana Dunes National Lakeshore.

4. Physical Description

The watershed of Long Lake is limited in size, and it is located near residential and industrial areas (Whitman et al. 2002). Lake Michigan lies less than 0.5 mile north of Long Lake, across the dunes. A heavily used road is located directly south (U.S. 12) of the lake, and another heavily used road (County Line Road) divides Long Lake into the present east and west sections. Surface drainage from these roads flows into Long Lake. The natural habitat of the area is a dune and swale ecosystem. To the south and east of the region there is agricultural land, and to the west there is prairie.

The east section of Long Lake is encircled by successional vegetation, including sand reeds and cottonwoods (Whitman et al. 2002). Aquatic vegetation in the marshy areas immediately surrounding the lake is primarily cattails (*Typha* spp.). Submerged vegetation grows abundantly within the lake, and massive root systems of the floating vegetation also grow on the sediment surface. Shoreline length equals 4622 meters (Simon et al. 1997), and changes in water level and infilling have led to the formation of embayments. The lake also has three small islands, and the shoreline development factor equals 2.5. Total surface area equals approximately 34 hectares. At its greatest width, Long Lake measures 378 meters, and during high winds, the lake’s shallow waters are often completely mixed. According to Simon et al. (1997), maximum depth of the lake is 1.8 meters, and the mean depth is 1.1 meters. Deep areas can be found at different locations around the lake, but a deeper basin is located in the west end, near to the largest island. Less technical information is available on the western portion of the lake. The west section of Long Lake is little more than a temporary wetland that is generally less than 30 cm deep and is surrounded by a cattail monoculture (Mr. Eric Garza, personal observation). Because of the shallowness, the shoreline is variable, and open water may be nonexistent when the west section dries up in hot or dry years.

The water in Long Lake is often turbid and colored with a heavy brown appearance. Early in the spring, the Secchi disk can be seen to the bottom of the lake, but by autumn, visibility is reduced considerably. Mean Secchi disk depth for the year is generally slightly less than one meter. Water clarity decreases through the sampling season in Long Lake, as is evident in increasing levels of total suspended solids. This is due in part to wave action; during winter, when the lake is covered with ice, most suspended solids can settle out of the water column. Once the ice melts, wave action begins to mix the water, re-suspending particulate matter. Organic decomposition through the warm summer months also increases suspended solids. The lake does not stratify, due to its shallow depth, and the surface temperature can get very high. Yearly measured highs have ranged up to 30 degrees, which is a temperature fatal to many fishes. Mean dissolved oxygen for a given year was 5.87 mg/L, with a range of 2.74-10.12 mg/L.

Long Lake is a polymictic lake, mixing throughout the ice-free season. It is not unusual, however, for this lake to lack oxygen during late summer months and extended periods of ice cover. Much of the lake is covered by macrophytes from late spring through fall, and blue-green blooms are common. Recurring winter fish kills have been documented. Long Lake is a eutrophic water body with a limited capability to sustain a balanced, diverse aquatic fauna. American Water Company has isolated a small section at the far east of the lake for use in its water treatment processes.

5. Hydrology

A study of groundwater movement in the area indicated that Long Lake is a recharge lake with water leaving to the south and likely to the north (Isiorho et al. 1996). Other studies of groundwater movement have indicated that ditching on the south side of U.S. 12 may be draining water away from the lake (Dolak 1985).

Sediment in Long Lake is composed primarily of organic material. There is sand under the layers of organics, but the surface sediments are almost solely degrading plants and other organic material (Simon et al. 1997). A study of four sediment cores taken from various areas of Long Lake reveal an organic or partially organic layer at the surface with a thick layer of fine to medium grained sand beneath (Fisher, unpublished data). At the greatest depth to which the cores were taken, a layer of gravel was found in some samples. In most core samples, the uppermost layer was formed of black organic peat, formed from the decomposing aquatic plants that are so abundant in most of Long Lake. Beneath this generally lies a thin layer of organic-rich mud that may be interspersed with peat, and this may be mixed with organic-rich mud that is interspersed with fine grained sand. In two samples, a layer of sandy loam soil was found beneath this. This organic layer may be roughly one half meter in some areas, and in other areas of Long Lake may be as much as one meter thick. Beneath this organic layer lies a thick layer of fine to medium grained sand that may be interspersed with some organic material; the sand layer may be nearly two meters thick in some areas. In three of the four core samples taken, the core penetrated this sand layer, and beneath this layer was found coarse gravel.

The Long Lake watershed is that area bounded on the north by Lake Michigan, on the east by Burns Ditch, on the south by the Little Calumet River/Burns Ditch, and on the west by a north-south line approximately coincident with Lake St. in Gary, Indiana. The Long Lake area is underlain by approximately 50 to more than 65 meters of unconsolidated sediments of Pleistocene and Holocene age deposited on a bedrock surface modified by pre-Pleistocene erosion (Mr. David Cohen, May 22, 2002, pers. comm.). These sediments form a surficial aquifer and an underlying confining unit that overlie a carbonate bedrock aquifer. Eolian and lacustrine sands form a surficial aquifer in the area commonly known as the Calumet aquifer. The saturated thickness of the Calumet aquifer in the area ranges from approximately 20 to 80 feet and is generally unconfined throughout most of the area; however, in some areas, the aquifer may contain small lenses of paludal deposits and calcareous clay in the subsurface that function as local confining layers for the underlying parts of the aquifer.

Underlying the Calumet aquifer and above the bedrock is a confining unit that is composed primarily of clay till, and may contain thin discontinuous sand deposits. This confining unit generally varies in thickness from slightly less than 15 m to about 50 m. A carbonate bedrock aquifer is at the bedrock surface throughout the study area. The bedrock aquifer is composed of Devonian and Silurian carbonates.

Surface drainage in the area is to the Little Calumet River and Burns Ditch along the southern and western perimeter, and to Lake Michigan along the northern perimeter of the area. Surface drainage in the central portions of the area is to Long Lake, the wetland areas south and west of Long Lake, and the ditch immediately south of US 12 that originates just west of County Line Road. The ground-water-flow system in the area is typified by broad flat water-table mounds that function as ground-water divides. These divides typically underlie the area between US 12 and the Little Calumet River to the south. Ground water in the Calumet aquifer generally flows laterally away from these divides and discharges to streams and wetlands in adjacent low-lying areas, and directly to Lake Michigan.

Research is presently underway to characterize more thoroughly the groundwater movement in the area of Long Lake. East and West Long Lake are generally flow-through systems – groundwater discharges to these lakes along their southern shorelines and surface water discharges from these lakes to the groundwater system along their northern shorelines. There is one exception when surface water in West Long Lake appears to discharge southward along its southern shoreline toward a US 12 ditch – this is most likely a short-term phenomenon that may be likely to occur during generally high water levels. There is no groundwater divide underlying the dune-beach complex north of East and West Long Lakes. Surface water discharging to the groundwater system along the northern shorelines continues moving northward and discharges to Lake Michigan. East of County Line Road the flow divide is often approximately located in the area immediately south of East Long Lake, and may occasionally be coincident with East Long Lake itself. This divide most likely shifts to the south during periods of high water levels. West of County Line Road the flow divide is located approximately midway between the US 12 ditch and the Little Calumet River. Its location is probably at least partially attributable to the lowering of groundwater levels by the US 12 ditch to the north. This divide, unlike that east of County Line Road, appears to be more stable and does not appear to shift substantially northward during periods of higher water levels.

6. Sediment Chemistry

The absence of data specific to the west section of Long Lake necessitates extrapolation from the similar east section. Total organic carbon over the course of the 1997 sampling season was stable between 0.5 and 2.7% (Whitman et al. 2002). Total phosphorus was also very constant with a range of 62-77 mg/kg. There was some variation in sediment TKN, but overall it was also stable, with a range of 189-684 mg/kg. Nitrate plus nitrite as N was 2.1 mg/kg in August, and below detection limits in all other months sampled. Aluminum was found in concentrations of 933 mg/kg of sediment, chromium was found at 3 mg/kg, iron at 8640 mg/kg, lead at 9.7 mg/kg, mercury at 0.096 mg/kg, and zinc at levels of 17.4 mg/kg.

7. Water Chemistry

In the absence of data specific to the west section of Long Lake, the eastern portion is the best available model (Whitman et al. 2002). Water chemistry data are available for the east section of Long Lake for the years 1997, 1998, 1999, and 2000. An attempt will be made to make generalizations from the 2000 data, as the consistent sampling design in this year allowed the calculation of means and likely offers a better picture of the lake chemistry than other years. It is necessary to realize that there may be a significant amount of variability between years, and thus this information is not to be used in a predictive manner.

Alkalinity readings tended to be relatively high early in the testing season (mean 130 mg/L in May), and concentrations fluctuated through the rest of the season, with a low of 90.8 mg/L in October (Whitman et al. 2002). Ammonia measurements were generally low early in the testing season (mean of 0.19 mg/L in May) and reached a yearly high by late June. Ammonia concentrations then fell to a low of 0.11 mg/L in August, followed by a slight rise for the remaining part of the sampling season. Calcium hardness was high early (mean 129 mg/L), and continued to fall until early August. There was a slight increase in September, but the low concentration was then reached in October (79.1 mg/L). Magnesium hardness also started high (62.3 mg/L) and decreased steadily until August (39 mg/L). There were minor fluctuations late in the season. Potassium concentrations also started high in May (2.1 mg/L), and concentrations decreased until the season low in July (0.6 mg/L). There was a general increase for the rest of the season, with a spike in September, which may be the result of an anomalous reading. Sulfate concentration peaked in June (33.6 mg/L), followed by a decrease that continued to a low of 6.2 mg/L in September. Increased concentrations of sulfate were measured in October. Little pattern was visible in total phosphorus concentration in 2000. Most concentrations ranged between 0.03 and 0.05 mg/L, with a high on 0.094 mg/L. Chloride concentrations generally ranged between 40 and 60 mg/L, with no distinct pattern. Sodium concentrations similarly lacked any obvious trends. Sodium concentrations tended to stay within the 15-25 mg/L range in 2000. Because nitrate and nitrite concentrations were below detection limits most of the time in 1999 and 2000, no trends can be reliably estimated.

Surface water chemistry was collected between 1997 and 2000 (Whitman et al. 2002). Water characteristics observed included specific conductivity, total dissolved solids, dissolved oxygen, and pH. Specific conductivity generally increased through each summer sampling season, although this trend was not evident in all years. Dissolved oxygen remained relatively high during the colder open water months, and it decreased during the heat of summer. Low measured dissolved oxygen values were between 2 and 3 mg/L in the heat of the summer. The east portion of Long Lake has been documented as becoming anoxic near the sediment/water interface during summer months. Additionally, Long Lake becomes anoxic in the lower water layers during ice cover in winter; during severe winters, the zone of anoxia extends into the water column. Acidity of the east section of Long Lake generally decreased until autumn with an increase later in the year, although the lake in general maintained a pH greater than 7 throughout the sampling season.

8. Plankton

Zooplankton mean density in 1997 in Long Lake was 336 individuals/liter (Whitman et al. 2002). Zooplankton density peaked in early July to approximately 1100 individuals/liter. During other samplings, the density was near or below 200 individuals/liter. The high abundance in July reflected increases across most of the dominant taxa. The abundance of macrophytes creates significant refuge for the zooplankton from predatory fish, and high primary production also may contribute to the zooplankton abundance by supplying adequate energy sources.

Zooplankton diversity during this period had a Margalef's richness of 4.0 and a Shannon-Wiener index of 1.5-1.8 (Whitman et al. 2002). In total, 36 taxa were identified, and *Bosmina longirostris*, *Conochilus unicornis*, *Polyarthra* spp., *Collotheca* spp., and *Keratella* spp. represented greater than ten percent of the total number of individuals. The taxa were dominated by rotifers, which composed around 75% of the individuals. The dominant taxa included the rotifers *Conochilus unicornis* and *Keratella* spp., and the cladoceran *Bosmina longirostris*. The rotifers are often dominant taxa for small, temperate lakes in the Great Lakes area (Hutchinson 1967). In the Great lakes region *C. unicornis* tends to be at maximum densities in early spring then again in July (Hutchinson 1967), as was seen in Long Lake. *B. longirostris* is commonly associated with lakes that are becoming eutrophic (Hutchinson 1967). Long Lake is a eutrophic lake, so the high abundance of *B. longirostris* was expected.

Phytoplankton were collected on both the east and west sections of Long Lake in 1998 and 1999, with samples taken on the east portion of the lake in 1997. Table 1 lists taxa identified from these samples, and which portion(s) of Long Lake they were identified from (Dr. Richard Whitman, unpublished data). All taxa were located in the larger east section of Long Lake with the exception of *Neidium* spp., which was only identified from the west section. Many taxa were found to be absent from the west section of Long Lake. Water samples were collected and analyzed for chlorophyll *a*, a measure of phytoplankton biomass, in 1997, 1998, and 1999 (Whitman et al. 2002). While some years did not show distinct trends, data collected in 1998 and 1999 showed a peak in the summer months, particularly July and August. This indicates that peak biomass is reached during the summer months, which would be expected.

9. Vascular Plants

The west section of Long Lake has not been extensively sampled for aquatic vegetation. One of the limiting factors for west Long Lake is that it dries up in years of low precipitation, therefore limiting what aquatic plants can survive. It is important to note, however, that many vascular plant species can persist for very long periods in the sediments as seeds, and in the event of a rise in water level in the west section of Long Lake, many dormant species may 'recolonize' the area. Aquatic vegetation found in the east section of Long Lake includes floating vegetation, water lilies (*Nymphea* spp.) and pond lilies (*Nuphar* spp.), and submerged vegetation such as pondweed (*Potamogeton* spp.), and pickerel weed (*Pontederia cordata*) (Simon et al. 1997). By the end of summer, the plants begin to deteriorate, and dead plants are abundant on the lake (Figures 1, 2, and 3).

A total of 12 macrophyte species were collected in Long Lake during a 1997 survey (Simon et al. 1997). Macrophyte coverage was dense throughout the lake, including almost complete coverage by pond lilies and water lilies (Figure 4). It was noted that although the area was not sampled, extensive stands of cattails were visible on the southern side of the lake. Most of the species collected were found in both zones. Common boneset (*Eupatorium perfoliatum*), common pondweed (*Potamogeton natans*), and comb pondweed (*Potamogeton pectinatus*) were only present in the western portion of east Long Lake, and large-leaved pondweed (*Potamogeton amplifolius*) and flat-stemmed pondweed (*Potamogeton zosteriformes*) were only present in the eastern portion. Other species collected during this survey include water shield (*Brasenia schreberi*), purple loosestrife (*Lythrum salicaria*), yellow pond lily (*Nuphur advena*), white water lily (*Nymphaea odorata*), pickerel weed (*Pontederia cordata*), Illinois pondweed (*Potamogeton illinoensis*), and purple bladderwort (*Utricularia purpurea*). The west section of Long Lake is surrounded primarily by a monospecific stand of cattails. The east section maintains higher diversity along part of its shoreline. False rusty nut sedge (*Cyperus engelmannii*) is known along the north shore of Long Lake and in areas where the soil remains moist nearby (Wilhelm 1990). Water pennywort (*Hydrocotyle umbellate*) was found along the east margin of Long Lake in 1930, although it is presently regarded as probably extinct in the Indiana Dunes. Lake shore rush (*Juncus balticus*) is occasionally found in areas of moist sand throughout the West Beach area. Brown-fruited rush (*Juncus pelocarpus*) is a rare species of rush that is extant along the north shore of Long Lake. Red honeysuckle (*Lonicera dioica*) is considered a rare species in a few of the mesophytic areas near Long Lake. Buckbean, or bogbean, (*Menyanthes trifoliate*) is known from the marshy area of Long Lake. Marsh cinquefoil (*Potentilla palustris*) is thought to be locally confined to the shores of Long Lake. A population of Pursh's tufted bulrush (*Scirpus purshianus*) was found along the north shore of Long Lake in 1986. Humped bladderwort (*Utricularia gibba*) is found along the north shore of Long Lake and is locally common. Fox grape (*Vitus labrusca*), yellow-eyed grass (*Xyris torta*), and wild rice (*Zizania aquatica*) are known from the Long Lake area as well.

10. Aquatic Macroinvertebrates

Although macroinvertebrates have not been collected in the west section of Long Lake, the community is likely similar to east Long Lake (Dr. Richard Whitman, unpublished data). Species capable of withstanding drying or limited water would likely be found in the years that water dries up in west Long Lake. Samples taken from the east section of Long Lake indicate a relatively depauperate macroinvertebrate community. Among the order Annelida, large numbers of tubifex worms (Tubificidae) were found in samples, and some leeches (*Helobdela stagnalis*) were also found. The only mollusks found were some fingernail clams (*Pisidium* spp.). An isopod (*Lirceus* spp.) was identified in samples later in the year, and large numbers of the amphipod *Hyalella azteca* were found throughout the sampling period. In 1998, a crayfish (*Procambarus* spp.) was noted during a fish survey on Long Lake (Dr. Thomas Simon, unpublished data).

Among the insects, the springtails, order Collembola, are represented by a single species, *Podura aquatica* (Dr. Richard Whitman, unpublished data). No mayflies (order Ephemeroptera), dragonflies (order Odonata), or caddisflies (order Trichoptera) were identified, and as these taxa are considered very sensitive, their absence may be due to Long Lake's history of degradation. The order Diptera (flies) is the most well represented order of insects collected from the east section of Long Lake. Among the midges (Chironomidae) found were *Ablabesmyia* spp., *Chironomus* spp., *Glyptotendipes* spp., and *Rheotanytarsus* spp. *Chaoborus* spp. is the one genus of ghost midge (Chaorbidae) that was found.

Of the taxa present, tubifex worms and midges are likely the most important to the food web, being consumed by many vertebrates such as fish and larval amphibians. Amphipods and isopods may also be very important, depending on their numbers; they are readily consumed by fishes and some larval amphibians.

While no large scale effort has been done to ascertain the level of bioaccumulation of contaminants in Long Lake's macroinvertebrates, some crayfish were tested in 1990 (Steffeck 1990). Crayfish were found to contain relatively high levels of many contaminants when compared to crayfish collected from a waterbody near a hazardous waste disposal site. Acetone was found in concentrations up to 490 ppb, and other contaminants found included chloroform (16 ppb), 2-butanone (34 pbb), toluene (20 ppb), ethylbenzene (7.0 ppb), total xylenes (18.0 ppb), aluminum (82.8 ppm), barium (25.5 ppm), copper (15.3 ppm), iron (405.0 ppm), lead (1.2 ppm), magnesium (940 ppm), manganese (38.0 ppm), and zinc (30.2 ppm). Long Lake crayfish surpassed those collected from the hazardous waste disposal site in the concentration of iron, magnesium, and zinc.

11. Fishes

One of the earliest records of Long Lake ecology includes a list of fish species found in Long Lake (Brenan 1923). At that time, the lake was well used by recreational fishermen, and fish species included yellow perch (*Perca flavescens*), largemouth bass (*Micropterus salmoides*), and chain pickerel (*Esox niger*). A survey of the fish community was again conducted in 1988, and similar species were identified. Additional species present included green sunfish (*Lepomis cyanellus*), bluegill (*Lepomis macrochirus*), carp (*Cyprinus carpio*), black bullhead (*Ictalurus melas*), yellow bullhead (*Ictalurus nebulosus*), golden shiners (*Notemigonus crysoleucas*), and fathead minnows (*Pimephales promelas*) (Spacie 1988). The population has changed dramatically in recent years. Yellow perch have not been identified in Long Lake since a massive fish kill in 1990 that was likely the result of winter die-off (Dr. Richard Whitman, personal communication, June 1, 2002). Among the fish species thought to be present at that time in Long Lake were green sunfish, bluegill, black bullhead, golden shiner, grass pickerel (*Esox americanus*), and the common carp (Spacie 1988). Figure 5 illustrates a photograph taken of a fish kill that occurred in late winter of 2000.

The most recent fish surveys on the east section of Long Lake in July 1998 and October 1999 yielded many of the same species collected by Spacie (1988). Green sunfish, bluegill, black bullhead, golden shiner, and common carp were again found, although grass pickerel were not found in this survey. Interestingly, many fathead minnows (*Pimephales promelas*) were caught in a reptile and amphibian trap that had been submerged by rising water levels in 2002 (Mr. Eric Garza, personal obervation). This species was not reported in the 1998 or 1999 fish surveys.

The west section of Long Lake, since cut off from the east section with the construction of County Line Road, has maintained neither sufficient depth nor adequate water supply to maintain a fish population. During periods of high water, it is likely that green sunfish and fathead minnows may enter this section of the lake via shallow in or outflowing streams. Increasing water depth with hydrologic restoration may allow these and other fish species to maintain permanent populations in the west section of Long Lake.

Green sunfish and common carp accumulated many organic and inorganic compounds (Steffeck 1990). Individual fish accumulated methylene chloride to levels as high as 48 ppb, acetone to levels as high as 760 ppb, chloroform up to 10 ppb, 2-butanone up to 37 ppb, toluene up to 19 ppb, and xylene compounds up to 7 ppb. Among inorganic compounds that were abnormally high in green sunfish collected from Long Lake are aluminum (23.2 ppm), iron (up to 56.7 ppm), lead (0.8 ppm), magnesium (up to 560 ppm), manganese (up to 3.8 ppm), mercury (0.099 ppm), and zinc (up to 41.9 ppm). Common carp collected from Long Lake also accumulated high concentrations of some compounds. Methylene chloride was found in concentrations up to 63.8 ppb, while acetone (2105 ppb), carbon disulfide (27.6 ppb), chloroform (25.4 ppb), 2-butanone (26 ppb), and toluene (8.9 ppb) were also relatively high. Among inorganic compounds high in common carp, iron (91.7 ppm), lead (0.8 ppm), magnesium (502.5 ppm), manganese (8.0 ppm), and zinc (49.9 ppm) were also high. Black bullhead had relatively high concentrations of acetone (430 ppb), 2-butanone (15 ppb), toluene (11 ppb), aluminum (48.7 ppm), iron (149 ppm), lead (1.3 ppm), magnesium (280 ppm), manganese (5.2 ppm), and zinc (25.2 ppm). All of these readings were above those noted from specimens collected near a hazardous waste disposal site.

12. Amphibians and Reptiles

The area surrounding both the east and west sections of Long Lake attracts many species of reptiles and amphibians, which likely use the lake. Among the tree frogs (family Hylidae), the chorus frog (*Pseudacris triseriata*) and the spring peeper (*Pseudacris crucifer*) are abundant around both sections of Long Lake. The tetraploid gray treefrog (*Hyla versicolor*) and the diploid Cope's gray treefrog (*Hyla chrysoscelis*) may also be located in this area. The two toad (family Bufonidae) species found in the area are the American toad (*Bufo americanus*) and the state listed Fowler's toad (*Bufo fowleri*). These species occur near east Long Lake, and likely occur near the west section as well. Among the true frogs (family Ranidae), the green frog (*Rana clamitans*) and the bullfrog (*Rana catesbiana*) occur in this area of the park.

Two species of salamanders (family Ambystomidae) have been found in the vicinity of Long Lake, and both are thought to use the east and west sections for breeding purposes. These two salamanders are the tiger salamander (*Ambystoma tigrinum*) and the state listed blue-spotted salamander (*Ambystoma laterale*). As a side note, while the blue-spotted salamander is listed here, there is a variety of salamander that is a hybrid between the blue-spotted salamander and the Jefferson's salamander (*Ambystoma jeffersonianum*) that can look identical to the pure bred blue-spotted salamander. As genetic analysis has not been done in this area to our knowledge, there exists the possibility that the blue-spotted salamanders that live in the vicinity of Long Lake may not be pure bred, and thus would not be categorized as state listed.

Among the reptiles, many species of turtle, snakes and one species of lizard are known to occur in the area around east and west Long Lake. Turtles that have been found near east Long Lake include the common snapping turtle (Chelydridae: *Chelydra serpentina*), the common musk turtle (*Sternotherus odoratus*) and the painted turtle (Emydidae: *Chrysemys picta*). The only water snake (Natricidae) found in the area is the eastern garter snake (*Thamnophis sirtalis*). Colubrids that have been seen near east and west Long Lake include the racer (*Coluber constrictor*) and the eastern hognose snake (*Heterodon platyrhinos*). Recently, an eastern massasauga rattlesnake (Crotalidae: *Sistrurus catenatus*) was reported near the western section of Long Lake, but the sighting remains unconfirmed and should be treated with some skepticism.

One species of lizard is found in the area surrounding east and west Long Lake. The six-lined racerunner (Teiidae: *Cnemidophorus sexlineatus*) is entirely terrestrial and lives in the dry, open areas near the shores of east and west Long Lake. The possibility exists that slender glass lizards (Anguidae: *Ophisaurus attenuatus*) may persist in the area surrounding Long Lake, although none have been noted from the area recently. A population of these lizards is known to exist in the area of Inland Marsh, and this area is not far from Long Lake. These lizards prefer open, grassy areas, and the areas surrounding Long Lake would provide this habitat.

Common snapping turtles were tested in 1990 for contaminants (Steffeck 1990). These reptiles had very high concentrations of many contaminants, often maintaining higher concentrations than turtles collected near a hazardous waste disposal site. Methylene chloride concentrations were 130 ppb, and other compounds found included acetone (2000.0 ppb), 2-butanone (390.0 ppb), chloroform (17.0 ppb), 1,1,1,-trichloroethane (8.0 ppb), 4-methyl-2-pentanone (49.0 ppb), toluene (28.0 ppb), antimony (0.5 ppm), iron (176.0 ppm), manganese (4.7 ppm), mercury (0.354 ppm), and zinc (15.3 ppm). While it is concerning that snapping turtles accumulate such high concentrations of these compounds, it is not particularly surprising. Turtles are very long lived, and thus may be exposed to low levels of contamination for 50 years or longer, allowing them to accumulate toxins in their fatty tissues to detectible concentrations.

13. Birds

Both the east and west portions of Long Lake present some open water habitat, and surrounding uplands offer a variety of habitat types, including cattail marsh, forest, and savanna, and many bird species have been identified in the vicinity of east and west Long Lake (Table 2). Many of the waterfowl are migrants and may only stop at Long Lake for a limited time during the year. Many other birds, such as warblers, are also migrants that typically use upland habitats, but they may occasionally be seen foraging near the shore. Some birds, such as the killdeer and sandpipers, forage near the shore as well. Birds that depend on water, such as waterfowl and edge-foraging birds, would benefit most from hydrologic changes that increase water level in the western section of Long Lake.

14. Mammals

In an extensive survey of the Indiana Dunes National Lakeshore, twelve species of mammals were found in marshes similar to Long Lake's cattail dominated habitat (Whitaker et al. 1994). These species included, in roughly their order of importance, the masked shrew (*Sorex cinereus*), the white-footed mouse (*Peromyscus leucopus*), the meadow vole (*Microtus pennsylvanicus*), the northern short-tailed shrew (*Blarina brevicauda*), the common raccoon (*Procyon lotor*), white-tailed deer (*Odocoileus virginianus*), eastern cottontail (*Sylvilagus floridanus*), eastern chipmunk (*Tamias striatus*), the woodchuck (*Marmota monax*), the prairie vole (*Microtus ochrogaster*), the common muskrat (*Ondatra zibethicus*), and the long-tailed weasel (*Mustela frenata*).

A survey of a panne north of Long Lake in the West Beach area also yielded prairie deer mice (*Peromyscus maniculatus bairdii*) as well as a Virginia opossum (*Didelphis virginiana*). Because part of the shoreline of the eastern section of Long Lake more resembles a panne than a marsh, it is possible that these species may be present in the vicinity of east and west Long Lake.

A survey of another interdunal pond system in the Miller Woods section of Indiana Dunes National Lakeshore yielded similar findings, although there were a few additions (Whitman et al. 1990). The eastern mole (*Scalopus floridianus*) was found near one of the interdunal ponds, and the fox squirrel (*Sciurus niger rufiventer*), the gray squirrel (*Sciurus carolinensis pennsylvanicus*), and the thirteen-lined ground squirrel (*Spermophilus tridecemlineatus tridecemlineatus*) were also located. Although these species were not found by Whitaker et al. (1994), the close proximity of Miller Woods and the similarities of the habitat suggest the possibility that these species may also be present in the vicinity of Long Lake, although none are necessarily dependant on aquatic systems.

In 1990, white-footed mice were collected near Long Lake and tested for contaminants (Steffeck 1990). Many compounds were found in the mice, including methylene chloride (180 ppb), acetone (500.0 ppb), chloroform (20.0 ppb), 2-butanone (42.0 ppb), toluene (370 ppb), ethylbenzene (6.0 ppb), total xylenes (21.0 ppb), aluminum 60.0 ppm), antimony (0.4 ppm), copper (2.6 ppm), iron (106 ppm), lead (1.0 ppm), magnesium (370.0 ppm), manganese (3.0 ppm), and (88.3 ppm). The compounds that were found in higher concentrations in white-footed mice collected near Long Lake than in mice collected near a hazardous waste disposal site were methylene chloride, and toluene, while concentrations of chloroform were higher than at some of the hazardous waste disposal sites, although not all.

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Figure 1. An April 29 photo of Long Lake illustrating the lack of emergent aquatic vegetation early in the season.

Figure 2. An August 8 photo illustrating the dominance of white water lilies and yellow pond lilies during the peak of the growing season.

Figure 3. An autumn photo taken on September 29 illustrating the beginning of the die-back of emergent vegetation in Long Lake.

Figure 4. A view of east Long Lake illustrating the nearly complete coverage by white water lilies.

Figure 5. A photo taken along the Long Lake shoreline illustrating the fish kill that occurred over the winter of 1999-2000. Most fish in this photo are panfish (Centrarchidae).

Table 1. Phytoplankton taxa identified in Long Lake by genera (Dr. Richard Whitman, unpublished data).

Taxa	east	west	Taxa	east	west
Achnanthes spp.	x	x	*Fragilaria* spp.	x	x
Anabaena spp.	x		*Glenodinium* spp.	x	x
Ankistrodesmus spp.	x		*Gomphonema* spp.	x	x
Arthrodesmus spp	x		*Hormidium* spp.	x	x
Asterionella spp.	x		*Kirchneriella* spp.	x	
Aulacosira spp.	x		*Navicula* spp.	x	x
Caloneis spp.	x	x	*Neidium* spp.		x
Carteria spp.	x		*Oocystis* spp.	x	x
Ceratium spp.	x		*Ophiocytium* spp.	x	
Chlamydomonas spp.	x		*Oscillatoria* spp.	x	x
Chlorochromonas spp.	x	x	*Pediastrum* spp.	x	x
Chorococcus spp.	x		*Phacus* spp.	x	x

Cocconeis spp.	x	x	*Rhaplodia* spp.	x	
Cosmarium spp.	x	x	*Rhizosolenia* spp.	x	
Crucegenia spp.	x		*Scenedesmus* spp.	x	x
Cryptomonas spp.	x	x	*Sphaerocystis* spp.	x	x
Cyclotella spp.	x	x	*Staurastrum* spp.	x	
Cymatopleura spp.	x	x	*Stauroneis* spp.	x	
Cymbella spp.	x		*Stephanodiscus* spp.	x	
Denticula spp	x	x	*Synedra* spp.	x	x
Diatoma spp.	x		*Tabellaria* spp.	x	x
Dinobryon spp.	x	x	*Tetraedron* spp.	x	
Euastrum spp.	x		*Tetrastrum* spp.	x	
Euglena spp.	x	x	*Trachelmonas* spp.	x	x
Eunotia spp.	x				

Table 2. Birds found in the vicinity of east and west Long Lake (Brock 1997, Dr. Ralph Grundel, April 22, 2002, personal communication). Birds with an * are considered incidental migrants that likely strayed from their normal course during migration.

Pied-billed grebe (*Podilymbus podiceps*)	Red-headed woodpecker (*Melanerpes erythrocephalus*)
Horned grebe (*Podiceps auritus*)	Northern flicker (*Colaptes auratus*)
Eared grebe (*Podiceps nigricollis*)*	Great-crested flycatcher (*Myiarchus crinitus*)
Double-crested cormorant (*Phalacrocorax auritus*)	Least flycatcher (*Empidonax minimus*)
American bittern (*Botaurus lentiginosus*)	Empidonax flycatcher (*Empidonax* spp.)
Least bittern (*Ixobrychuse exilis*)	Eastern wood-pewee (*Contopus virens*)
Great blue heron (*Ardea herodias*)	Eastern phoebe (*Sayornis phoebe*)
Great egret (*Ardea albus*)	Eastern kingbird (*Tyrannus tyrannus*)
Green heron (*Butorides striatus*)	Purple martin (*Progne subis*)
Black-crowned nightheron (*Nycticorax nycticorax*)	Barn swallow (*Hirundo rustica*)
Tundra swan (*Cygnus columbianus*)*	Northern rough-winged swallow (*Stelgidopteryx serripennis*)
Mute swan (*Cygnus olor*)*	Tree swallow (*Tachycineta bicolor*)
Great white-fronted goose (*Anser albifrons*)	Blue jay (*Cyanocitta cristata*)
Brant (*Branta bernicula*)*	Black-capped chickadee (*Parus atricapillus*)
Canada goose (*Branta canadensis*)	Tufted titmouse (*Parus bicolor*)
Wood duck (*Aix sponsa*)	White-breasted nuthatch (*Sitta carolinensis*)
Green-winged teal (*Anas crecca*)	Carolina wren (*Thryothorus ludovicianus*)
Mallard (*Anas platyrhynchos*)	House wren (*Troglodytes aedon*)
Northern pintail (*Anas acuta*)	Golden-crowned kinglet (*Regulus satrapa*)
Blue-winged teal (*Anas discors*)	Ruby-crowned kinglet (*Regulus calendula*)
Northern shoveler (*Anas clypeata*)	Blue-gray gnatcatcher (*Polioptila caerulea*)
Gadwall (*Anas strepera*)	Eastern bluebird (*Sialia sialis*)
Eurasian wigeon (*Anas penelope*)	American robin (*Turdus migratorius*)
American wigeon (*Anas americana*)	Hermit thrush (*Catharus guttatus*)
Canvasback (*Aythya valisineria*)	Swainson's thrush (*Catharus ustulatus*)
Redhead (*Aythya americana*)	Gray catbird (*Dumetella carolinensis*)
Ring-necked duck (*Aythya collaris*)	
Hooded merganser (*Lophodytes cucullatus*)	

Ruddy duck (*Oxyura jamaicensis*) Turkey vulture (*Cathartes aura*) Cooper's hawk (*Accipiter cooperii*) Sharp-shinned hawk (*Accipiter striatus*) Red-tailed hawk (*Buteo jamaicensis*) Peregrine falcon (*Falco peregrinus*) American kestral (*Falco sparverius*) Northern bobwhite (*Colinus virginianus*) Killdeer (*Charadrius vociferus*) Spotted sandpiper (*Actitis macularia*) Mourning dove (*Zenaida macroura*) Rock dove (*Columba livia*) Common nighthawk (*Chordeiles minor*) Ruby-throated hummingbird (*Archilochus colubris*) Chimney swift (*Chaetura pelagica*) Downey woodpecker (*Picoides pubescens*) Red-bellied woodpecker (*Melanerpes carolinus*) Red-winged blackbird (*Agelaius phoeniceus*) Eastern meadowlark (*Sturnella magna*) Baltimore oriole (*Icterus galbula*) Common grackle (*Quiscalus quiscula*) Brown-headed cowbird (*Molothrus ater*) American goldfinch (*Carduelis tristis*) House finch (*Carpodacus mexicanus*) Purple finch (*Carpodacus purpureus*)	Brown thrasher (*Toxostoma rufum*) Cedar waxwing (*Bombycilla cedrorum*) European starling (*Sturnus vulgaris*) Warbling vireo (*Vireo gilvus*) Red-eyed vireo (*Vireo olivaceus*) American redstart (*Setophaga ruticilla*) Common yellowthroat (*Geothlypis trichas*) Chestnut-sided warbler (*Dendroica pensylvanica*) Magnolia warbler (*Dendroica magnolia*) Nashville warbler (*Vermivora ruficapilla*) Yellow-rumped warbler (*Dendroica coronata*) Yellow warbler (*Dendroica petechia*) Tennessee warbler (*Vermivora peregrina*) Palm warbler (*Dendroica palmarum*) Scarlet tanager (*Piranga olivacea*) Northern cardinal (*Cardinalis cardinalis*) Indigo bunting (*Passerina cyanea*) Eastern towhee (*Pipilo erythrophthalmus*) American tree sparrow (*Spizella arborea*) Chipping sparrow (*Spizella passerina*) Field sparrow (*Spizella pusilla*) White-throated sparrow (*Zonotrichia albicollis*) White-crowned sparrow (*Zonotrichia leucophrys*) Swamp sparrow (*Melospiza georgiana*) Song sparrow (*Melospiza melodia*) Savanna sparrow (*Passerculus sandwichensis*) Lincoln's sparrow (*Melospiza lincolnii*) Dark-eyed junco (*Junco hyemalis*)