

4.1.8 Total Kjeldahl Nitrogen

Total Kjeldahl Nitrogen (TKN) is the sum of nitrate (NO_3^-), nitrite (NO_2^-), ammonia (NH_4^+), and organic nitrogen forms in freshwater systems. Much nitrogen (amino acids and proteins) also comprises the bulk of living organisms in an aquatic ecosystem. Nitrogen originates from atmospheric inputs (i.e. burning of fossil fuels), wastewater sources from developed areas (i.e. runoff from fertilized lawns), agricultural lands, septic systems, and from waterfowl droppings. It also enters lakes through groundwater or surface drainage, drainage from marshes and wetlands, or from precipitation (Wetzel, 2001). In lakes with an abundance of nitrogen ($\text{N} : \text{P} > 15$), phosphorus may be the limiting nutrient for phytoplankton and aquatic macrophyte growth. Alternatively, in lakes with low nitrogen concentrations (and relatively high phosphorus), the blue-green algae populations may increase due to the ability to fix nitrogen gas from atmospheric inputs. Lakes with a mean TKN value of 0.66 mg L^{-1} may be classified as oligotrophic, those with a mean TKN value of 0.75 mg L^{-1} may be classified as mesotrophic, and those with a mean TKN value greater than 1.88 mg L^{-1} may be classified as eutrophic. **The TKN concentrations in Duck Lake ranged between $< 0.50\text{-}1.8 \text{ mg L}^{-1}$, which is moderate for an inland lake of similar size.**

4.1.9 Chlorophyll-*a* and Algae

Chlorophyll-*a* is a measure of the amount of green plant pigment present in the water, often in the form of planktonic algae. High chlorophyll-*a* concentrations are indicative of nutrient-enriched lakes. Chlorophyll-*a* concentrations greater than $6 \mu\text{g L}^{-1}$ are found in eutrophic or nutrient-enriched aquatic systems, whereas chlorophyll-*a* concentrations less than $2.2 \mu\text{g L}^{-1}$ are found in nutrient-poor or oligotrophic lakes. Chlorophyll-*a* is measured in micrograms per liter ($\mu\text{g L}^{-1}$) with the use of an acetone extraction method and a spectrometer. The chlorophyll-*a* concentrations in Duck Lake were determined by collecting a composite sample of the algae throughout the water column at the deep basin site from just above the lake bottom to the lake surface. **The chlorophyll-*a* concentration in the deep basin was $0.45 \mu\text{g L}^{-1}$ and $0.89 \mu\text{g L}^{-1}$ in April and July, respectively, which indicates a low amount of planktonic algae throughout the water column.** It is likely that these values are higher in the spring after spring runoff or in late summer when water temperatures increase and lead to the growth of algae in the water column (planktonic form) or on the surface (filamentous form).

Algal genera from a composite water sample collected over the deep basin of Duck Lake were analyzed under a compound brightfield microscope. Genera are listed here in the order of most abundant to least abundant. The genera present included the Chlorophyta (green algae): *Gleocystis* sp., *Ulothrix* sp., *Spirogyra* sp., *Chlorella* sp., *Rhizoclonium* sp., *Closterium* sp., *Haematococcus* sp., *Pandorina* sp., *Scenedesmus* sp., *Zygnema* sp., *Pediastrum* sp., and *Chloromonas* sp. the Cyanophyta (blue-green algae): *Oscillatoria* sp.; the Bacillariophyta (diatoms): *Stephanodiscus* sp., *Fragilaria* sp., *Cymbella* sp., *Navicula* sp. and *Synedra* sp. The aforementioned species indicate a diverse algal flora and represent a relatively balanced freshwater ecosystem, capable of supporting a strong zooplankton community in favorable water quality conditions. **The waters of Duck Lake are rich in the Chlorophyta (green algae) and diatoms, which are indicators of productive but healthy waters that would support a robust zooplankton population for a healthy fishery.**

4.1.10 Secchi Transparency

Secchi transparency is a measure of the clarity or transparency of lake water, and is measured with the use of an 8-inch diameter standardized Secchi disk. Secchi disk transparency is measured in feet (ft.) or meters (m) by lowering the disk over the shaded side of a boat around noon and taking the mean of the measurements of disappearance and reappearance of the disk. Elevated Secchi transparency readings allow for more aquatic plant and algae growth. Eutrophic systems generally have Secchi disk transparency measurements less than 7.5 feet due to turbidity caused by excessive planktonic algae growth. **The Secchi transparency of Duck Lake averaged 30.5 feet over the deep basin during the spring sampling event, which was collected during calm wind conditions.** Secchi readings in early July were significantly lower with a mean of 12.0 feet, due to the presence of boat traffic stirring up the lake bottom (suspending sediments). This transparency is adequate to allow abundant growth of algae and aquatic plants in the majority of the littoral zone of the lake. Secchi transparency is variable and depends on the amount of suspended particles in the water (often due to windy conditions of lake water mixing) and the amount of sunlight present at the time of measurement.

4.1.11 Sediment Organic Matter

Organic matter (OM) contains a high amount of carbon which is derived from biota such as decayed plant and animal matter. Detritus is the term for all dead organic matter which is different than living organic and inorganic matter. OM may be autochthonous or allochthonous in nature where it originates from within the system or external to the system, respectively. Sediment OM is measured with the ASTM D2974 Method and is usually expressed in a percentage (%) of total bulk volume. Many factors affect the degradation of organic matter including basin size, water temperature, thermal stratification, dissolved oxygen concentrations, particle size, and quantity and type of organic matter present

The organic content ranged from 3.3-12% organic matter which is quite low and indicates that the lake sediments are comprised of clay and inorganic minerals. A map showing the relative hard versus soft bottom areas in Duck Lake is shown below in Figure 5.

<i>Depth</i>	<i>Water</i>	<i>DO</i>	<i>pH</i>	<i>Cond.</i>	<i>Turb.</i>	<i>Total</i>	<i>Total</i>	<i>Total Phos.</i>
<i>ft.</i>	<i>Temp</i>	<i>mg L⁻¹</i>	<i>S.U.</i>	<i>μS cm⁻¹</i>	<i>NTU</i>	<i>Kjeldahl</i>	<i>Alk.</i>	<i>mg L⁻¹</i>
	<i>°F</i>					<i>Nitrogen</i>	<i>mgL⁻¹</i>	
						<i>mg L⁻¹</i>	<i>CaCO₃</i>	
0	53.2	11.7	8.2	371	0.9	0.750	200	< 0.010
30	48.9	12.2	8.1	369	1.4	0.680	160	0.011
60	48.8	12.0	8.2	373	2.2	0.730	370	< 0.010

Table 3. Duck Lake water quality parameter data collected in the deep basin #1 (April 24, 2015).

<i>Depth</i>	<i>Water</i>	<i>DO</i>	<i>pH</i>	<i>Cond.</i>	<i>Turb.</i>	<i>Total</i>	<i>Total</i>	<i>Total Phos.</i>
<i>ft.</i>	<i>Temp</i>	<i>mg L⁻¹</i>	<i>S.U.</i>	<i>μS cm⁻¹</i>	<i>NTU</i>	<i>Kjeldahl</i>	<i>Alk.</i>	<i>mg L⁻¹</i>
	<i>°F</i>					<i>Nitrogen</i>	<i>mgL⁻¹</i>	
						<i>mg L⁻¹</i>	<i>CaCO₃</i>	
0	72.4	7.7	8.2	346	1.0	< 0.50	130	0.015
30	63.5	5.4	7.9	373	1.6	0.70	160	0.022
60	56.1	4.0	7.1	386	2.7	1.8	160	0.065

Table 4. Duck Lake water quality parameter data collected in the deep basin #2 (July 9, 2015).

<i>Sample Location</i>	<i>Sediment Organic Matter %</i>	<i>Sediment Total Phosphorus (mg/kg)</i>
S1	11	160
S2	10	240
S3	3.3	130
S4	13	250
S5	12	150

Table 5. Duck Lake sediment data collected on July 9, 2015.

4.2 Duck Lake Aquatic Vegetation Communities

Aquatic plants (macrophytes) are an essential component in the littoral zones of most lakes in that they serve as suitable habitat and food for macroinvertebrates, contribute oxygen to the surrounding waters through photosynthesis, stabilize bottom sediments (if in the rooted growth form), and contribute to the cycling of nutrients such as phosphorus and nitrogen upon decay. In addition, decaying aquatic plants contribute organic matter to lake sediments which further supports healthy growth of successive aquatic plant communities that are necessary for a balanced aquatic ecosystem. An overabundance of aquatic vegetation may cause organic matter to accumulate on the lake bottom faster than it can break down. Aquatic plants generally consist of rooted submersed, free-floating submersed, floating-leaved, and emergent growth forms. The emergent growth form (i.e. Cattails, Native Loosestrife) is critical for the diversity of insects onshore and for the health of nearby wetlands. Submersed aquatic plants can be rooted in the lake sediment (i.e. Milfoils, Pondweeds), or free-floating in the water column (i.e. Coontail). Nonetheless, there is evidence that the diversity of submersed aquatic macrophytes can greatly influence the diversity of macroinvertebrates associated with aquatic plants of different structural morphologies (Parsons and Matthews, 1995). Therefore, it is possible that declines in the biodiversity and abundance of submersed aquatic plant species and associated macroinvertebrates, could negatively impact the fisheries of inland lakes. Alternatively, the overabundance of aquatic vegetation can compromise recreational activities, aesthetics, and property values.

4.2.1 Duck Lake Exotic Aquatic Macrophytes

Exotic aquatic plants (macrophytes) are not native to a particular site, but are introduced by some biotic (living) or abiotic (non-living) vector. Such vectors include the transfer of aquatic plant seeds and fragments by boats and trailers (especially if the lake has public access sites), waterfowl, or by wind dispersal. In addition, exotic species may be introduced into aquatic systems through the release of aquarium or water garden plants into a water body. An aquatic exotic species may have profound impacts on the aquatic ecosystem. **Eurasian Watermilfoil (*Myriophyllum spicatum*; Figure 7) is an exotic aquatic macrophyte** first documented in the United States in the 1880's (Reed 1997), although other reports (Couch and Nelson 1985) suggest it was first found in the 1940's. In recent years, this species has hybridized with native milfoil species to form hybrid species. Eurasian Watermilfoil has since spread to thousands of inland lakes in various states through the use of boats and trailers, waterfowl, seed dispersal, and intentional introduction for fish habitat. **Eurasian Watermilfoil is a major threat to the ecological balance of an aquatic ecosystem through causation of significant declines in favorable native vegetation within lakes (Madsen et al. 1991), in that it forms dense canopies (Figure 8) and may limit light from reaching native aquatic plant species (Newroth 1985; Aiken et al. 1979).** Additionally, Eurasian Watermilfoil can alter the macroinvertebrate populations associated with particular native plants of certain structural architecture (Newroth 1985).

Some individual plants of hybridized Eurasian Watermilfoil were found at depths of approximately 12 feet; however, the **majority of the growth was located at depths between 5-10 feet.** Hybridized Eurasian Watermilfoil growth is thus capable of growing in nearly all depths of the littoral zone of Duck Lake, where light is adequate due to the high water transparency. Eurasian Watermilfoil growth in Duck Lake is capable of producing dense surface canopies. **The results of a detailed aquatic vegetation assessment site (AVAS) survey of Duck Lake on July 9, 2014 demonstrated that approximately 30 acres of hybrid Eurasian Watermilfoil infested the lake.** The species of aquatic macrophytes present and relative abundance of each macrophyte are recorded and then the amount of cover in the littoral zone is calculated. Exotic aquatic plant species in Duck Lake are shown in Table 6 below.

Purple Loosestrife (*Lythrum salicaria*; Figure 9) is an invasive (i.e. exotic) emergent aquatic plant that inhabits wetlands and shoreline areas and was found in nearly 5.0 acres of shoreline of Duck Lake. *L. salicaria* has showy magenta-colored flowers that bloom in mid-July and terminate in late September. The seeds are highly resistant to tough environmental conditions and may reside in the ground for extended periods of time. It exhibits rigorous growth and may out-compete other favorable native emergents such as Cattails (*Typha latifolia*) or native Swamp Loosestrife (*Decodon verticillatus*) and thus reduce the biological diversity of localized ecosystems. The plant is spreading rapidly across the United States and is converting diverse wetland habitats to monocultures with substantially lower biological diversity. Lake residents should be educated about its invasiveness and threat to the health of the Duck Lake ecosystem. The plant was located at the following locations on the Duck Lake map and should be removed promptly (i.e. by hand pulling or using a shovel to remove the roots and then discarding the plant into the garbage) if it is discovered to avoid further infestation. If the plant is not promptly removed by hand, it could dominate in wetland areas and require larger-scale systemic herbicide treatments.

In addition to milfoil, Duck Lake contained approximately 0.25 acres of the emergent Giant Common Reed (*Phragmites australis*; Figure 10), which should be promptly removed before mitigation efforts become too costly. *Phragmites* is an imminent threat to the surface area of Duck Lake since it may grow submersed in water depths of ≥ 2 meters (Herrick and Wolf, 2005), thereby drying up wetland habitat and reducing lake surface area. In addition, large, dense stands of *Phragmites* accumulate sediments, reduce habitat variability, and impede natural water flow (Wang et al., 2006).

A map showing the distribution of invasive hybrid milfoil in Duck Lake is shown in Figure 11 below. A map showing the distribution of the emergent invasive Purple Loosestrife and *Phragmites* is shown below in Figure 12.



Figure 7. Eurasian Watermilfoil ©RLS

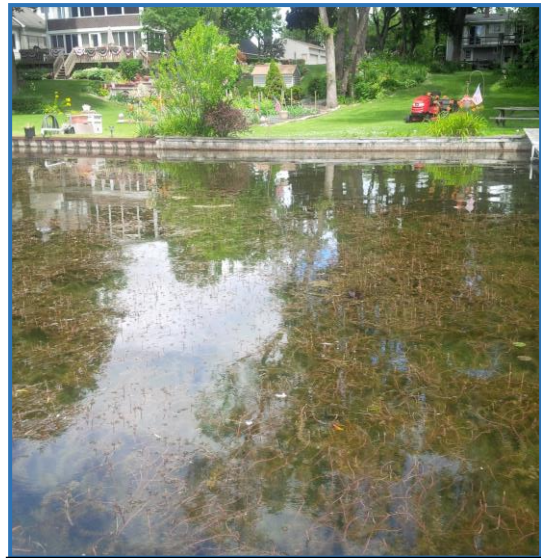


Figure 8. Eurasian Watermilfoil canopy ©RLS



Figure 9. Purple Loosestrife ©RLS



Figure 10. Phragmites ©RLS

<i>Exotic Aquatic Plant Species</i>	<i>Common Name</i>	<i>Growth Habit</i>	<i>Abundance in or around Duck Lake</i>
<i>Myriophyllum spicatum</i>	Hybrid Eurasian Watermilfoil	Submersed; Rooted	4.8
<i>Lythrum salicaria</i>	Purple Loosestrife	Emergent	3.3
<i>Phragmites australis</i>	Giant Common Reed	Emergent	1.5

Table 6. Duck Lake exotic aquatic plant species (July 9, 2015).

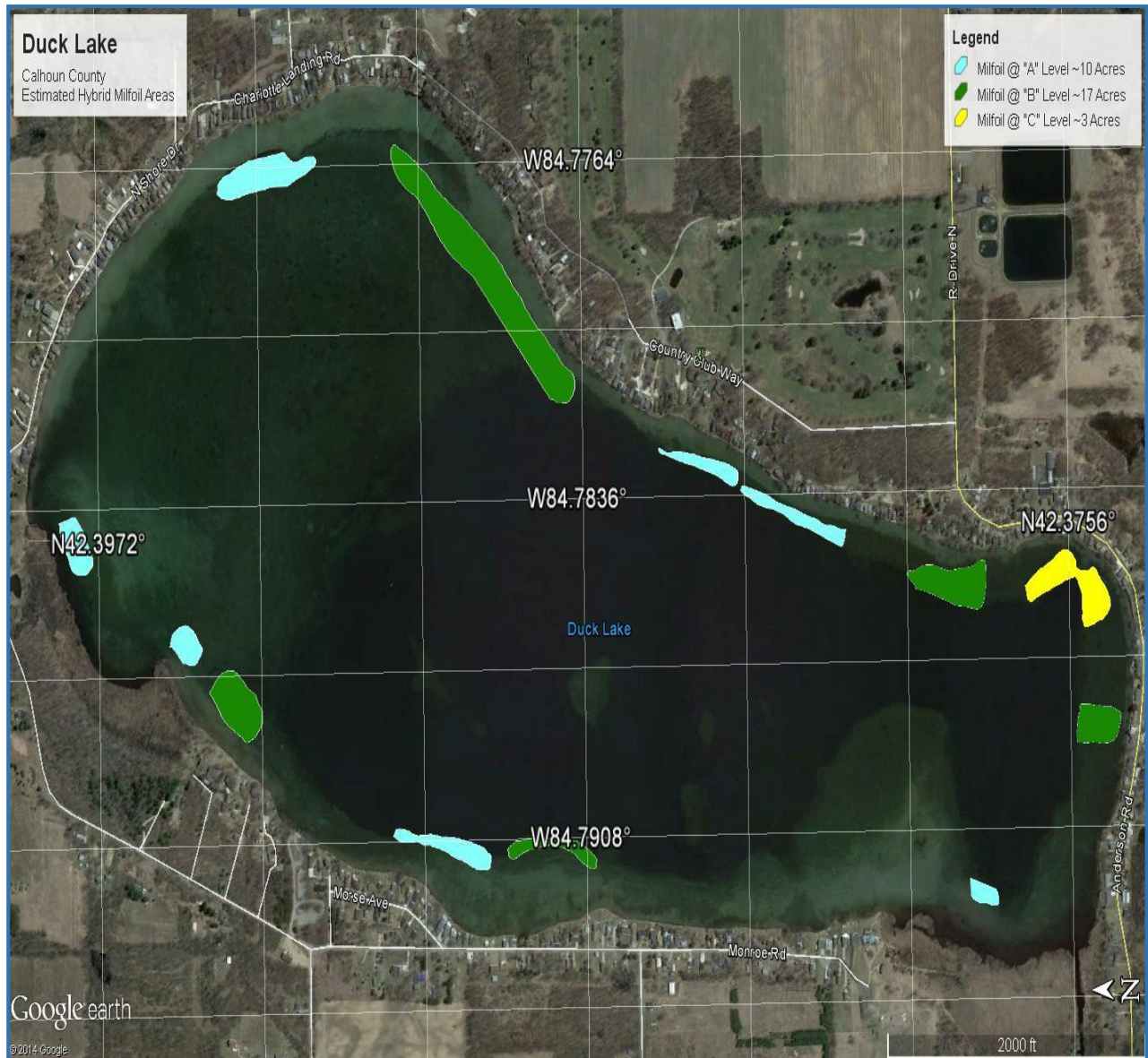


Figure 11. Distribution of Eurasian Watermilfoil in Duck Lake (July 9, 2015).

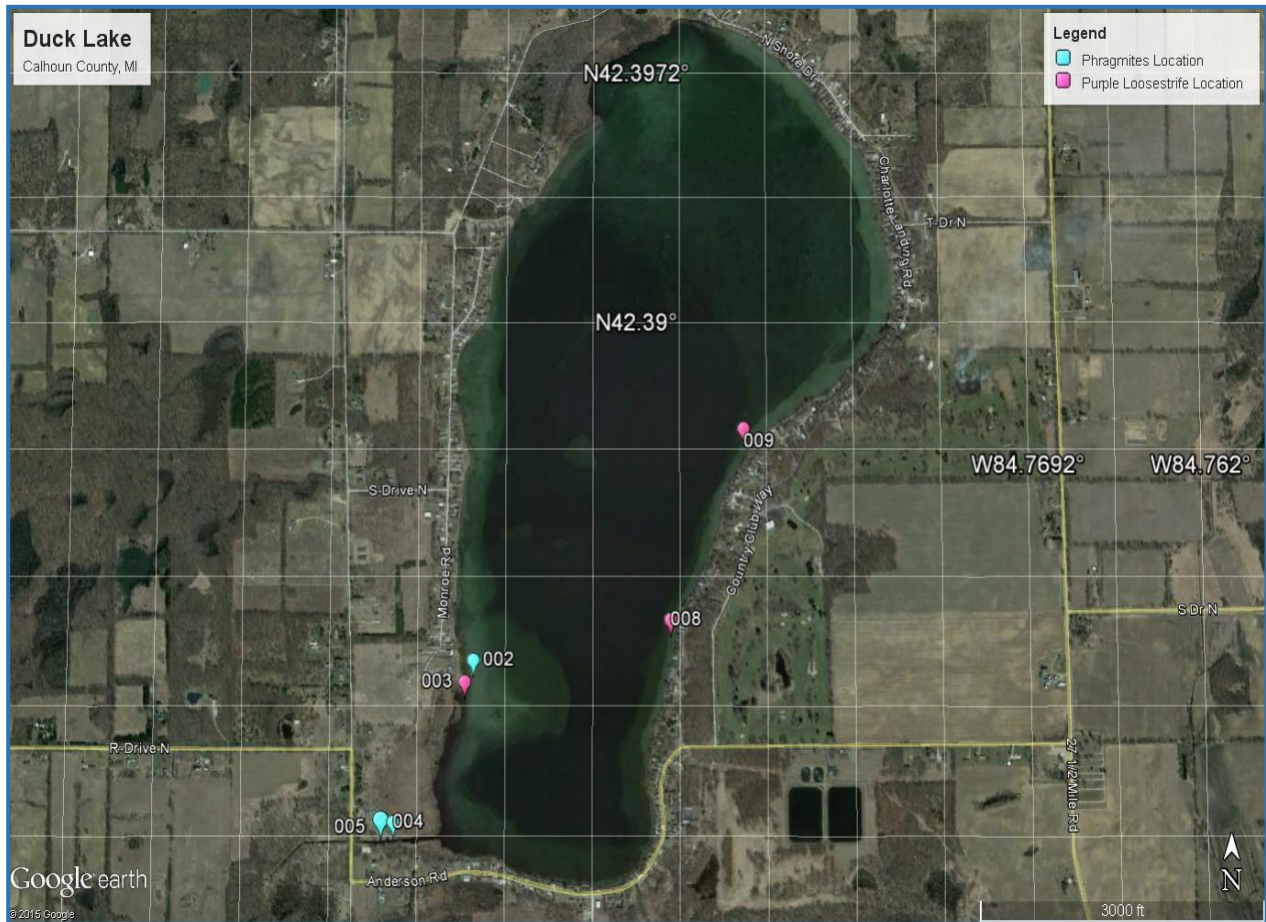


Figure 12. Locations of the emergent invasives, Purple Loosestrife and Phragmites (RLS, 2015).

4.2.2 Duck Lake Native Aquatic Macrophytes

There are hundreds of native aquatic plant species in the waters of the United States. The most diverse native genera include the Potamogetonaceae (Pondweeds) and the Haloragaceae (Milfoils). Native aquatic plants may grow to nuisance levels in lakes with abundant nutrients (both water column and sediment) such as phosphorus, and in sites with high water transparency. The diversity of native aquatic plants is essential for the balance of aquatic ecosystems, because each plant harbors different macroinvertebrate communities and varies in fish habitat structure.

Duck Lake contained 15 native submersed, 4 floating-leaved, and 6 emergent aquatic plant species, for a total of 26 native aquatic macrophyte species (Table 7). Photos of all native aquatic plants are shown below in Figures 13-36. The majority of the emergent macrophytes may be found along the shoreline of the lake. Additionally, the majority of the floating-leaved macrophyte species can be found near the shoreline. This is likely due to enriched sediments and shallower water depth with reduced wave energy, which facilitates the growth of aquatic plants with various morphological forms. **A map**

showing the relative biovolume (height of the aquatic plants in the water column) can be found in Appendix A. Red colors denote dense, floating-leaved or submersed vegetation, green colors denote low growing vegetation, and blue color denotes lack of growing vegetation. The entire lake bottom was scanned on July 9, 2015.

The dominant aquatic plants in the main part of the lake included the macroalga Chara and Thinleaf Pondweed. The Pondweeds grow tall in the water column and serve as excellent fish cover. In dense quantities, they can be a nuisance for swimming and boating and can be controlled with selective herbicide management. Chara was also very abundant in many areas and grows low to the lake bottom but can reach the surface in shallow areas. It serves as excellent fish spawning habitat and keeps the sediments down and out of the water column which reduces turbidity. **Also abundant was the native watermilfoil, Whorled Watermilfoil (*Myriophyllum verticillatum*) which appears olive green and forms dense underwater bouquets that do not form surface canopies.** It is a beneficial plant for fishery habitat.

The relative abundance of rooted aquatic plants (relative to non-rooted plants) in the lake suggests that the lake sediments are the primary source of nutrients (relative to the water column), since these plants obtain most of their nutrition from the sediments. There was also **the floating-leaved macrophytes such as, *Nymphaea odorata* (White-Waterlily)**, which are critical for housing macroinvertebrates and should be protected and preserved in non-recreational areas to serve as food sources for the fishery and wildlife around the lake. The **emergent plants, such as (Cattails), and *Scirpus acutus* (Bulrushes)** are critical for shoreline stabilization as well as for wildlife and fish spawning habitat. The presence of Purple Loosestrife and invasive Phragmites around the Duck Lake shoreline is an imminent threat to the emergent macrophyte populations, which could be displaced if left untreated or removed.

<i>Native Aquatic Plant Species Name</i>	<i>Aquatic Plant Common Name</i>	<i>Abundance in/around Duck Lake</i>	<i>Aquatic Plant Growth Habit</i>
<i>Chara vulgaris</i>	Muskgrass	17.5	Submersed, Rooted
<i>Potamogeton pectinatus</i>	Thinleaf Pondweed	17.3	Submersed, Rooted
<i>Potamogeton zosteriformis</i>	Flatstem Pondweed	10.3	Submersed, Rooted
<i>Potamogeton amplifolius</i>	Large-leaf Pondweed	0.5	Submersed, Rooted
<i>Potamogeton gramineus</i>	Variable-leaf Pondweed	2.3	Submersed, Rooted
<i>Potamogeton praelongus</i>	White-stem Pondweed	0.8	Submersed, Rooted
<i>Potamogeton pusillus</i>	Small-leaf Pondweed	4.0	Submersed, Rooted
<i>Potamogeton zosteriformis</i>	Flat-stem Pondweed	3.7	Submersed, Rooted
<i>Zosterella dubia</i>	Water Stargrass	16.8	Submersed, Rooted
<i>Potamogeton illinoensis</i>	Illinois Pondweed	5.8	Submersed, Rooted
<i>Vallisneria americana</i>	Wild Celery	11.3	Submersed, Rooted
<i>Myriophyllum verticillatum</i>	Whorled Watermilfoil	16.0	Submersed, Rooted
<i>Ceratophyllum demersum</i>	Coontail	7.7	Submersed, Non-Rooted
<i>Utricularia vulgaris</i>	Bladderwort	1.5	Submersed, Non-Rooted
<i>Najas guadalupensis</i>	Southern Naiad	0.6	Submersed, Rooted
<i>Nymphaea odorata</i>	White Waterlily	4.6	Floating-Leaved, Rooted
<i>Nuphar variegata</i>	Yellow Waterlily	12.6	Floating-Leaved, Rooted
<i>Lemna minor</i>	Duckweed	1.0	Floating-Leaved, non-rooted
<i>Azolla sp.</i>	Watermeal	1.0	Floating-Leaved, non-rooted
<i>Typha latifolia</i>	Cattails	13.6	Emergent
<i>Scirpus acutus</i>	Bulrushes	7.0	Emergent
<i>Sagittaria sp.</i>	Arrowhead	0.5	Emergent
<i>Pontedaria cordata</i>	Pickerelweed	2.3	Emergent
<i>Decodon verticillatus</i>	Swamp Loosestrife	11.5	Emergent
<i>Iris sp.</i>	Iris	0.3	Emergent

Table 7. Duck Lake native aquatic plants (July 9, 2015).