



Lake Cadillac 2021 Aquatic Vegetation, Water Quality, and 2022 Management Recommendations Annual Report



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The following Cadillac report is a summary of key lake findings collected in 2021.

The overall condition of Lake Cadillac relative to invasive species management has been improving over the years due to rigorous aquatic vegetation surveys and selective spot-treatments to control invasive aquatic plant species such as hybrid Eurasian Watermilfoil (EWM), and Curly-leaf Pondweed. Both of these species are declining in Lake Cadillac and providing space for the 20 native aquatic plant species that are so important to the ecological balance of Lake Cadillac.

The 2021 season for Lake Cadillac was very favorable with controlled invasive aquatic plant growth and an occasional blue-green algal bloom later in the season as noted by RLS staff. Such blooms were quite sparse and localized to small areas near the boat launch and near the park shoreline.

RLS offers many improvement recommendations for the 2022 season and beyond relative to storm drain monitoring, nutrient reduction, blue-green algal reduction, continued management of invasive aquatic plant species, reduction of Canada geese, and the education of Lake Cadillac riparians. The bottom total phosphorus concentrations in the deep basins have been increasing and thus intervention is needed to reduce nutrient loads to Lake Cadillac. A continued millage is critical for making effective, long-term improvements to the lake that go beyond the use of herbicides to address sources of algae and nuisance plant growth.

Lake Cadillac Water Quality Data (2021)

Water Quality Parameters Measured

There are hundreds of water quality parameters one can measure on an inland lake, but several are the most critical indicators of lake health. These parameters include water temperature (measured in °C or °F), dissolved oxygen (measured in mg/L), pH (measured in standard units-SU), conductivity (measured in micro-Siemens per centimeter- $\mu\text{S}/\text{cm}$), total alkalinity (mg/L CaCO_3), total dissolved solids (mg/L), turbidity (NTU's), secchi transparency (feet), total phosphorus, and total nitrogen (both in mg/L), chlorophyll-a (in $\mu\text{g}/\text{L}$), and algal community composition. Water quality was measured in the three deep basins of Lake Cadillac in spring (May 24, 2021) and late summer (September 20, 2021) (Figure 1). There was very little variation in 1-foot interval readings, so the top, middle, and bottom depth measurements are reported below to show the change in water column conditions from the surface to the bottom of the lake.

Table 1 below demonstrates how lakes are classified based on key parameters. Lake Cadillac would be considered eutrophic (productive) since it does contain ample phosphorus, nitrogen, and aquatic vegetation and periodic blue-green algae growth. General water quality classification criteria are defined in Table 1. 2021 water quality data for Lake Cadillac are shown below in Tables 2-7.

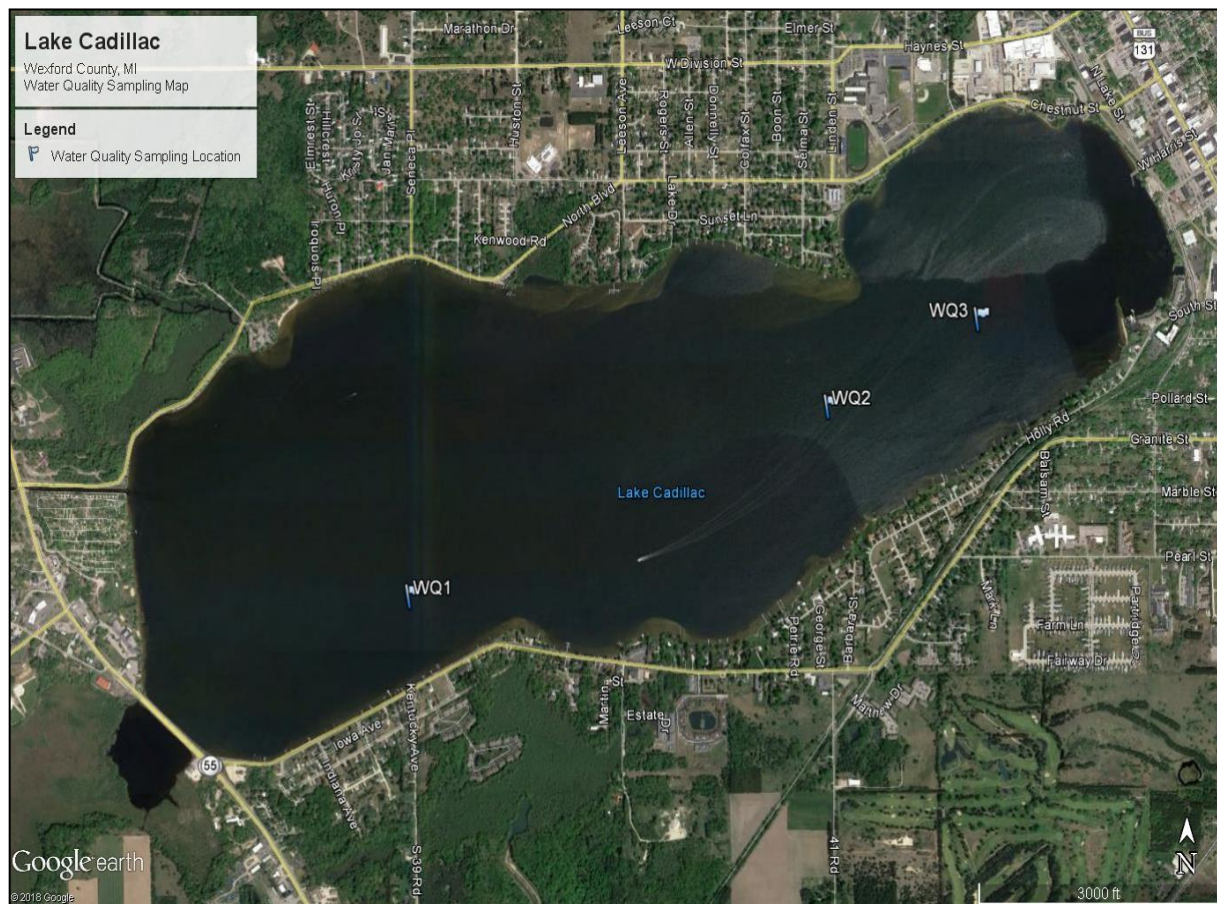


Figure 1. Deep Basin Water Quality Sampling Locations (n=3) in Lake Cadillac.

Table 1. Lake trophic classification (MDNR).

<i>Lake Trophic Status</i>	<i>Total Phosphorus ($\mu\text{g L}^{-1}$)</i>	<i>Chlorophyll-a ($\mu\text{g L}^{-1}$)</i>	<i>Secchi Transparency (feet)</i>
Oligotrophic	< 10.0	< 2.2	> 15.0
Mesotrophic	10.0 – 20.0	2.2 – 6.0	7.5 – 15.0
Eutrophic	> 20.0	> 6.0	< 7.5

Lake Cadillac Deep Basin Water Quality Data Tables:

Table 2. Lake Cadillac water quality parameter data collected over deep basin #1 on May 24, 2021.

<i>Depth ft.</i>	<i>Water Temp $^{\circ}\text{C}$</i>	<i>DO mg L^{-1}</i>	<i>pH S.U.</i>	<i>Cond. $\mu\text{S cm}^{-1}$</i>	<i>Turb. NTU</i>	<i>TDS mg L^{-1}</i>	<i>TP mg L^{-1}</i>	<i>TKN mg L^{-1}</i>	<i>Chl-a $\mu\text{g L}^{-1}$</i>
0	19.5	8.2	8.4	170	1.9	108	<0.020	<0.5	2.0
11.0	17.2	7.6	8.4	172	2.5	110	<0.020	<0.5	--
22.0	13.8	6.7	8.3	180	2.9	115	<0.050	1.0	--

Table 3. Lake Cadillac water quality parameter data collected over deep basin #2 on May 24, 2021.

<i>Depth ft.</i>	<i>Water Temp $^{\circ}\text{C}$</i>	<i>DO mg L^{-1}</i>	<i>pH S.U.</i>	<i>Cond. $\mu\text{S cm}^{-1}$</i>	<i>Turb. NTU</i>	<i>TDS mg L^{-1}</i>	<i>TP mg L^{-1}</i>	<i>TKN mg L^{-1}</i>	<i>Chl-a $\mu\text{g L}^{-1}$</i>
0	19.2	8.6	8.4	179	1.8	115	<0.020	<0.5	3.0
11.0	17.5	7.0	8.4	188	2.2	120	<0.020	0.5	--
22.0	13.6	6.9	8.4	188	2.7	120	<0.050	1.0	--

Table 4. Lake Cadillac water quality parameter data collected over deep basin #3 on May 24, 2021.

<i>Depth ft.</i>	<i>Water Temp °C</i>	<i>DO mg L⁻¹</i>	<i>pH S.U.</i>	<i>Cond. μS cm⁻¹</i>	<i>Turb. NTU</i>	<i>TDS mg L⁻¹</i>	<i>TP mg L⁻¹</i>	<i>TKN mg L⁻¹</i>	<i>Chl-a μg L⁻¹</i>
0	19.5	8.2	8.4	191	1.9	121	<0.020	<0.5	3.0
13.0	16.4	6.6	8.4	190	2.8	120	<0.020	0.5	--
26.0	12.0	6.6	8.3	190	3.1	120	0.080	0.5	--

Table 5. Lake Cadillac water quality parameter data collected over deep basin #1 on September 20, 2021.

<i>Depth ft.</i>	<i>Water Temp °C</i>	<i>DO mg L⁻¹</i>	<i>pH S.U.</i>	<i>Cond. μS cm⁻¹</i>	<i>Turb. NTU</i>	<i>TDS mg L⁻¹</i>	<i>TP mg L⁻¹</i>	<i>TKN mg L⁻¹</i>	<i>Chl-a μg L⁻¹</i>
0	20.5	9.6	8.3	156	2.2	100	0.030	<0.5	6.0
11.0	19.5	8.9	8.2	155	3.5	99	0.035	<0.5	--
22.0	19.3	7.4	7.5	162	3.9	103	0.095	3.4	--

Table 6. Lake Cadillac water quality parameter data collected over deep basin #2 on September 20, 2021.

<i>Depth ft.</i>	<i>Water Temp °C</i>	<i>DO mg L⁻¹</i>	<i>pH S.U.</i>	<i>Cond. μS cm⁻¹</i>	<i>Turb. NTU</i>	<i>TDS mg L⁻¹</i>	<i>TP mg L⁻¹</i>	<i>TKN mg L⁻¹</i>	<i>Chl-a μg L⁻¹</i>
0	20.3	9.1	8.2	156	1.9	100	0.023	<0.5	7.0
11.0	19.9	9.0	8.1	156	2.7	100	0.042	<0.5	--
22.0	19.5	8.2	7.8	156	4.0	100	0.350	<0.5	--

Table 7. Lake Cadillac water quality parameter data collected over deep basin #3 on September 20, 2021.

<i>Depth ft.</i>	<i>Water Temp °C</i>	<i>DO mg L⁻¹</i>	<i>pH S.U.</i>	<i>Cond. µS cm⁻¹</i>	<i>Turb. NTU</i>	<i>TDS mg L⁻¹</i>	<i>TP mg L⁻¹</i>	<i>TKN mg L⁻¹</i>	<i>Chl-a µg L⁻¹</i>
0	20.3	9.2	8.1	156	1.9	100	0.021	<0.5	8.0
13.0	19.8	8.5	8.0	156	2.6	100	0.035	<0.5	--
26.0	19.4	7.3	7.6	157	3.9	101	0.160	<0.5	--

Dissolved Oxygen

Dissolved oxygen is a measure of the amount of oxygen that exists in the water column. In general, dissolved oxygen levels should be greater than 5 mg L⁻¹ to sustain a healthy warm-water fishery. Dissolved oxygen concentrations may decline if there is a high biochemical oxygen demand (BOD) where organismal consumption of oxygen is high due to respiration. Dissolved oxygen is generally higher in colder waters.

Dissolved oxygen was measured in milligrams per liter (mg L⁻¹) with the use of a calibrated Eureka Manta II® dissolved oxygen meter and multi-probe. During the summer months, dissolved oxygen at the surface is generally higher due to the exchange of oxygen from the atmosphere with the lake surface, whereas dissolved oxygen is lower at the lake bottom due to decreased contact with the atmosphere and increased biochemical oxygen demand (BOD) from microbial activity. Dissolved oxygen concentrations during the May 24, 2021 sampling event ranged from a high of 8.6 mg L⁻¹ to a low of 6.6 mg L⁻¹. On the September 20, 2021 sampling date, the dissolved oxygen concentration ranged from a high of 9.6 mg L⁻¹ among the deep basins to a low of 7.3 mg L⁻¹. The dissolved oxygen concentration in the channel ranged from 8.2-8.6 mg L⁻¹ in May and September of 2021.

Water Temperature

A lake's water temperature varies within and among seasons and is nearly uniform with depth under the winter ice cover because lake mixing is reduced when waters are not exposed to the wind. When the upper layers of water begin to warm in the spring after ice-off, the colder, dense layers remain at the bottom. This process results in a "thermocline" that acts as a transition layer between warmer and colder water layers. During the fall season, the upper layers begin to cool and become denser than the warmer layers, causing an inversion known as "fall turnover". In general, shallow lakes will not stratify and deeper lakes may experience single or multiple turnover cycles. Water temperature was measured in degrees Celsius (°C) with the use of a calibrated submersible thermometer electrode. The May 24, 2021 water temperatures of Lake Cadillac demonstrated a thermocline with a maximum temperature difference of <7.5°C in the three deep basins.

During the September 20, 2021 sampling event, the three deep basins demonstrated a temperature difference of 1.2°C from the surface to the bottom. Lake Cadillac likely turns over multiple times per season with strong wind events that evenly mix the water column. The water temperatures of the channel ranged between 19.4-20.5 °C during the May and September sampling events.

Oxidative Reduction Potential

The oxidation-reduction potential (E_h) of lake water describes the effectiveness of certain atoms to serve as potential oxidizers and indicates the degree of reductants present within the water. In general, the E_h level (measured in millivolts) decreases in anoxic (low oxygen) waters. Low E_h values are therefore indicative of reducing environments where sulfates (if present in the lake water) may be reduced to hydrogen sulfide (H_2S). Decomposition by microorganisms in the hypolimnion may also cause the E_h value to decline with depth. The E_h values for Lake Cadillac ranged from 145.3 mV to 91.0 mV from the surface to the bottom in both May and September are within a normal range for a large inland lake.

Water Clarity (Secchi Transparency)

Elevated Secchi transparency readings allow for more aquatic plant and algae growth. The transparency throughout Lake Cadillac was adequate on May 24, 2021 (mean of 14.8 feet) to allow abundant growth of algae and aquatic plants in the majority of the littoral zone of the lake. On September 20, 2021, the mean Secchi transparency was 6.4 feet due to observed algal blooms which were moderate in 2021. Secchi transparency is variable and depends on the number 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. Other parameters such as turbidity (measured in NTU's) and Total Dissolved Solids (measured in mg/L) are correlated with water clarity and show an increase as clarity decreases. The Secchi transparency of Lake Cadillac has been decreasing over time later in the season due to intense blue-green algal blooms that limit light penetration throughout the water column. This can also negatively impact native aquatic plant communities that depend on adequate light.

Total Phosphorus

Total phosphorus (TP) is a measure of the amount of phosphorus (P) present in the water column. Phosphorus is the primary nutrient necessary for abundant algae and aquatic plant growth. TP concentrations are usually higher at increased depths due to higher release rates of P from lake sediments under low oxygen (anoxic) conditions. Phosphorus may also be released from sediments as pH increases. The TP levels in Lake Cadillac are moderate; however, the dissolved oxygen levels are low enough at the bottom to possibly cause release of phosphorus from the bottom.

The TP concentrations on May 24, 2021 ranged from <0.020 - 0.080 mg L^{-1} , which is above the eutrophic threshold at depth ($\leq 0.025 \text{ mg L}^{-1}$). The TP concentrations on September 20, 2021 ranged from 0.021 - 0.350 mg L^{-1} . The bottom TP concentrations were all high and have been increasing but internal loading is unlikely if the dissolved oxygen remains elevated at the lake bottom. The TP concentrations in the channel were all $<0.030 \text{ mg L}^{-1}$.

Total Kjeldahl Nitrogen

Total Kjeldahl Nitrogen (TKN) is the sum of 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 ground or surface drainage, drainage from marshes and wetlands, or from precipitation (Wetzel, 2001). In lakes with an abundance of nitrogen ($\text{N: P} > 15$), phosphorus may be the limiting nutrient for phytoplankton and aquatic macrophyte growth. 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 mean TKN concentration in Lake Cadillac on May 24, 2021 averaged 0.6 mg L^{-1} , which is moderate for an inland lake. The mean TKN concentration in Lake Cadillac on September 20, 2021 averaged 0.8 mg L^{-1} . The mean TKN concentration in the channel was also around $<0.5 \text{ mg L}^{-1}$.

Total Alkalinity

Lakes with high alkalinity ($> 150 \text{ mg L}^{-1}$ of CaCO_3) are able to tolerate larger acid inputs with less change in water column pH. Many Michigan lakes contain high concentrations of CaCO_3 and are categorized as having “hard” water. Total alkalinity may change on a daily basis due to the re-suspension of sedimentary deposits in the water and respond to seasonal changes due to the cyclic turnover of the lake water. The total alkalinity of Lake Cadillac and the channel was moderately low and averaged around 57 mg L^{-1} of CaCO_3 throughout the summer and this indicates a slightly soft water lake.

Turbidity and Total Dissolved Solids

Turbidity is a measure of the loss of water transparency due to the presence of suspended particles. The turbidity of water increases as the number of total suspended particles increases. Turbidity may be caused by erosion inputs, phytoplankton blooms, storm water discharge, urban runoff, re-suspension of bottom sediments, and by large bottom-feeding fish such as carp in shallow areas. Particles suspended in the water column absorb heat from the sun and raise water temperatures. Since higher water temperatures generally hold less oxygen, shallow turbid waters are usually lower in dissolved oxygen. Turbidity is measured in Nephelometric Turbidity Units (NTU's) with the use of a calibrated Lutron® turbidimeter. The World Health Organization (WHO) requires that drinking water be less than 5 NTU's; however, recreational waters may be significantly higher than that.

The turbidity of Lake Cadillac was moderately low and ranged from 1.8-4.0 NTU's during the 2021 sampling events. Spring values would likely be higher due to increased watershed inputs from spring runoff and/or from increased algal blooms in the water column from resultant runoff contributions. The mean turbidity of the channel was 3.2 NTU's.

Total dissolved solids (TDS) is a measure of the amount of dissolved organic and inorganic particles in the water column. Particles dissolved in the water column absorb heat from the sun and raise the water temperature and increase conductivity. TDS was measured with the use of a calibrated TDS probe in mg L^{-1} . Spring values are usually higher due to increased watershed inputs from spring runoff and/or increased planktonic algal communities. The TDS in Lake Cadillac ranged from 99-121 mg L^{-1} for the deep basins during the 2021 sampling events, which is moderate for an inland lake and lower than in recent years. The preferred range for TDS in surface waters is between 0-1,000 mg L^{-1} but the lower values are most favorable. The TDS in the channel ranged from 110-145 mg L^{-1} which is lower than the lake.

pH

Most Michigan lakes have pH values that range from 6.5 to 9.5. Acidic lakes ($\text{pH} < 7$) are rare in Michigan and are most sensitive to inputs of acidic substances due to a low acid neutralizing capacity (ANC). Lake Cadillac is considered "slightly basic" on the pH scale. The pH of Lake Cadillac and channel ranged from 7.5-8.4 S.U. during the 2021 sampling events which is ideal for an inland lake. All of these values are normal and favorable for aquatic environments.

Conductivity

Conductivity is a measure of the number of mineral ions present in the water, especially those of salts and other dissolved inorganic substances. Conductivity generally increases as the amount of dissolved minerals and salts in a lake increases, and also increases as water temperature increases. The conductivity in Lake Cadillac ranged from 170-191 $\mu\text{S/cm}$ on May 24, 2021 and from 155-162 $\mu\text{S/cm}$ on September 20, 2021. These values are ideal for an inland lake and will fluctuate annually with storm drain inputs and runoff. Severe water quality impairments do not occur until values exceed 800 $\mu\text{S/cm}$ and are toxic to aquatic life around 1,000 $\mu\text{S/cm}$.

Chlorophyll-*a* and Algal Species Composition

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 $\mu\text{g/L}$ are found in nutrient-poor or oligotrophic lakes. The chlorophyll-*a* concentrations on May 24, 2021 ranged from 2.0-3.0 $\mu\text{g L}^{-1}$ and the chlorophyll-*a* concentrations on September 20, 2021 ranged from 6.0-8.0 $\mu\text{g L}^{-1}$. These values were recorded with a calibrated in situ Turner Designs® fluorimeter.

The algal genera were determined from composite water samples collected over the deep basins of Lake Cadillac in 2021 were analyzed with a compound bright field microscope.

The genera present included the Chlorophyta (green algae): *Chlorella* sp., *Haematococcus* sp., *Chroococcus* sp., *Mougeotia* sp., *Rhizoclonium* sp., *Scenedesmus* sp. *Cladophora* sp., and *Chloromonas* sp. The Cyanophyta (blue-green algae): *Microcystis* sp., and *Oscillatoria* sp., the Bascillariophyta (diatoms): *Navicula* sp., *Cymbella* sp., *Synedra* sp., and *Fragillaria* sp. The aforementioned species indicate a diverse algal flora and represent a good diversity of alga. In 2021, the most dominant blue-green algae in the water samples was *Microcystis* sp., which is problematic for dense algal blooms that may form toxins and present a risk for public health and the overall health of the Lake Cadillac ecosystem. In 2020-1, certain areas of the lake were monitored by EGLE, and advisories were issued if concentrations exceeded safe contact.

Lake Cadillac Aquatic Vegetation Data (2021)

Status of Native Aquatic Vegetation in Lake Cadillac

The native aquatic vegetation present in Lake Cadillac is essential for the overall health of the lake and the support of the lake fishery. There were two types of surveys conducted on Lake Cadillac during the 2021 season. The first type of survey was a whole-lake aquatic plant survey, and the second type of survey was a whole-lake benthic scan which utilized 14,595 points to generate an updated lake depth contour map and aquatic vegetation biovolume map.

A whole-lake aquatic plant survey using the GPS Point-Intercept survey method as in Figure 2 below determined that there was a total of 20 native aquatic plant species in the lake. These included 13 submersed species, 2 floating-leaved species, and 5 emergent species. This indicates a good biodiversity of aquatic vegetation in Lake Cadillac. The overall % cover of the lake by native aquatic plants is low relative to the lake size due to the great mean depth and thus these plants should be protected unless growing near swim areas at nuisance levels. A list of all current native aquatic plant species and their frequency is shown below in Table 8. Aquatic vegetation biovolume is displayed in Figure 3 below. The blue color represents a lack of aquatic vegetation whereas the green color represents low-growing aquatic vegetation. A red color represents aquatic plants that grow high into the water column such as milfoil or pondweeds. This figure demonstrates that a lot of area in the lake lacks aquatic vegetation.

The most dominant aquatic plant species in September of 2021 included: 1) Large-leaf Pondweed which grows tall in the water column and has large, wide brown leaves, and 2) White-stem Pondweed which has long green leaves with a prominent seed head and the plant also grows tall into the water column; and 3) Fern-leaf Pondweed which forms dense mats near the lake bottom and has leaves that resemble small ferns. The latter can also prevent EWM fragments from rooting in areas where it is dense.

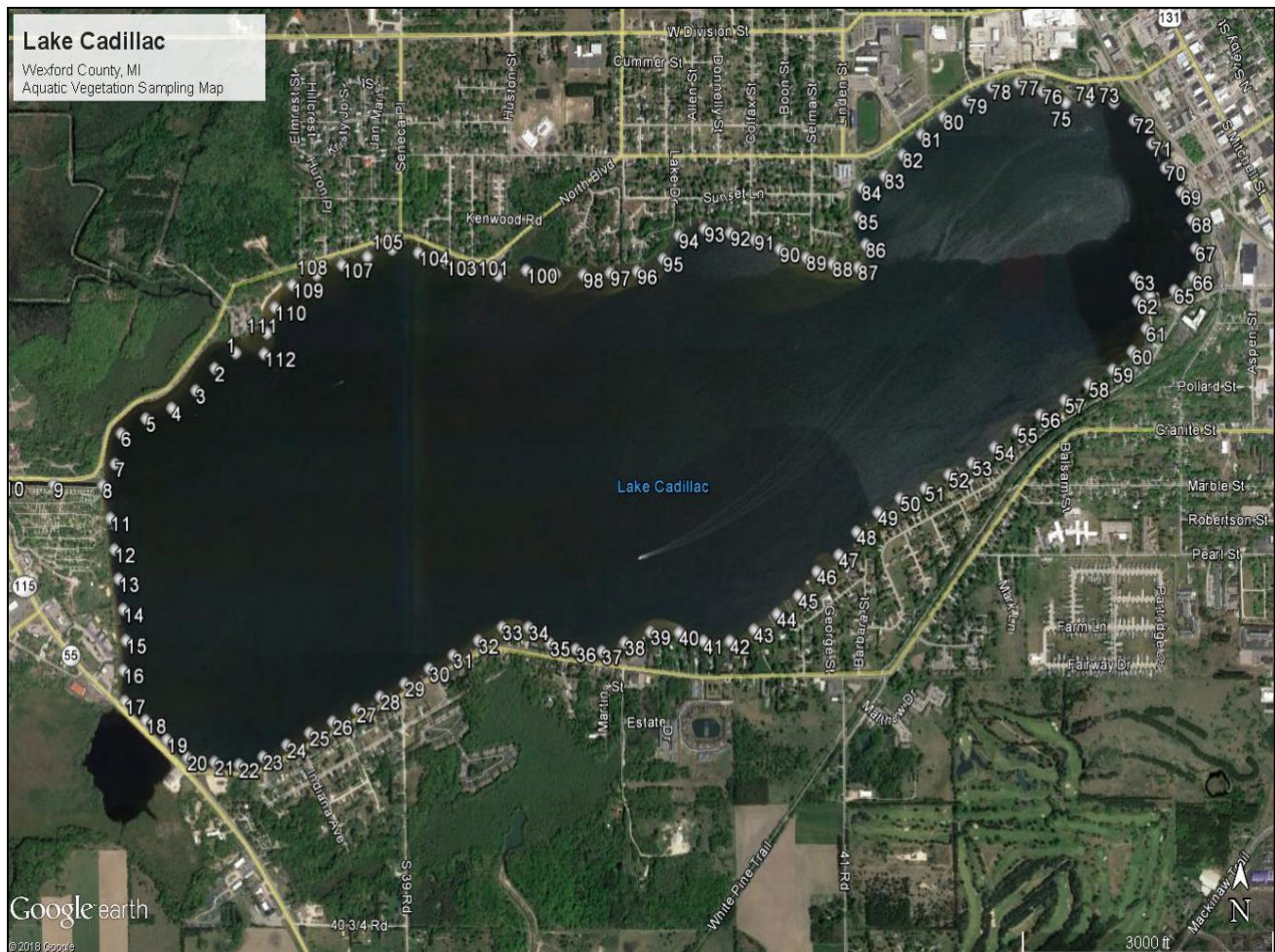


Figure 2. Aquatic vegetation sampling points in Lake Cadillac (May 24 and September 20, 2021: Note: Each of these locations includes survey areas from the shoreline to the 10-foot depth contour).

Table 8. Lake Cadillac Native Aquatic Plant Species (September 20, 2021).

<i>Native Aquatic Plant Species Name</i>	<i>Aquatic Plant Common Name</i>	<i>Frequency (%)</i>	<i>Aquatic Plant Growth Habit</i>
<i>Chara vulgaris</i>	Muskgrass	41.0	Submersed, Rooted
<i>Potamogeton pectinatus</i>	Thin-leaf Pondweed	8.2	Submersed, Rooted
<i>Potamogeton amplifolius</i>	Large-leaf Pondweed	42.0	Submersed, Rooted
<i>Potamogeton zosteriformis</i>	Flat-stem Pondweed	7.3	Submersed, Rooted
<i>Potamogeton gramineus</i>	Variable-leaf Pondweed	8.1	Submersed, Rooted
<i>Potamogeton robbinsii</i>	Fern-leaf Pondweed	29.2	Submersed, Rooted
<i>Potamogeton praelongus</i>	White-stem Pondweed	32.0	Submersed, Rooted
<i>Potamogeton richardsonii</i>	Clasping-leaf Pondweed	9.6	Submersed, Rooted
<i>Potamogeton illinoensis</i>	Illinois Pondweed	20.0	Submersed, Rooted
<i>Elodea canadensis</i>	Common Waterweed	5.1	Submersed, Rooted
<i>Ceratophyllum demersum</i>	Coontail	4.1	Submersed, Non-Rooted
<i>Utricularia vulgaris</i>	Bladderwort	6.0	Submersed, Non-Rooted
<i>Najas guadalupensis</i>	Southern Naiad	7.6	Submersed, Rooted
<i>Nuphar variegata</i>	Yellow Waterlily	3.8	Floating-leaved, Rooted
<i>Spirodella</i> sp.	Duckweed	0.2	Floating-leaved, Non-Rooted
<i>Typha latifolia</i>	Cattails	4.0	Emergent
<i>Scirpus acutus</i>	Bulrushes	3.0	Emergent
<i>Iris</i> sp.	Iris	1.9	Emergent
<i>Sagittaria</i> sp.	Arrowhead	3.7	Emergent
<i>Pontedaria cordata</i>	Pickerelweed	4.3	Emergent

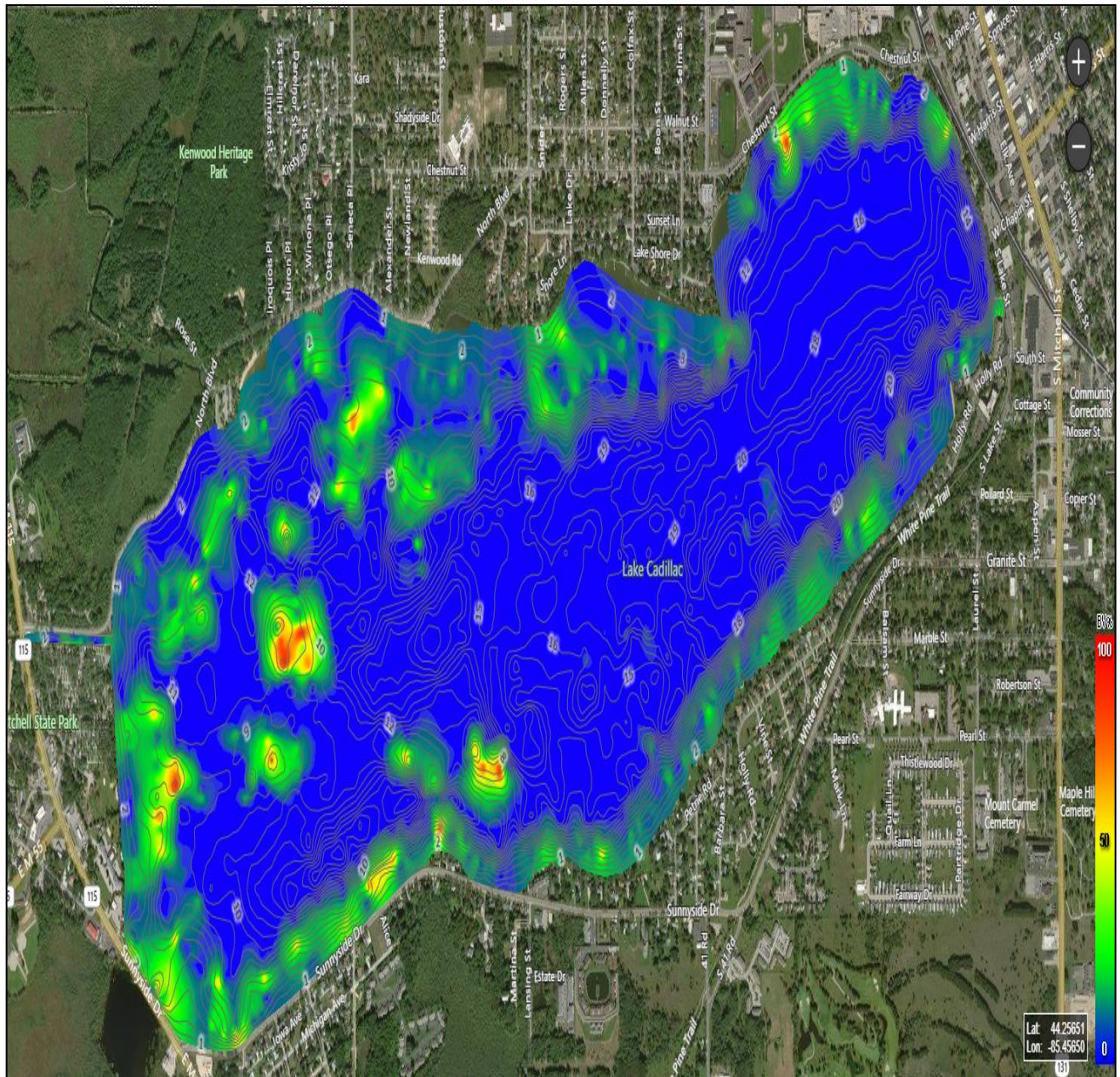


Figure 3. Aquatic vegetation biovolume scan and map of Lake Cadillac on September 20, 2021 (RLS). NOTE: The blue color represents no vegetation present; Red color represent tall, high-growing aquatic plants; Green color represents low-growing vegetation on the lake obttom such as Chara.

Status of Invasive (Exotic) Aquatic Plant Species

The amount of Eurasian Watermilfoil (Figure 4) and Curly-leaf Pondweed (Figure 5) present in Lake Cadillac varies each year and is dependent upon climatic conditions, especially runoff-associated nutrients. The 2021 season was mostly dry and only periodic algae was noted later in the season. The May 24, 2021 survey revealed that approximately 5.0 acres of dense EWM were found throughout the entire lake (Note: 2.6 acres were found during the survey and a few additional acres on the day of treatment). These areas were treated on June 3, 2021 by PLM with the systemic and contact herbicide combination ProcellaCOR® and diquat. An August 4, 2021 survey revealed approximately 0.6 acres of EWM which were treated along with a few additional acres of new growth also with systemic and contact herbicide combination ProcellaCOR® and diquat on September 29, 2021. Treatment maps are shown in the maps below (Figures 6 and 7). Table 9 shows the treatment history for Lake Cadillac relative to the use of herbicides and previously biocontrol for the management of invasive aquatic plants.



Figure 4. Eurasian Watermilfoil



Figure 5. Curly-leaf Pondweed

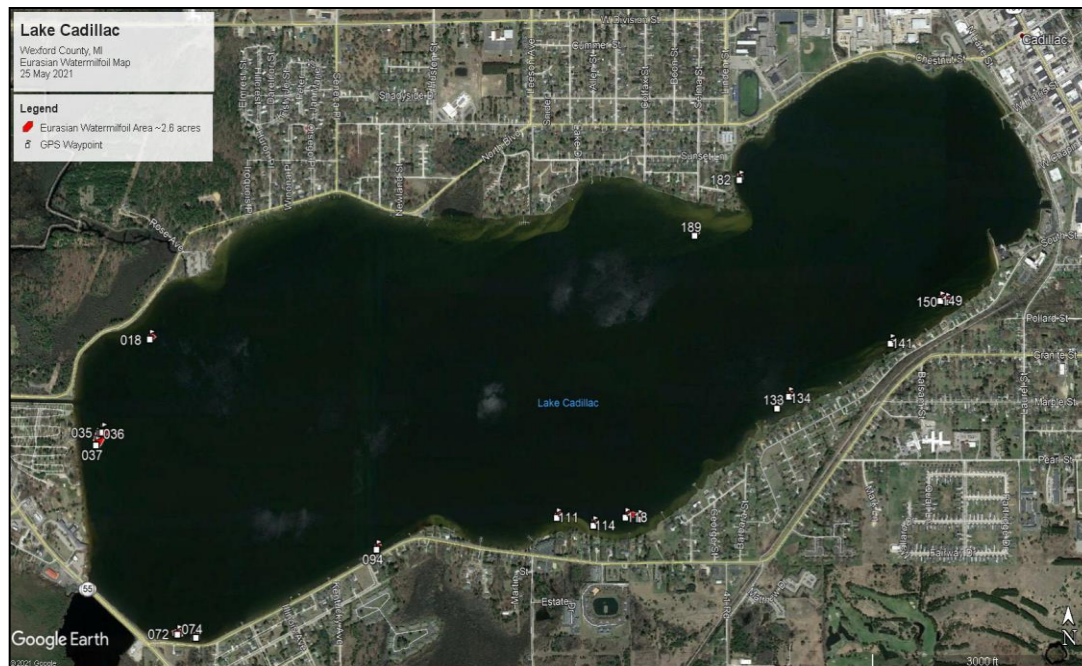


Figure 6. Dense EWM in Lake Cadillac (May 24, 2021).

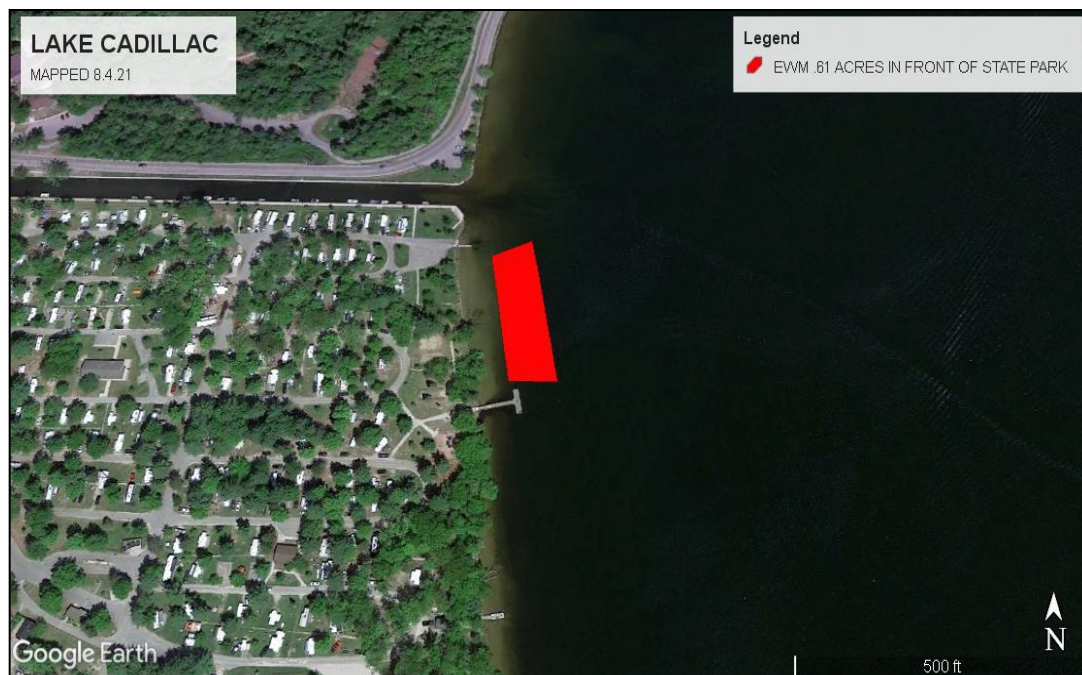


Figure 7. Late season EWM growth in Lake Cadillac (August 4, 2021).

Table 9. Lake Cadillac invasive aquatic plant treatment history to date (2006-2021). Note: RLS did not have access to the 2016 treatment acreage.

Year	Acres Treated with Aquatic Herbicides	# Milfoil Weevils Stocked
2006	180	12,000
2007	50	12,000
2008	47	6,000
2009	143	12,000
2010	160	0
2011	113	0
2012	140	0
2013	101	0
2014	89	0
2015	97	0
2016	NA	0
2017	23.5	0
2018	23.5	0
2019	18.1	0
2020	27.5	0
2021	9.0	0

Lake Cadillac Benthic Macroinvertebrates

RLS scientists collected sediment samples at the three deep basins of Lake Cadillac on May 24, 2021 and September 20, 2021 with the use of an Ekman hand dredge to evaluate sediment macroinvertebrate communities as a measure of lake health. Tables 10-11 list all of the aquatic macroinvertebrates found during the sampling. In general, the biodiversity of sediment macroinvertebrates was fair with some improvement over the past few years with the occurrence of mayfly larvae.

Freshwater macroinvertebrates are ubiquitous, as even the most impacted lake contains some representatives of this diverse and ecologically important group of organisms. Benthic macroinvertebrates are key components of lake food webs both in terms of total biomass and in the important ecological role that they play in the processing of energy. Others are important predators, graze alga on rocks and logs, and are important food sources (biomass) for fish. The removal of macroinvertebrates has been shown to impact fish populations and total species richness of an entire lake or stream food web (Lenat and Barbour 1994). In the food webs of lakes, benthic macroinvertebrates have an intermediate position between primary producers and higher trophic levels (as fish) on the other side. Hence, they play an essential role in key ecosystem processes (food chain dynamics, productivity, nutrient cycling and decomposition). These may also include many rare species.

The macroinvertebrates found in Lake Cadillac in 2021 demonstrated good biodiversity but there were Zebra Mussels. Most of the taxa found were indicative of fair to good water quality.

Taxa found included midge larvae (Chironomidae), mayfly larvae, wheel snails (Planorbidae), sow bugs (Oniscoidea), and Banded Mystery snails. In addition, there were many Zebra Mussels (*Dreisseniidae*) found. Of all the species found, all were native except for the Zebra Mussels. While the majority of the species were native, some are located universally in low quality and high-quality water. The midge larvae family Chironomidae can be found in both high- and low-quality water (Lenat and Barbour 1994).

Native lake macroinvertebrate communities can and have been impacted by exotic and invasive species. A study by Stewart and Haynes (1994) examined changes in benthic macroinvertebrate community in southwestern Lake Ontario following the invasion of Zebra and Quagga Mussels (*Dreissena spp.*). They found that *Dreissena* had replaced a species of freshwater shrimp as the dominant species. However, they also found that additional

macroinvertebrates actually increased in the ten-year study, although some species were considered more pollution-tolerant than others. This increase was thought to have been due to an increase in *Dreissena* colonies increasing additional habitat for other macroinvertebrates.

In addition to exotic and invasive macroinvertebrate species, macroinvertebrate assemblages can be affected by land-use. Stewart et al. (2000) showed that macroinvertebrates were negatively affected by surrounding land-use. They also indicated that noted these land-use practices are important to restoration and management of lakes. Schreiber et al., (2003) stated that disturbance and anthropogenic land use changes are usually considered to be key factors facilitating biological invasions.

References:

- Lenat, D.R. and M.T. Barbour. Using benthic macroinvertebrate community structure for rapid, cost-effective, water quality monitoring: rapid bio assessment. Biological monitoring of aquatic systems. Lewis Publishers, Boca Raton, Florida (1994): 187-215.
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- Stewart, P.M., Butcher, J.T. and T.O. Swinford. 2000. Land use, habitat, and water quality effects on macroinvertebrate communities in three watersheds of a Lake Michigan associated marsh system. *Aquatic Ecosystem Health & Management* Vol. 3.

Table 10. Lake Cadillac sediment macroinvertebrate sampling data (May 24, 2021).

Sample DB 1	Grab	Order/Family	Total Number	Common name
		Gastropoda	9	Pond snails
		Diptera	12	Midge larvae
		Veneroida	6	Zebra Mussels
		Ephemeroptera	2	Mayfly larvae
		Isopoda	2	Sow bugs
		Total	31	
Sample DB 2	Grab	Order	Total Number	Common Name
		Gastropoda	8	Wheel snails
		Isopoda	6	Sow bugs
		Diptera	13	Midge larvae
		Ephemeroptera	2	Mayfly larvae
		Total	29	
Sample DB 3		Planorbidae	10	Wheel snails
		Diptera	9	Midge larvae
		Isopoda	9	Sow bugs
		Total	28	

Table 11. Lake Cadillac sediment macroinvertebrate sampling data (September 20, 2021).

Sample DB 1	Grab	Order/Family	Total Number	Common name
		Diptera	11	Midge larvae
		Veneroida	4	Zebra Mussels
		Ephemeroptera	1	Mayfly larvae
		Gastropoda	13	Wheel snails
		Isopoda	5	Sow bugs
		Total	34	
Sample DB 2	Grab	Order	Total Number	Common Name
		Gastropoda	9	Wheel snails
		Gastropoda	2	Pond snails
		Viviparidae	4	Banded Mystery Snails
		Diptera	12	Midge larvae
		Total	27	
Sample DB 3		Isopoda	6	Sow bugs
		Gastropoda	16	Wheel snails
		Veneroida	2	Zebra mussels
		Diptera	10	Midges
		Total	34	

Management Recommendations for 2022

1. Aquatic Vegetation Surveys:

Continuous aquatic vegetation surveys are needed to determine the precise locations of Eurasian Watermilfoil (EWM) Curly-leaf Pondweed (CLP), or other problematic invasives in or around Lake Cadillac. Typically, only EWM would be treated unless the CLP is a severe navigational impedance. These surveys should include a whole lake inventory in late May to mid-June and again later in the season. In addition, partial surveys post-treatment as needed in 2022. Scientists from RLS will be present to oversee all aquatic herbicide treatments in 2022 as in previous years.

2. Aquatic Herbicide Treatments:

Due to the relative scarcity of native aquatic vegetation (for the lake size) in Lake Cadillac, the treatment of these species with aquatic herbicides is not recommended and re-colonization of the lake by these species is a major goal for the health of Lake Cadillac. Reduction in blue-green algae throughout the lake should also assist with this re-colonization as the plants will have more access to light for continued growth. The plan for 2022 includes the use of high doses of systemic aquatic herbicides (such as a combination of ProcellaCOR® and diquat) for the hybrid milfoil that may be present. Only dense areas of CLP will be recommended for treatment. Doses will be dependent upon the EGLE permit requirements as well as the size and density of the weed beds.

3. Lake Water Quality Monitoring:

Water quality parameters will also be monitored in Lake Cadillac for 2022 as in previous years. RLS is in the process of gathering additional historical data and comparing units of measure to assist with the goal of graphing the data for each water quality parameter to determine these trends. In addition, water quality from the in-flow areas may also be sampled if running and an independent sample can be collected. RLS will use that data to make any necessary recommendations for additional BMPs (best management practices) if needed.

4. Goose Control:

As in recent years, during the 2021 season, RLS noted that there is an abundance of geese around the parks on Lake Cadillac (Figure 10). A study by Manny et al. (1994) found that the annual contribution of carbon, nitrogen, and phosphorus from migratory waterfowl including Canada geese (*Branta canadensis*) can exceed the external loading contributions on some inland lakes. Thus, an overabundance of geese can lead to increased nutrient loads to Lake Cadillac. Fortunately, there are some strategies for reducing geese populations which include but are not limited to the following:

1. Encourage riparians to grow waterfront grass to ≥ 3 inches tall as geese prefer short grass.
2. Plant tall native plants near the shore to encourage a soft shoreline that geese may avoid due to the potential of predators hiding in the tall weeds.
3. Avoid mowing to the water's edge.
4. Do not feed geese or waterfowl as this encourages their presence.
5. Egg replacement, goose round-up, and nest destruction methods are effective to a degree but require an MDNR permit and training.
6. Coyote or other intimidating effigies can scare geese away from lawns.
7. The Audubon Society recommends placement of string 6 inches above the ground followed by another row of string an additional 6 inches above the water.
8. Visit the following website for more methods:
<http://icwdm.org/handbook/Birds/CanadadGeese/Default.aspx>

Reference: Manny B.A., Johnson W.C., Wetzel R.G. (1994) Nutrient additions by waterfowl to lakes and reservoirs: predicting their effects on productivity and water quality. In: Kerekes J.J. (eds) Aquatic Birds in the Trophic Web of Lakes. Developments in Hydrobiology, vol 96. Springer, Dordrecht.

Reference: Canada Goose Management Website. University of Nebraska-Lincoln, NRES 348 Wildlife Damage Management class, Spring Semester, 2010. Scott Hygnstrom, Instructor; Stephen Vantassel, Webmaster.



Figure 10. An over-abundance of Canada geese near the shore of Lake Cadillac during the 2017-2021 season.

5. Stormwater Monitoring/Nutrient Loading:

RLS recommends meeting with the City of Cadillac to mutually determine the possibility of storm drain sampling to determine whether they are contributing to the nutrient loading of Lake Cadillac. This is becoming very important given the high total phosphorus concentrations that have been measured at the bottom of the deep basins. RLS will meet with the City of Cadillac to discuss these priority areas and create a sampling plan.

6. Lake Cadillac Improvement Millage Needed:

RLS recommends that a City-wide millage be continued for the betterment of Lake Cadillac. RLS would like to mitigate more than the invasive species issue to reduce long-term algal blooms and a decline in water quality.