Paradise Lake 2022 Annual Progress Report to the Paradise Lake Improvement Board

November 9, 2022

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1.0 EXECUTIVE SUMMARY

Paradise Lake (Figure 1) is an 1,878-acre, shallow, eutrophic lake with a maximum depth of 15.1 feet. Paradise Lake is located in sections 7, 18, 10-15, 23, and 24 of Emmet and Cheboygan Counties (T.38N, R. 3,4W). Previously, the lake had become colonized with zebra mussels (*Dreissena polymorpha*), which has resulted in increased light transparency of the lake water and has caused accelerated growth rates of all aquatic vegetation, including the exotic submersed aquatic plant, Eurasian Watermilfoil (*Myriophyllum spicatum*). Invasive milfoil has become a threat to the native aquatic vegetation communities within Paradise Lake, severely impedes navigation and recreational activities within the lake, creates a swimming hazard in areas of dense canopy growth, and has been shown to decrease lakefront property values (Halstead et *al*., 2003).

Prior recommended approaches for treatment of the EWM infestation in Paradise Lake included weevil stocking in protected areas where their reproductive life cycle success was most probable and where the *M. spicatum* canopy was least likely to be disturbed by boat propeller action (i.e., the most highly trafficked and developed areas). In addition, other methods such as laminar flow aeration (LFA) were used in the West Basin with a few years of acceptable results but eventually failed to reduce further growth. Mechanical harvesting was also used in the West Basin and at a dense area of growth in the North area of the lake with only temporary success in reducing the EWM canopy. A Diver Assisted Suction Harvesting (DASH) boat has also been used in some areas of Paradise Lake, but this method is used primarily for small areas of EWM growth, given the density and relative abundance of EWM in the lake.

Two whole-lake surveys occurred on June 22, 2022 (pre-treatment) and on August 26, 2022 (post-treatment). Two additional interim surveys were conducted on July 11, 2022 and August 3, 2022. Such surveys were conducted by aquatic scientists at RLS and consisted of 722 GPS sampling locations located throughout Paradise Lake and determined that approximately 401 acres of *M. spicatum* exists in the lake. The lake also contained a moderate amount of submersed native vegetation that includes pondweeds and other native milfoil species such a Whorled Watermilfoil (*M. verticillatum*).

This is a substantial reduction from the 401 acres present in 2021 which occurred due to rigorous systemic treatments in 2021 with the use of the systemic herbicide triclopyr and spot-treatments in 2022 with the systemic herbicide ProcellaCOR®. It is beneficial to rotate products every few years so that herbicide tolerance to one product does not occur by the milfoil.

The use of aquatic herbicides is regulated by the USDA and also EGLE and an herbicide permit was issued for 2021-2022. The herbicide application was conducted by PLM on July 19, 2022 and consisted of 20.5 acres of EWM. The dose of ProcellaCOR® was 6 PDU. RLS was present to oversee these treatments on Paradise Lake to assure due diligence and that the proper herbicide doses are applied to only the targeted areas. An additional spot-treatment was conducted on August 11, 2022 and included 3.0 acres with ProcellaCOR® at a dose of 6 PDU.

In 2023 and future years, rigorous seasonal surveys and timely and responsive spot-treatments will assure a rapid response and reduce the spread of EWM and consequential need for more herbicide use. It is critical to realize that there are no eradication methods available for EWM. This means that although there may be periods of “no growth” between treatments, the seed bank will always be active and dormant seeds could germinate at any time. The goal for this program is to successfully reduce the EWM over a period of a few years so that DASH could become a utilized method on remaining small areas of EWM to lessen the dependency on aquatic herbicide use or simply rely on the use of less herbicide for spot-treatments.

The water quality of Paradise Lake continues to be very good and was measured on August 3, 2022. Overall, the lake has low to moderate nutrient concentrations, favorable dissolved oxygen and water clarity, and algae. Paradise Lake riparians are strongly encouraged to follow good lake best management practices. This includes avoiding the dumping of grass clippings or leaves into the lake, abstaining from the use of lawn fertilizers, and regular maintenance of septic systems and drain fields. These behaviors will protect the lake from additional nutrient inputs which further enhance aquatic vegetation and algal growth.

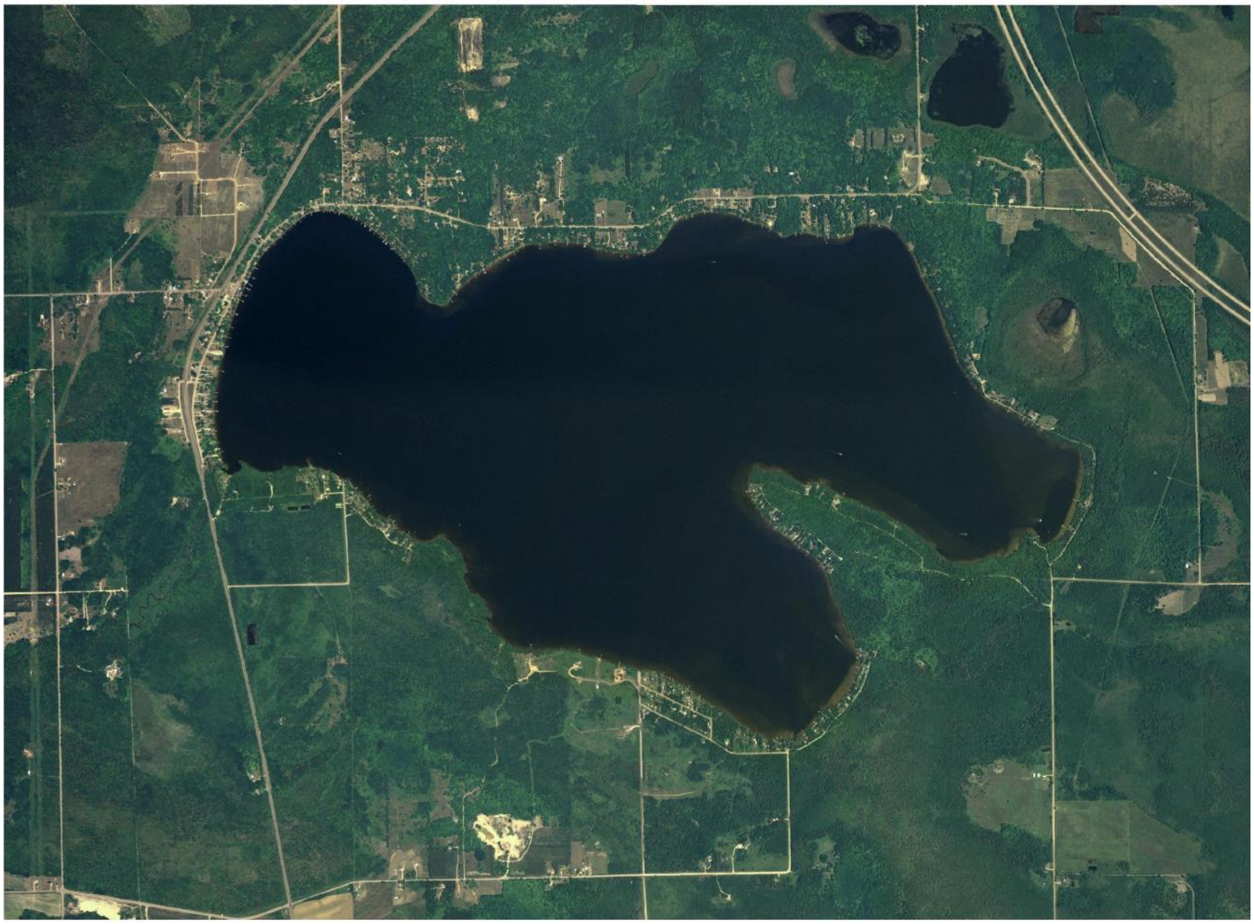

Figure 1. Aerial photo of Paradise Lake, Emmet and Cheboygan Counties, Michigan (MIRIS, 2006 aerial photo database).

2.0 PARADISE LAKE 2022 WATER QUALITY DATA

Paradise Lake is approximately 1,878 acres and has a maximum and average depth of 15.1 feet and 3.9 feet, respectively (Figure 2). The shoreline length is approximately 14.3 miles, and the volume of the lake is approximately 10,358,982 m^3. The watershed is approximately 16,685 acres, which is nearly 8.9 times the lake surface area. The shoreline development factor (SDF) is 1.5 (Gannon and Paddock, 1974). Primary land uses in the watershed include wetlands (nearly 50%), followed by forested lands (~21.4%). The watershed contains 3.3% urban land use and 8.3% agricultural land use (Tipp of the Mitt Watershed Council, 2008). Paradise contains one inlet (Mud Creek) and one outlet (Carp River).

The Carp River outlet drains Paradise Lake into the Straits of Mackinaw. Lake sediments consist of a mixture of sands and organic deposits with the sands closer to shore and the organic deposits located in the deeper areas.

In 2022, RLS scientists collected water quality data on Paradise Lake on August 3, 2022 (Tables 2-7). The water quality sampling consisted of physical water quality parameters including water temperature, dissolved oxygen, pH, turbidity, total dissolved solids, specific conductivity, and Secchi transparency. Additionally, chemical water quality parameters such as total phosphorus, total nitrogen, chlorophyll-a and algal communities were also measured. All of these parameters were measured at 3 locations within the lake and included the west, central, and east basins. At each location, samples were collected at top, middle, and bottom depths.

Water quality is highly variable among Michigan's inland lakes, although some characteristics are common among particular lake classification types. The water quality of Paradise Lake is affected by both land use practices and climatic events. Climatic factors (i.e., spring runoff, heavy rainfall) may alter water quality in the short term; whereas anthropogenic (man-induced) factors (i.e., shoreline development, lawn fertilizer use) alter water quality over longer time periods. Since many lakes have a fairly long hydraulic residence time, the water may remain in the lake for years and is therefore sensitive to nutrient loading and pollutants. Furthermore, lake water quality helps to determine the classification of particular lakes (Table 1). Lakes that are high in nutrients (such as phosphorus and nitrogen) and chlorophyll-*a*, and low in transparency are classified as eutrophic; whereas those that are low in nutrients and chlorophyll-*a*, and high in transparency are classified as oligotrophic. Lakes that fall in between these two categories are classified as mesotrophic. Paradise Lake is classified as a meso-eutrophic (nutrient-rich) lake due to the moderate nutrients and moderate Secchi transparency and moderate chlorophyll-a concentrations.

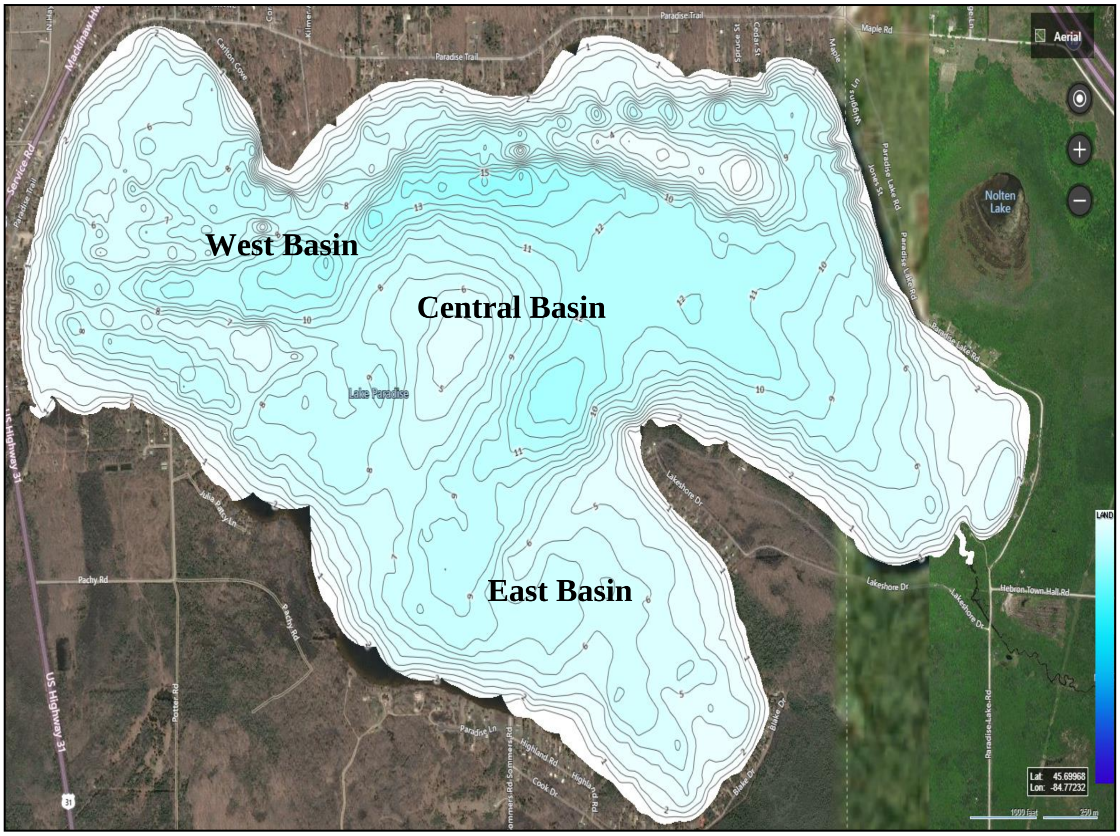

Figure 2. Water quality sampling sites on August 3, 2022 in Paradise Lake, Emmet County, Michigan.

Table 1. General Lake Trophic Status Classification Table.

Lake Trophic Status	*Total Phosphorus (mg L^{-1})*	*Chlorophyll-a (µg L^{-1})*	*Secchi Transparency (feet)*
Oligotrophic	< 0.010	< 2.2	> 15.0
Mesotrophic	0.010-0.025	2.2 – 6.0	7.5 – 15.0
Eutrophic	> 0.025	> 6.0	< 7.5

2.1.1 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 to sustain a healthy warm-water fishery and even higher around 6 mg/L for trout. 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) with the use of a calibrated Eureka Manta II® dissolved oxygen meter. Dissolved oxygen (DO) concentrations in the deep basins ranged from 8.9-9.0 mg/L, with the highest values measured at the surface and mid-depth and lowest values near the lake bottom. The bottom of the lake produces a biochemical oxygen demand (BOD) due to microbial activity attempting to break down high quantities of organic plant matter, which reduces dissolved oxygen in the water column at depth.

2.1.2 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 (ºC) with the use of a calibrated Eureka Manta II® submersible thermometer. The August 3, 2022 water temperatures of Paradise Lake demonstrated an absence of thermoclines and are indicative of a well-mixed lake. On the day of sampling, water temperatures ranged from 23.0°C at the surface to 22.9°C at the bottom of the three deep basins.

2.1.3 Specific Conductivity

Specific conductivity is a measure of the number of mineral ions present in the water, especially those of salts and other dissolved inorganic substances that can conduct an electrical current. Specific conductivity generally increases with water temperature and the amount of dissolved minerals and salts in a lake. Specific conductivity was measured in micro Siemens per centimeter (µS/cm) with the use of a calibrated Eureka Manta II® specific conductivity probe and meter. Specific conductivity values for Paradise Lake were identical among depths at the deep basins and were recorded at 235 mS/cm which are moderate and favorable values.

Baseline parameter data such as specific conductivity are important to measure the possible influences of land use activities (i.e., road salt influences) on Paradise Lake over a long period of time, or to trace the origin of a substance to the lake in an effort to reduce pollutant loading. Elevated conductivity values over 800 mS/cm can negatively impact aquatic life.

2.1.4 Turbidity and Total Dissolved Solids

Turbidity

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. 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 was measured in Nephelometric Turbidity Units (NTU's) with the use of a calibrated Lutron® turbidity meter. 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 Paradise Lake was low and ranged from 1.5-3.6 NTU's during the August 3, 2022 sampling event. On the day of sampling, the winds were calm in the morning, and turbidity was not likely influenced by much re-suspension of sediments although bottom samples are usually higher in turbidity. These numbers also correlate with the measured high transparency and low chlorophyll-a concentrations.

Total Dissolved Solids

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. Total dissolved solids were measured with the use of a calibrated Eureka Manta II® meter in mg/L. Spring values are usually higher due to increased watershed inputs from spring runoff and/or increased planktonic algal communities. The TDS in Paradise Lake on August 3, 2022 ranged from 150-151 mg/L for the deep basins which is moderate for an inland lake and correlates with the measured moderate conductivity.

2.1.5 pH

pH is a measure of acidity or basicity of water. pH was measured with a calibrated Eureka Manta II® pH electrode and pH-meter in Standard Units (S.U). The standard pH scale ranges from 0 (acidic) to 14 (alkaline), with neutral values around 7. Most Michigan lakes have pH values that range from 7.0 to 9.5 S.U.

Acidic lakes (pH < 7) are rare in Michigan and are most sensitive to inputs of acidic substances due to a low acid neutralizing capacity (ANC). The pH of Paradise Lake water ranged from 8.4-8.5 S.U. during the August 3, 2022 sampling event. This range of pH is neutral to alkaline on the pH scale and is ideal for an inland lake. pH tends to rise when abundant aquatic plants are actively growing through photosynthesis or when abundant marl deposits are present.

2.1.6 Total Phosphorus

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. Lakes which contain greater than 0.020 mg/L (or 20 µg/L) of TP are defined as eutrophic or nutrient-enriched. TP concentrations are usually higher at increased depths due to the higher release rates of P from lake sediments under low oxygen (anoxic) conditions. Phosphorus may also be released from sediments as pH increases. Total phosphorus was measured in milligrams per liter (mg/L) with the use of Method EPA 200.7 (Rev. 4.4) or in situ with a Hach® chemical test. The total phosphorus (TP) concentrations in the lake deep basins ranged from 0.014-0.019 mg/L during the August 3, 2022 sampling event. Septic systems may be a significant source of TP for Paradise Lake and thus proper maintenance of the system is necessary.

2.1.7 Total Kjeldahl Nitrogen

Total Kjeldahl Nitrogen (TKN) is the sum of nitrate (NO_3^-), nitrite (NO_2^-), and organic nitrogen forms in freshwater systems. TKN was measured with Method EPA 351.2 (Rev. 2.0). 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 (N: P > 15), phosphorus may be the limiting nutrient for phytoplankton and aquatic macrophyte growth, which is correct for Paradise Lake. 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 may be classified as oligotrophic, those with a mean TKN value of 0.75 mg /L may be classified as mesotrophic, and those with a mean TKN value greater than 1.88 mg/L may be classified as eutrophic. Paradise Lake contained low concentrations of TKN at all depths (≤ 0.50-1.0 mg/L), which are normal for an inland lake of similar size.

2.1.8 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 µg/L are found in eutrophic or nutrient-enriched aquatic systems, whereas chlorophyll-*a* concentrations less than 2.2 µg/L are found in nutrient-poor or oligotrophic lakes.

Chlorophyll-*a* was measured in micrograms per liter (µg/L) with an *in situ* Turner Designs® fluorimeter. The chlorophyll-*a* concentrations in Paradise Lake were determined by collecting a composite sample of the algae throughout the water column at the deep basin sites from just above the lake bottom to the lake surface. The chlorophyll-*a* concentration in the deep basins ranged from 3.0-4.0 µg/L during the August 3, 2022 sampling event. These concentrations were favorable, especially during the late summer.

Algal genera from a composite water sample collected from the deep basins of Paradise Lake on August 3, 2022 were analyzed under a Zeiss® compound brightfield microscope. The genera present included the Chlorophyta (green algae): *Haematococcus* sp., *Chlorella* sp., *Cosmarium* sp., *Akinestrodesmus* sp., *Mougeotia* sp., *Scenedesmus* sp., and *Closterium* sp.,; the Cyanophyta (blue-green algae): *Chroococcus* sp.; the Bascillariophyta (diatoms): *Cymbella* sp., *Fragilaria* sp., *Stephanodiscus* sp., and *Navicula* sp. The aforementioned species indicate a moderately diverse algal flora and represent a relatively balanced freshwater ecosystem, capable of supporting a strong zooplankton community in favorable water quality conditions. The diatoms were the most abundant, followed by the green algae.

2.1.9 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 Paradise Lake was measured on August 3, 2022 and averaged around 9.5 feet over the deepest basins which are very favorable measurements. Measurements were collected during calm conditions (winds out of the northwest at 5-10 mph in the early morning). This transparency indicates a low quantity of suspended particles and algae throughout the water column which would result in better water clarity.

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. Secchi transparency has increased throughout time due to the presence and abundance of Zebra Mussels which filter the algae out of the water for food.

Table 2. Paradise Lake physical water quality parameter data collected at deep basin West (August 3, 2022).

Depth (ft)	Water Temp (°C)	DO (mg/L)	pH (S.U.)	Conduc. (mS/cm)	TDS (mg/L)	Turb. (NTU)	Secchi Depth (ft)
0	23.0	9.0	8.5	235	150	2.5	9.5
7.0	22.9	9.0	8.5	235	150	2.5	
14.0	22.9	9.0	8.5	235	150	2.5	

Table 3. Paradise Lake chemical water quality parameter data collected at deep basin West (August 3, 2022).

Depth (m)	TKN (mg/L)	TP (mg/L)	Chl-a (µg/L)
0	<0.5	0.014	--
7.0	<0.5	0.014	4.0
14.0	<0.5	0.014	--

Table 4. Paradise Lake physical water quality parameter data collected at deep basin Central (August 3, 2022).

Depth (ft)	Water Temp (°C)	DO (mg/L)	pH (S.U.)	Conduc. (mS/cm)	TDS (mg/L)	Turb. (NTU)	Secchi Depth (ft)
0	23.0	9.0	8.5	235	151	1.5	9.5
6.5	23.0	9.0	8.4	235	151	2.0	
13.0	23.0	9.0	8.4	235	151	2.8	

Table 5. Paradise Lake chemical water quality parameter data collected at deep basin Central (August 3, 2022).

Depth (m)	TKN (mg/L)	TP (mg/L)	Chl-a (µg/L)
0	0.5	0.019	--
6.5	1.0	0.019	3.0
13.0	1.0	0.019	--

Table 6. Paradise Lake physical water quality parameter data collected at deep basin East (August 3, 2022).

Depth (ft)	Water Temp (°C)	DO (mg/L)	pH (S.U.)	Conduc. (mS/cm)	TDS (mg/L)	Turb. (NTU)	Secchi Depth (ft)
0	23.0	8.9	8.4	235	150	1.5	7.0+
3.5	23.0	8.9	8.4	235	150	2.2	
7.0	23.0	8.9	8.5	235	150	3.6	

Table 7. Paradise Lake chemical water quality parameter data collected at deep basin East (August 3, 2022).

Depth (m)	TKN (mg/L)	TP (mg/L)	Chl-a (µg/L)
0	<0.5	0.017	--
3.5	<0.5	0.017	3.0
7.0	0.6	0.017	--

3.0 2022 AQUATIC VEGETATION IN PARADISE LAKE

The June 22, 2022 and August 26, 2022 whole-lake aquatic vegetation survey by RLS utilized the GPS Point-Intercept Method for aquatic vegetation sampling, which is used widely among aquatic scientists to sample large aquatic ecosystems in an unbiased manner. The U.S. Army Corps of Engineers utilizes this methodology for pre-treatment and post-treatment surveys to assess the efficacy of lake improvement programs (Madsen et *al*., 1994; 1996). This type of survey is also amenable to statistical analysis, which is instrumental in measuring the success of any improvement protocol. At each of the 722 sampling locations (Figure 3), a WAAS-enabled 50-satellite capacity GPS unit with an accuracy of 2.0 feet was used to accurately record geo-referenced data.

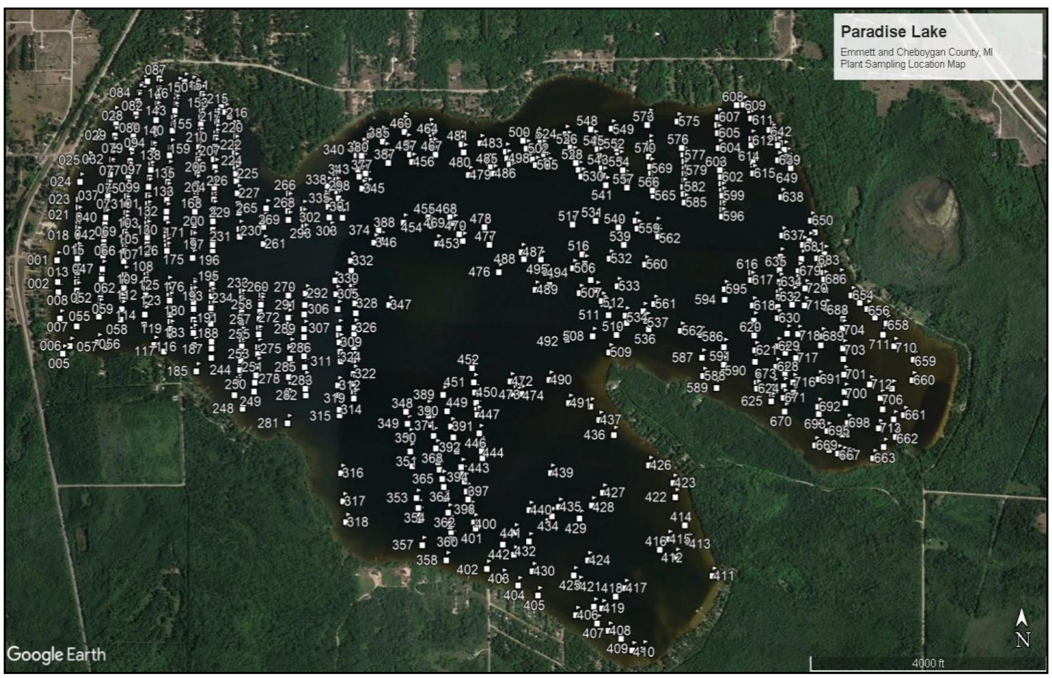

Figure 3. Aquatic vegetation sampling locations in Paradise Lake on June 22, 2022 and August 26, 2022. Note: Only locations with vegetation present were sampled. The vacant areas were bare sand with no aquatic vegetation present.

At each grid point two rake tosses were conducted and all species and relative abundance of rake specimens collected were recorded unless bare lake sediments were in view. The June 22, 2022 15.5 acre of EWM was present but an additional 5.0 acres was noted on the day of treatment. During the June 22, 2022 aquatic vegetation survey, EWM was located in 41.0% of the GPS sampling locations, with 22% of those at the “a” (found) density level, 17% at the “b” (sparse) density level, 16% at the “c” (common) density level, and 45% at the “d” (dense) level while utilizing the EGLE density protocol. There were five distinct beds located throughout the lake that varied in size from < 1.0 acre to 98.7 acres. The smallest beds were located in the central and southern eastern portions of the lake. Regular rigorous GPS Point-Intercept aquatic plant surveys utilizing this protocol are critical for the detection of exotic species such as EWM, which may limit more favorable, native aquatic plants and consequently alter the ecological balance and biotic integrity of aquatic ecosystems.

3.1 Paradise Lake Exotic Aquatic Plant Species

Eurasian Watermilfoil (*M. spicatum* or EWM; Figure 4) is an exotic, invasive, submersed, perennial aquatic plant which was introduced into the United States in the 1880’s (Reed 1997), although other reports (Couch and Nelson 1985) suggest it was discovered in the 1940’s. Exotic aquatic plants 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 in lakes with a public access site), 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. EWM 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) and may limit light from reaching native aquatic plant species (Newroth 1985; Aiken et *al*. 1979). The aquatic plant frequently forms dense surface canopies on inland lakes such as Paradise Lake. Additionally, EWM can alter the macroinvertebrate populations associated with particular native plants of certain structural architecture (Newroth 1985). EWM beds have been associated with less macroinvertebrate biodiversity than native aquatic vegetation beds (Soszka 1975; Keast 1984; Cattaneo et *al*. 1998). The canopy created by EWM creates an unfavorable environment for aquatic biota through the creation of stagnant water conditions which lead to increased water temperatures and lower dissolved oxygen concentrations (Unmuth et *al.* 2000; Figure 4). Cheruvelil et *al*. (2001) studied the macroinvertebrate communities on EWM in six southern Michigan lakes and discovered that the number of macroinvertebrates on the most dominant plant species declines as EWM biomass increases. Since the introduction of EWM, many nuisance aquatic plant management techniques such as chemical herbicides, biological control, and in extreme cases, mechanical harvesting, have been implemented. EWM must be managed as it reduces native aquatic plant biodiversity, impairs navigation and recreation, and accumulates on shorelines which can be difficult to remove

Most of the areas where aquatic vegetation biovolume is dense are occupied by dense EWM beds (Figure 5). The aquatic vegetation biovolume map can be quantified by percentage cover with the following breakdown:

0-20% plant biovolume = 61% cover
20-40% plant biovolume = 21% cover
40-60% plant biovolume = 8.8 % cover
60-80% plant biovolume = 3.1% cover
>80% plant biovolume = 6.8% cover

The majority of the biovolume exists in the 0-20% cover category which means low-growing vegetation. The >80% cover category only comprises 6.8% of the total biovolume and thus the topped-out EWM and nuisance growth have been substantially reduced. Areas with higher aquatic vegetation biovolume appear red on the biovolume map and areas with green color denote low-growing native vegetation. Figure 6 shows the EWM locations on June 22, 2022 and Figure 7 shows the EWM locations on August 3, 2022.

Figure 4. Eurasian Watermilfoil with seed head and lateral branches.
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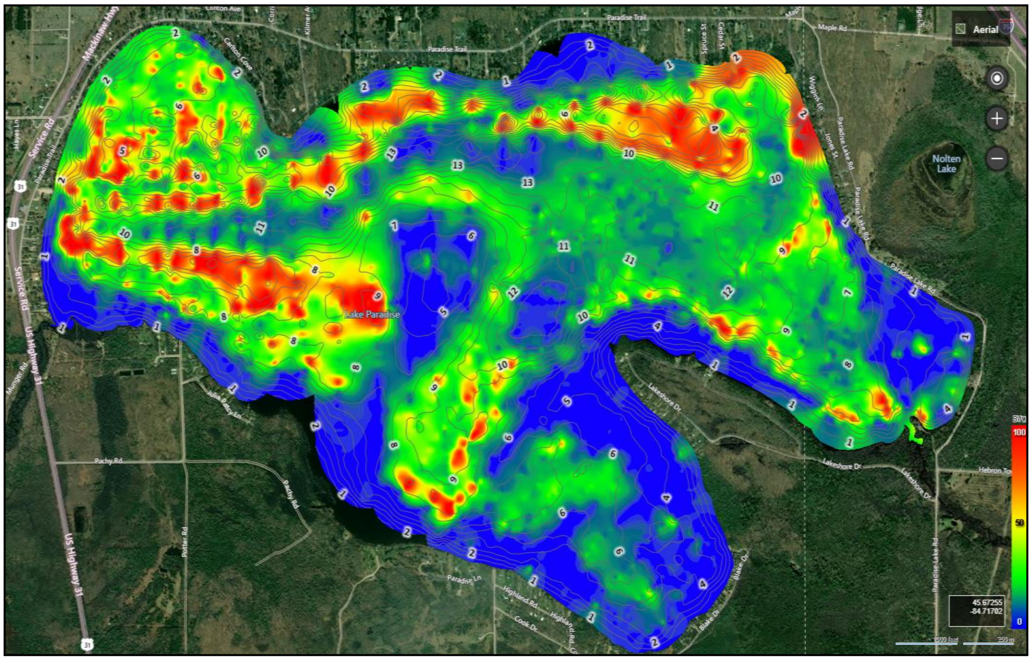

Figure 5. Aquatic vegetation biovolume in Paradise Lake (June 22, 2022). Note: Not all red color refers to EWM but a mix of EWM and pondweeds.

Figure 6. Eurasian Watermilfoil distribution (June 22, 2022)

Figure 7. Eurasian Watermilfoil distribution (August 3, 2022)

3.2 Paradise Lake Native Aquatic Plant Species

During the June and August 2022 surveys, a total of 17 submersed, 3 floating-leaved, and 4 emergent native aquatic plant species were found which is a total of 24 native species. Tables 8 and 9 display the pre-treatment relative frequencies and abundance of each species, respectively. Tables 10 and 11 display the post-treatment aquatic plant species. The most dominant native aquatic plant species within Paradise Lake were in the Potamogetonaceae family, which included the Pondweeds such as White-stem Pondweed (*Potamogeton praelongus*), and Fern-leaf Pondweed (*P. robbinsii*). *P. praelongus* was present in 35.2% of the grid points sampled and thus was the most dominant rooted native submersed aquatic plant in the littoral zone. *P. robbinsii* was the second most abundant species which was present in 10.5% of the sampling locations. *P. robbinsii* often carpeted the lake bottom and formed a thick layer which makes it difficult for newly formed EWM fragments to root in the lake bottom sediment. Thus, preservation of this and other low-growing species is critical for the long-term control of EWM and other nuisance species which spread through fragmentation.

The pondweeds serve as excellent cover for fish and macroinvertebrates and should be preserved to the extent possible to support a healthy fishery. The submersed rootless aquatic plant, Utricularia vilgaris was present in 6.3 % of the sampling locations. The majority of the native aquatic plant species in Paradise Lake were sparse to common in abundance and do not currently impart a threat to the balance of the ecosystem or to the safety of recreationalists on the lake. They should be protected and are expected to thrive once EWM beds are removed, and they receive more space and light for growth.

Table 8. Paradise Lake native aquatic vascular plants (June 22, 2022) by % frequency.

Native Aquatic Plant Species Name	***Native Aquatic Plant Common Name***	***Growth Form***	***% Frequency***
Chara vulgaris	Muskgrass	Submersed	6.0
Stuckenia pectinatus	Sago Pondweed	Submersed	0.1
Potamogeton zosteriformis	Flat-stem Pondweed	Submersed	0.9
Potamogeton robbinsii	Fern-leaf Pondweed	Submersed	10.5
Potamogeton gramineus	Variable-leaf Pondweed	Submersed	0.1
Potamogeton praelongus	White-stem Pondweed	Submersed	35.2
Potamogeton illinoensis	Illinois Pondweed	Submersed	0.1
Potamogeton richardsonii	Clasping-leaf Pondweed	Submersed	0.5
Potamogeton epihydrus	Ribbon-leaf Pondweed	Submersed	0.1
Potamogeton pulcher	Spotted Pondweed	Submersed	0.1
Potamogeton natans	Floating-leaf Pondweed	Submersed	0.1
Potamogeton amplifolius	Large-leaf Pondweed	Submersed	0.4
Myriophyllum sibiricum	Northern Watermilfoil	Submersed	0.1
Myriophyllum verticillatum	Whorled Watermilfoil	Submersed	0.1
Elodea canadensis	Common Waterweed	Submersed	2.5
Utricularia vulgaris	Bladderwort	Submersed	6.3
Najas guadalupensis	Southern Naiad	Submersed	0.1
Nymphaea odorata	White Waterlily	Floating-leaved	0.1
Nuphar advena	Yellow Waterlily	Floating-leaved	0.1
Brasenia schreberi	Watershield	Floating-leaved	0.1
Decodon verticillatus	Swamp Loosestrife	Emergent	0.1
Schoenoplectus acutus	Bulrushes	Emergent	1.2
Pontedaria cordata	Pickerelweed	Emergent	0.1
Typha latifolia	Cattails	Emergent	0.1

Table 9. Paradise Lake native aquatic vascular plants (June 22, 2022) by relative abundance.

Native Aquatic Plant Species Name	***Native Aquatic Plant Common Name***	***"a" Level***	***"b" Level***	***"c" Level***	***"d" Level***
Chara vulgaris	Muskgrass	30	2	1	0
Stuckenia pectinatus	Sago Pondweed	2	1	0	0
Potamogeton zosteriformis	Flat-stem Pondweed	0	3	2	0
Potamogeton robbinsii	Fern-leaf Pondweed	40	32	3	0
Potamogeton gramineus	Variable-leaf Pondweed	2	1	0	0
Potamogeton praelongus	White-stem Pondweed	115	200	15	1
Potamogeton illinoensis	Illinois Pondweed	2	1	0	0
Potamogeton richardsonii	Clasping-leaf Pondweed	3	6	1	0
Potamogeton epihydrus	Ribbon-leaf Pondweed	2	1	0	0
Potamogeton pulcher	Spotted Pondweed	2	1	0	0
Potamogeton natans	Floating-leaf Pondweed	2	1	0	0
Potamogeton amplifolius	Large-leaf Pondweed	5	3	1	0
Myriophyllum sibiricum	Northern Watermilfoil	2	0	0	0
Myriophyllum verticillatum	Whorled Watermilfoil	2	1	0	0
Elodea canadensis	Common Waterweed	4	5	5	0
Utricularia vulgaris	Bladderwort	50	2	0	0
Najas guadalupensis	Southern Naiad	2	0	0	0
Nymphaea odorata	White Waterlily	2	1	0	0
Nuphar advena	Yellow Waterlily	2	1	0	0
Brasenia schreberi	Watershield	2	0	0	0
Decodon verticillatus	Swamp Loosestrife	1	2	0	0
Schoenoplectus acutus	Bulrushes	3	6	1	0
Pontedaria cordata	Pickerelweed	2	1	0	0
Typha latifolia	Cattails	2	0	0	0

Table 10. Paradise Lake native aquatic vascular plants (August 26, 2022) by % frequency.

Native Aquatic Plant Species Name	*Native Aquatic Plant Common Name*	*Growth Form*	*% Frequency*
Chara vulgaris	Muskgrass	Submersed	12.0
Stuckenia pectinatus	Sago Pondweed	Submersed	0.1
Potamogeton zosteriformis	Flat-stem Pondweed	Submersed	1.5
Potamogeton robbinsii	Fern-leaf Pondweed	Submersed	11.8
Potamogeton gramineus	Variable-leaf Pondweed	Submersed	0.1
Potamogeton praelongus	White-stem Pondweed	Submersed	51.8
Potamogeton illinoensis	Illinois Pondweed	Submersed	0.1
Potamogeton richardsonii	Clasping-leaf Pondweed	Submersed	1.0
Potamogeton epihydrus	Ribbon-leaf Pondweed	Submersed	0.1
Potamogeton pulcher	Spotted Pondweed	Submersed	0.1
Potamogeton natans	Floating-leaf Pondweed	Submersed	0.1
Potamogeton amplifolius	Large-leaf Pondweed	Submersed	1.0
Myriophyllum sibiricum	Northern Watermilfoil	Submersed	0.1
Myriophyllum verticillatum	Whorled Watermilfoil	Submersed	0.2
Elodea canadensis	Common Waterweed	Submersed	6.6
Utricularia vulgaris	Bladderwort	Submersed	8.6
Najas guadalupensis	Southern Naiad	Submersed	0.1
Nymphaea odorata	White Waterlily	Floating-leaved	0.1
Nuphar advena	Yellow Waterlily	Floating-leaved	0.2
Brasenia schreberi	Watershield	Floating-leaved	0.2
Decodon verticillatus	Swamp Loosestrife	Emergent	0.2
Schoenoplectus acutus	Bulrushes	Emergent	1.7
Pontedaria cordata	Pickerelweed	Emergent	0.2
Typha latifolia	Cattails	Emergent	0.1

Table 11. Paradise Lake native aquatic vascular plants (August 26, 2022) by relative abundance.

Native Aquatic Plant Species Name	***Native Aquatic Plant Common Name***	***"a" Level***	***"b" Level***	***"c" Level***	***"d" Level***
Chara vulgaris	Muskgrass	70	16	1	0
Stuckenia pectinatus	Sago Pondweed	2	1	0	0
Potamogeton zosteriformis	Flat-stem Pondweed	10	1	0	0
Potamogeton robbinsii	Fern-leaf Pondweed	43	37	7	0
Potamogeton gramineus	Variable-leaf Pondweed	2	1	0	0
Potamogeton praelongus	White-stem Pondweed	123	218	32	1
Potamogeton illinoensis	Illinois Pondweed	2	1	0	0
Potamogeton richardsonii	Clasping-leaf Pondweed	7	0	0	0
Potamogeton epihydrus	Ribbon-leaf Pondweed	2	1	0	0
Potamogeton pulcher	Spotted Pondweed	2	1	0	0
Potamogeton natans	Floating-leaf Pondweed	2	1	0	0
Potamogeton amplifolius	Large-leaf Pondweed	2	0	0	0
Myriophyllum sibiricum	Northern Watermilfoil	2	1	0	0
Myriophyllum verticillatum	Whorled Watermilfoil	2	2	0	0
Elodea canadensis	Common Waterweed	21	23	4	0
Utricularia vulgaris	Bladderwort	60	2	0	0
Najas guadalupensis	Southern Naiad	2	0	0	0
Nymphaea odorata	White Waterlily	2	1	0	0
Nuphar advena	Yellow Waterlily	2	0	0	0
Brasenia schreberi	Watershield	2	1	0	0
Decodon verticillatus	Swamp Loosestrife	2	2	0	0
Schoenoplectus acutus	Bulrushes	4	8	0	0
Pontedaria cordata	Pickerelweed	2	1	0	0
Typha latifolia	Cattails	1	1	0	0

4.0 2022 MANAGEMENT SEASON CONCLUSIONS AND 2023 RECOMMENDATIONS

Due to the successful reduction of EWM with triclopyr in 2021 and with ProcellaCOR® in 2022, the recommended aquatic herbicide for Paradise Lake in 2022 is to use the systemic herbicide ProcellaCOR® again in 2023. In 2024, rotation of systemic herbicides are recommended and liquid triclopyr is proposed to be used at the 3.0 gallon per acre/dose.

These herbicides when used properly and according to label, are effective on EWM and poses little risk to the Paradise Lake ecosystem and its inhabitants. There are no swimming or fishing restrictions or shallow well restrictions with ProcellaCOR but swimming in treatment areas should be discouraged the day of treatment.

Restorative Lake Sciences is the only consulting firm that routinely over-sees each major herbicide application. Each application is documented for the product used, the weather conditions, wind speed, and other environmental conditions. RLS accompanies the herbicide applicator to insure proper application of the herbicide. This process is lengthy and time-consuming as both parties assure that all GPS points with EWM are thoroughly treated to provide the best outcomes. RLS recommends that herbicide applicators honor a target level of 80 to 90% success reduction in EWM in their contracts. Systemic herbicides usually take 6 to 8 weeks for successful results. After this time period, RLS again surveys the treatment area to verify the actual success rate. If the treatment is not successful in matching the guarantee, then the applicator must retreat at no cost to bring the treatment rate up to a successful condition. Since RLS uses strong geo-referenced data, comparisons can be made within and among years on the efficacy of EWM treatment by location. This allows for precise determination of weed bed reduction.

If the EWM found in 2023 is minimal (≤3 acres), then integrated management with DASH could be pursued to reduce reliance on herbicides. The eastern-most region of the lake lies within Hebron Township which is currently not a part of the Paradise Lake Improvement Program Special Assessment District (SAD). Although there are only 10.5 acres of EWM within this region of the lake, it is capable to re-infesting other areas of the lake once the herbicide treatments remove the EWM in those areas. Due to this possibility, it is recommended that either individual property owner permissions be obtained for treatment in specific areas, or a DASH permit be applied for to remove this EWM over a period of 2-5 years.

Lastly, nutrient pollution of inland lakes from septic systems and other land use activities is not a modern realization and has been known for multiple decades. The utilization of septic systems by riparians is still quite common around inland lake shorelines.

Ultimately the drain field receives the contents of the septic tank and disperses the materials into the surrounding soils. The problem arises when this material enters the zone of water near the water table and gradually seeps into the lake bottom. This phenomenon has been noted by many scholars on inland waterways as it contributes sizeable loads of nutrients and pathogens to lake water. Lakebed seepage is highly dependent upon water table characteristics such as slope (Winter 1981).

Table 12 below demonstrates the proposed costs for the continued EWM reduction program for Paradise Lake. Note that given the success of the 2021-2022 treatments, these updated cost estimates are significantly reduced from the recommended costs in the feasibility study. It should be cautioned that the PLIB should aim for a surplus of around $80,000 to allow for any possible seed bank regerminations that could necessitate future widespread, large treatments.

Table 12. Cost Estimates for the continued Paradise Lake EWM reduction program. Note: This budget does not include possible contributions from Hebron Township.

Proposed Paradise Lake Improvement Item	Estimated 2023 Cost	Estimated 2024-2025 Cost
Systemic herbicide for localized control of 75 acres[1] of invasive EWM @ $785 per acre (includes notifications from applicator and $1,500 EGLE permit fee)	$58,875	$33,750
DASH[2] operations (includes up to 10.5 acres of removal with annual removal of 3.0 acres and permit fees)	$10,000	$10,000
Professional Services (limnologist surveys, oversight, sampling, monitoring, education, reporting, meetings)[3]	$15,500	$16,500
Contingency[4]	$8,438	$6,025
TOTAL ANNUAL ESTIMATED COST	$92,813	$66,275

[1]This estimate assumes a return of 75 acres of EWM in 2023 with proposed use of ProcellaCOR® at 6 PDU dose. In 2024-2025, liquid triclopyr would be used at projected cost of $450/acre.
[2]DASH operations can also be replaced with herbicide treatments given required permissions.
[3]Professional services include professional limnologist services as outlined in the annual contract between the Paradise Lake Improvement Board and RLS.
[4]Contingency is 10-15% of total budget and may be used for administrative costs.

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