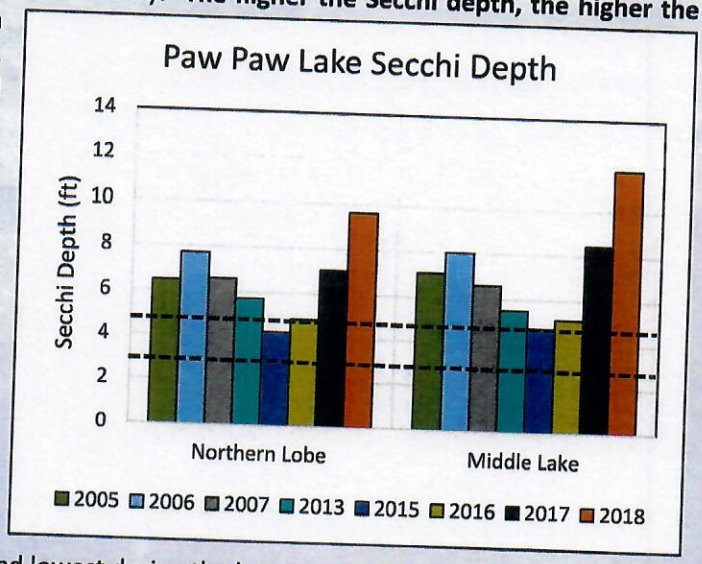
Summary of Water Quality Results
Paw Paw Lake

This document is intended to concisely summarize recent Paw Paw Lake water quality monitoring efforts. The complete database of water quality results and supporting documents is maintained by Spicer Group.

SUMMARY OF HISTORICAL RESULTS
PAW PAW LAKE
BERRIEN COUNTY, MI
JANUARY 18, 2019

SECCHI DEPTH

Secchi depth is a measurement of water clarity. **The higher the Secchi depth, the higher the water clarity is.** Water clarity is often associated with "good" water quality. However, invasive species like zebra and quagga mussels can cause large increases in water clarity and allow for more light to hit the bottom of the lake, thus increasing the growth of aquatic plants. Therefore, a happy medium is desired for water clarity: not too clear to allow for excess growth of aquatic plants and not too cloudy so that the water appears dirty and does not allow for a productive, healthy lake.



In recent years, Paw Paw Lake has exhibited an overall healthy range of water clarity. Within the course of a year, clarity is typically highest during spring and mid-fall and lowest during the late summer months.

CRITERIA FOR COMPARISON – Michigan does not have a set water quality standard for Secchi Depth. However, Minnesota has a variety of water quality standards for Secchi Depths on different water bodies. The most applicable criteria are:

- Lakes and Reservoirs in North Central Hardwood Forest Ecoregion: **Not to be below 4.6 ft.**
- Lakes and Reservoirs in Western Corn Belt Plains and Northern Glaciated Plains Ecoregion: **Not to be below 3.0 ft.**

WHY DOES IT INCREASE AND DECREASE? –

- **Increase and Decrease in Secchi Depth** – An increase in Secchi depth is caused by the reduction of particulate matter suspended in the water column and reduction of algae blooms, phytoplankton and zooplankton. Conversely, a decrease in Secchi depth is due to an increase in particulate matter suspended in water, algae, phytoplankton and zooplankton. An increase in particulate matter can be caused by more runoff and boat traffic, and an increase in algae blooms, phytoplankton, and zooplankton can be due to excess nutrients in the water.

- **The increase in Secchi Depth during 2018 is likely a result of the decreased nutrient levels causing a less productive ecosystem than years past. This shift may also be linked to the presence of zebra mussels and the associated filter feeding.**

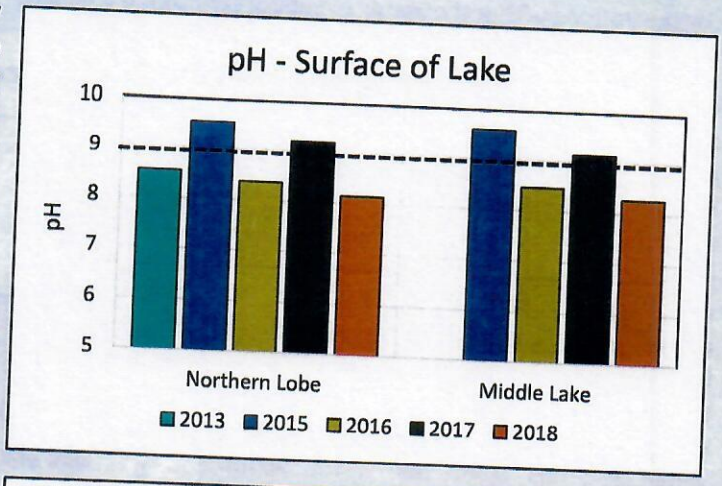
Spicer group

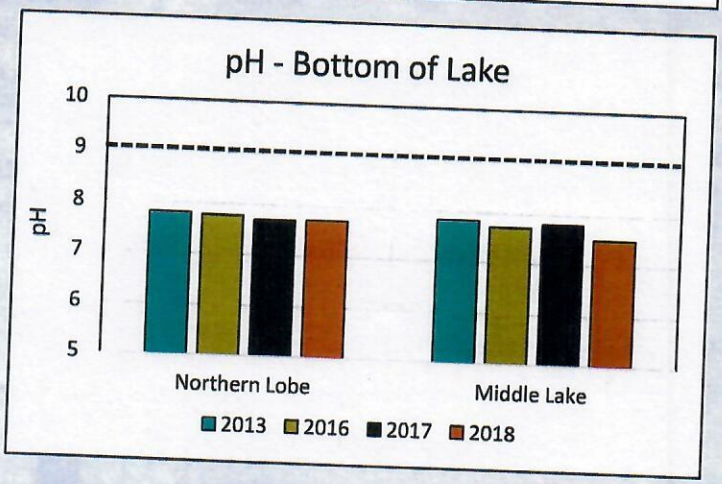
GEI Consultants

pH

pH is technically a measurement of how many hydrogen ions are in your water. To put it more simply, **pH is a measurement of how acidic (pH ranging from 0 – 7) or basic (pH ranging from 7 – 14) the water is.** Michigan tends to have more basic water due to the large amount of limestone present in the bedrock.

In inland lakes, pH may also be indicative of how productive a lake is and how much photosynthesis is occurring within a body of water. The pH will be higher if the lake is very productive and there is a lot of plant growth. Ideally, the pH of Michigan water bodies should **be within a range of 6.5 – 9.0.**





CRITERIA FOR COMPARISON –

MDEQ Rule 53 of Michigan Water Quality Standards (Part 4 of Act 451)

- **pH: 6.5 – 9.0**

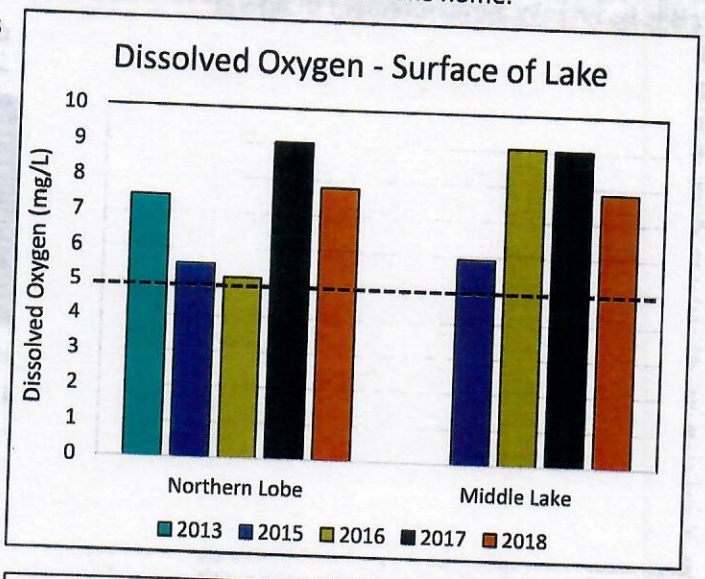
WHY DOES IT INCREASE AND DECREASE? –

- **Increase in pH** – pH can increase due to an increase in dissolved oxygen concentration, an increase in photosynthetic activity of aquatic plants and algae in the water, and an increase in the hardness of the water (i.e. higher calcium and magnesium concentrations in the water).
- **Decrease in pH** – pH can decrease due to a reduction in dissolved oxygen concentration, and an increase in carbon dioxide concentration in the water. This is why the pH is lower in the bottom of the lake versus the top of the lake.
- **The decrease in pH during the year 2018 could be due to the decrease in dissolved oxygen.** The water likely had increased CO_2 levels, which can act as an acid (lower pH). Increased CO_2 levels may occur for a variety of reasons, including the breakdown of organic material.

DISSOLVED OXYGEN (DO)

Dissolved oxygen is a measurement of **how much oxygen gas is dissolved in the water** and is typically measured in milligrams per liter (mg/L). It is important to have high enough dissolved oxygen concentrations within the water to support the aquatic wildlife that calls the lake home.

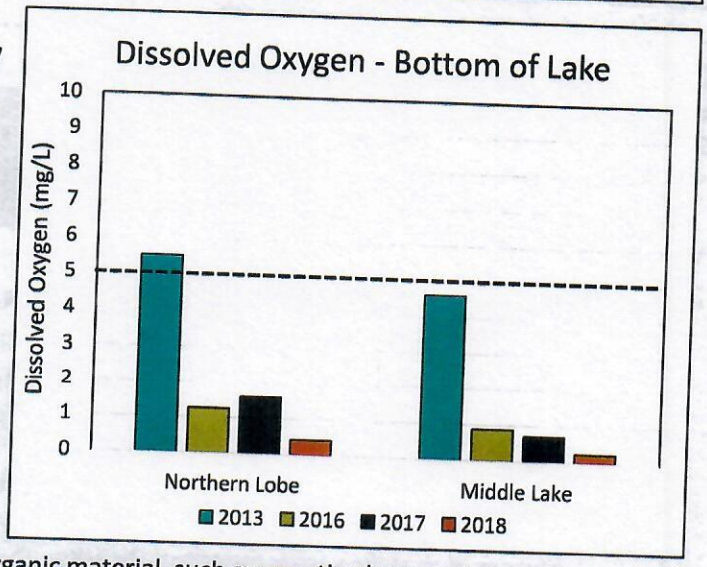
Dissolved oxygen can be reduced by excess algal growth, water that's too warm, and not enough wave action. Dissolved oxygen may be increased by more wave action, cooler temperatures, and non-invasive aquatic plants. The State of Michigan has developed water quality standards for dissolved oxygen. Paw Paw Lake is considered a "warm water fishery," as it is below the geographically designated line that extends horizontally from a point near Alma, Michigan that separates the cold water fisheries from the warm water fisheries. **The warm water fishery standard for dissolved oxygen is 5.0 mg/L.**



CRITERIA FOR COMPARISON –

MDEQ Rule 64 of Michigan Water Quality Standards (Part 4 of Act 451) –

- **Dissolved Oxygen (DO): 5 mg/L**

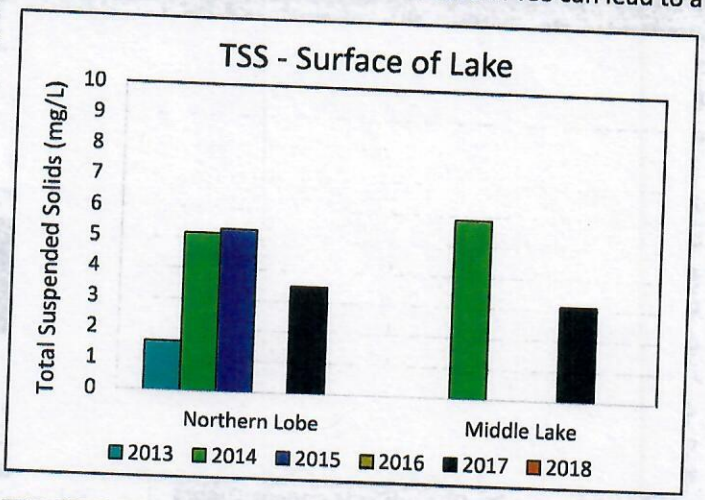


WHY DOES IT INCREASE AND DECREASE? –

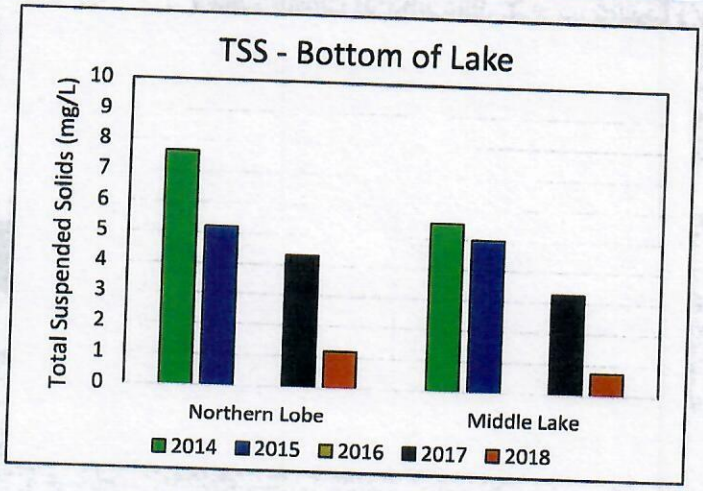
- **Increase** – Dissolved oxygen increases due to more wave action, lower water temperatures, and more photosynthetic activity from aquatic plants and macrophytes.
- **Decrease** – Dissolved oxygen decreases due to the decay of organic material, such as aquatic plants and algae, the increase of oxygen demand from bacteria that use oxygen to respire and break down organic material, and warmer water temperatures.
- **The reduction in DO may be due to the above average temperatures in summer 2018.** Increases in water temperature hinder its ability to store oxygen and other gases.
- The bottom of Paw Paw Lake is anoxic, or lacking in oxygen once it is stratified in the summer. 2013 has elevated DO, as there was only one sample event for the year earlier in the season.

TOTAL SUSPENDED SOLIDS (TSS)

Total suspended solids are small particles that consist of organic material, clay, and other **particulate matter suspended in the water** and are measured in milligrams per liter (mg/L). Often times, TSS carries with it other types of contaminants including nutrients, metals, and hydrocarbons (which is more common in urban areas). While TSS occurs naturally in some waterways, an excessive increase in TSS can lead to a decrease in visibility and an increase in other undesired contaminants previously mentioned, in addition to smothering fish eggs and other aquatic wildlife. Therefore, **low concentrations of TSS are desired.**



TSS can be introduced into Paw Paw Lake via incoming streams and rivers or by the stirring up of bottom sediments. The State of Michigan does not have a numerical standard for how much total suspended solids is too much, but have what is called a narrative standard, meaning that the waters of the state should not have un-natural characteristics attributed to TSS (i.e. excessive cloudiness, films, foams, etc.). Typically, water with a TSS value of less than 20 mg/L are considered to be "clear."



CRITERIA FOR COMPARISON –

MDEQ Rule 50 of Michigan Water Quality Standards (Part 4 of Act 451):

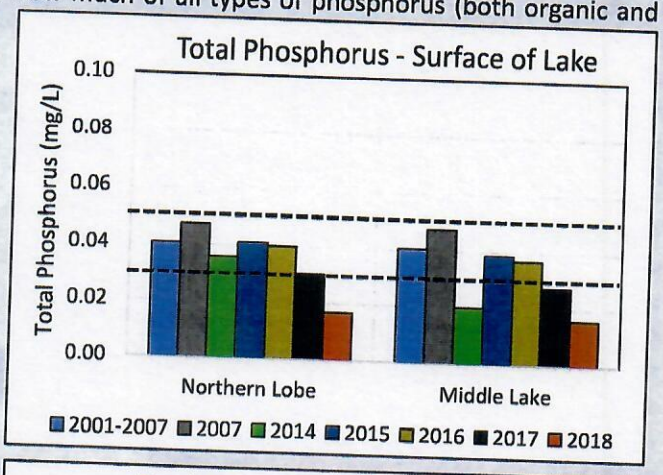
- **TSS = Narrative standard stating that water should not have un-natural physical characteristics**

WHY DOES IT INCREASE AND DECREASE? –

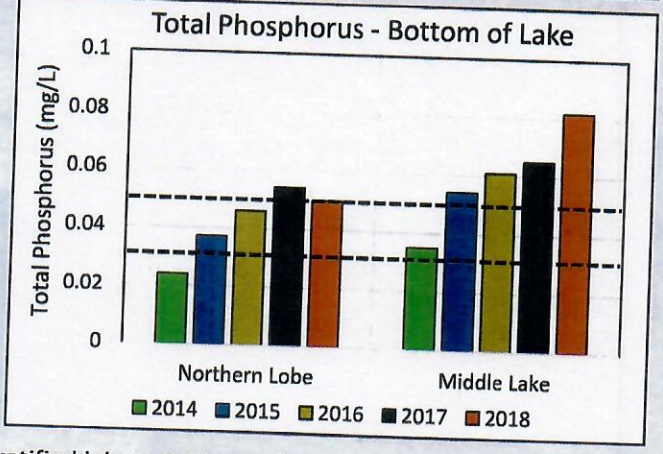
- **Increase and Decrease of Total Suspended Solids** – Total suspended solids increase due to more particulate matter, such as clay, organic material, and algae being suspended in the water column. These materials can get stirred up in a lake when there is a large amount of boat traffic, or when there is an increased amount of runoff from tributary drains. On the other hand, TSS can decrease if these materials settle out, there is little boat traffic, and minimal runoff.
- **The decrease in TSS for 2018 is likely related to the increase in Secchi depth.** Typically, if Secchi depth goes up, TSS will go down, and if Secchi depth goes down, TSS goes up. TSS may also be attributed to large algal particulate matter, which there was less of in 2018 on Paw Paw Lake compared to previous years.

TOTAL PHOSPHORUS (TP)

Phosphorus is an element that is a major component in all lifeforms, which includes everything from a human being to green algae. In fact, after calcium, phosphorus is the second most abundant mineral in the human body. Phosphorus can also be found in inorganic forms like in rocks. Therefore, as the name says, total phosphorus is the measurement of how much of all types of phosphorus (both organic and inorganic) are within the water, and is measured in milligrams per liter (mg/L). **Low TP concentrations that provide a balanced environment for aquatic wildlife are desired.**



The main concern regarding inland lakes and phosphorus is that if there is too much phosphorus within the water, **it can lead to excess algal and plant growth**. Excess algal growth can lead to reduced dissolved oxygen, reduced clarity, unpleasant odors/discolored water, and many more undesirable water quality issues. Excess aquatic plant growth can be an issue for motor boats, as propellers can get caught up in it. Phosphorus causes such a large impact on plant and algal growth because it is the limiting nutrient for plant and algal growth **(see limiting nutrient explanation below)**.



CRITERIA FOR COMPARISON: Michigan does not have defined water quality standards for inland lakes, but is in the process of creating them. However, Wisconsin and Illinois both have water quality standards for total phosphorus:

- Wisconsin standard for drainage, stratified lakes: **0.030 mg/L**
- Illinois standard for a reservoir or lake with a surface area of >20 acres: **0.050 mg/L**

WHAT IS A LIMITING NUTRIENT? A limiting nutrient can be explained like this:
A s'more is made up of three components: chocolate, graham crackers, and a marshmallow. Say that you have a plethora of chocolate and graham crackers and only four marshmallows. This means that you can only make four complete s'mores even though you have all the chocolate and grahams in the world. However, say your friend shows up with a new bag of marshmallows. Now you can make a bunch of s'mores where before you could only make four. The marshmallows were the controlling factor on how much of your final product was being made. Bringing this back to algae, think about the algae as the s'more; it is the final product. There are a lot of "ingredients" that go into algae production, but two particular ingredients, Nitrogen and Phosphorus, can control if you only have a little algae or a lot of algae. Often, phosphorus tends to be the marshmallow in this situation because there is usually more nitrogen available than phosphorus. So, when more phosphorus is introduced into the aquatic environment, there tends to be more algae growth.

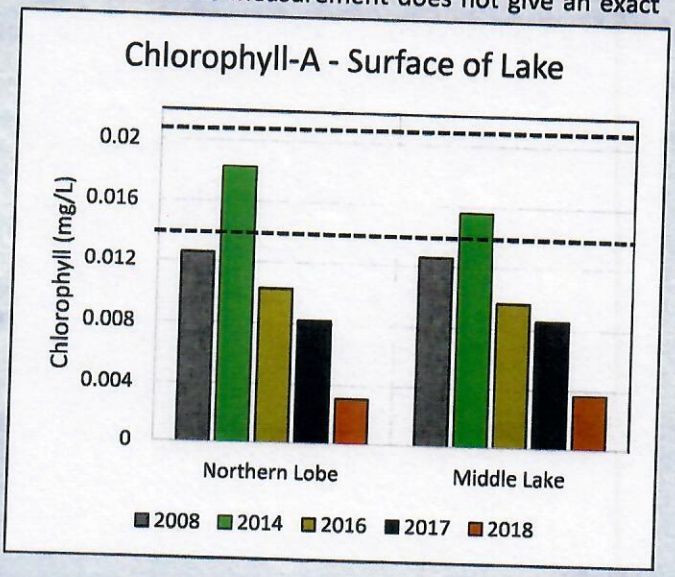
TOTAL PHOSPHORUS (TP), CONTINUED

WHY DOES IT INCREASE AND DECREASE? –

- **Increase in Total Phosphorus** – An increase in total phosphorus may be due to an increase of external inputs of TP into the lake from lawns, soil erosion, or runoff from tributary drains. Additionally, phosphorus can be released from bottom sediments if dissolved oxygen is very low near the surface of the sediment and when temperature is elevated.
- **Decrease in Total Phosphorus** – A decrease in TP can be due to the reduction in runoff and other external sources of TP. TP can also be reduced when dissolved oxygen levels are higher, and temperatures are lower near the surface of bottom sediment.
- **During 2018, TP levels dropped significantly from 2017.** Since zebra mussels have increased in population over the last two years, it is likely that they had influence in the reduction. When they filter feed, certain types of algae are removed, which uptake nutrients like phosphorus. Therefore, when they consume algae, they remove phosphorus from the water column and use it to build their bodies or eventually excrete it as waste.

CHLOROPHYLL-A

Chlorophyll-A is used as a measurement to determine the **relative amount of algal presence** within the water and is measured in milligrams per liter (mg/L). While this measurement does not give an exact concentration of how many algal cells are present within the water, it does serve as an indication of how much is in the water. Ideally, **chlorophyll-A concentration should be low enough to provide balance in the aquatic ecosystem.**



CRITERIA FOR COMPARISON: Michigan does not currently have a water quality standard for chlorophyll-A. However, the state of Minnesota does have water quality standards for a variety of waterways:

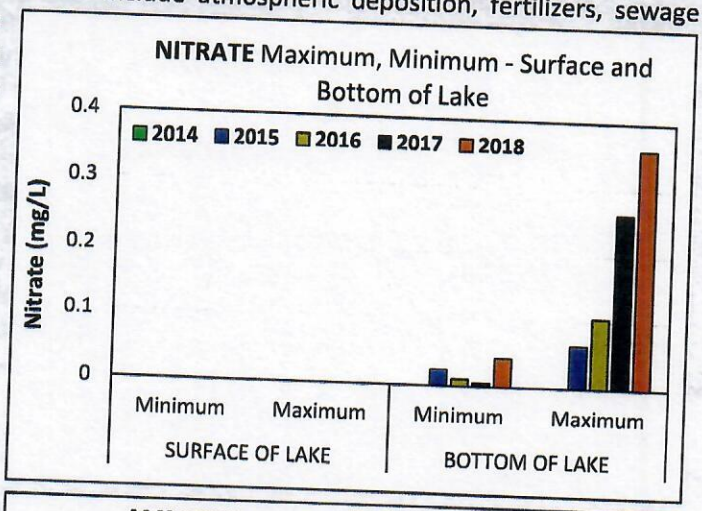
- Lakes and reservoirs in North Central Hardwood Forest Ecoregion: **0.014 mg/L**
- Lakes and reservoirs in Western Corn Belt Plains and Northern Glaciated Plains Ecoregions: **0.022 mg/L**

WHY DOES IT INCREASE AND DECREASE? –

- **Chlorophyll-A increases and decreases** based off of how much phytoplankton and algae are present in the water column. If chlorophyll-A is higher, there is likely more phytoplankton and algae, and if it is lower, there is less.
- **The drop in Chlorophyll-A during 2018 is likely due to increased filtration by zebra mussels and the reduction in phosphorus in the water.** This phosphorus reduction will lower the ecosystems productivity, resulting in decreased algal growth.

NITRATE AND AMMONIA

Nitrogen may be found in many forms in the environment. Nitrogen is used in agriculture to improve yield of a crop, and excess nitrogen may runoff through tile drainage or sheet flow. Other ways that nitrogen may be introduced to the environment include atmospheric deposition, fertilizers, sewage effluent, and the breakdown of organic materials. Nitrate (NO_3^-) and ammonia (NH_4^+) are two components that have been monitored on Paw Paw Lake. Both components are important parts of the nitrogen cycle that happens naturally; however, too much nitrogen can cause the over growth of algae and aquatic plants, and too much nitrate may result in harmful effects to humans. Excess exposure to nitrate in drinking water may cause the restriction of oxygen transport in the bloodstream in infants and young livestock.

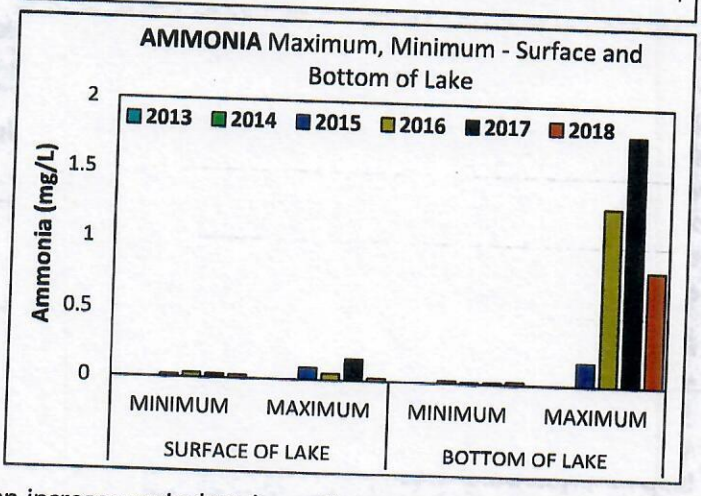


CRITERIA FOR COMPARISON:

The State of Michigan does have Part 4, Rule 57 Water Quality Criteria for both nitrate and ammonia. Criteria for ammonia are as follows, nitrate's water quality criteria is for drinking water and is therefore not listed:

Ammonia –

Final Chronic Value: **0.053 mg/L,** Aquatic Maximum Value: **0.210 mg/L,** Final Acute Value: **0.420 mg/L**



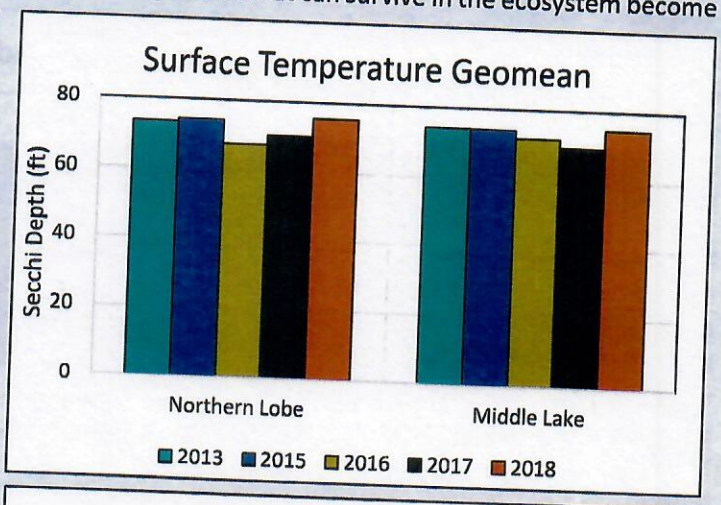
WHY DOES IT INCREASE AND DECREASE?

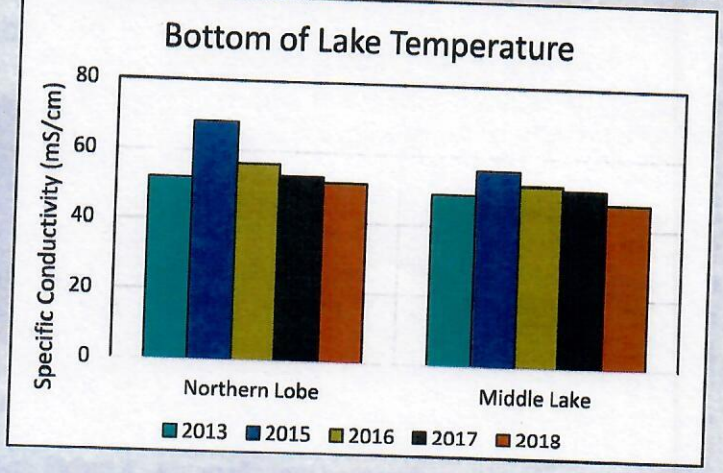
Nitrate and ammonia may increase due to an increase agricultural runoff, atmospheric deposition, and organic material breakdown. Concentrations of ammonia and nitrate in water may decrease due to uptake by various living organisms, reduction of nitrate and ammonia input to surface water, and release to the atmosphere via denitrification. The following are observed nitrate and ammonia trends on Paw Paw Lake:

- Nitrate was not detected in surface samples in 2014, 2015, and 2018 and had minimal detection in 2016 and 2017. Nitrate detected in bottom of the lake samples primarily during mid-summer
- Ammonia was not detected in surface samples during 2013 and 2014, and was in 69.4%, 8.3%, 32.4%, and 12.5% of samples in 2015, 2016, 2017, and 2018, respectively.
- Ammonia samples were not collected in the bottom of the lake during 2013 and 2014, but was in 97.2%, 90%, 44.4%, and 79.2% of samples collected during 2015, 2016, 2017, and 2018, respectively.
- The range of measured nitrate and ammonia concentrations are in the figure associated with this section.

TEMPERATURE

Water temperature in a lake can greatly impact its water quality, biological activity, and growth. Temperature controls which organisms can survive in the waterbody. If a waterbody increases or decreases in temperature too greatly, the number of organisms that can survive in the ecosystem become less diverse. Additionally, warmer water holds less dissolved oxygen, a component which is critical to the survival of aquatic species, and cooler water holds more dissolved oxygen.





CRITERIA FOR COMPARISON: The State of Michigan has the following water quality standards for temperature in inland lakes, according to MDEQ Part 4 Water Quality Standards (R 323.1072, Rule 72): Inland lakes shall not receive a heat load which would:

- Increase the temperature of the thermocline or hypolimnion or decrease the volume thereof.
- Increase the temperature of the receiving waters at the edge of the mixing zone more than 3 degrees Fahrenheit above the existing natural water temperature.
- Increase the temperature of the receiving waters at the edge of the mixing zone to temperatures greater than the following monthly maximum temperatures:

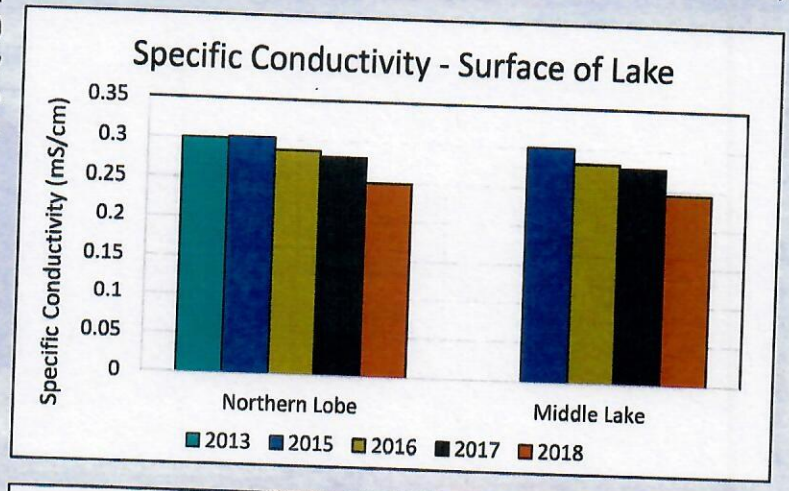
JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
45	45	50	60	70	75	80	85	80	70	60	50

WHY DOES IT INCREASE AND DECREASE? –

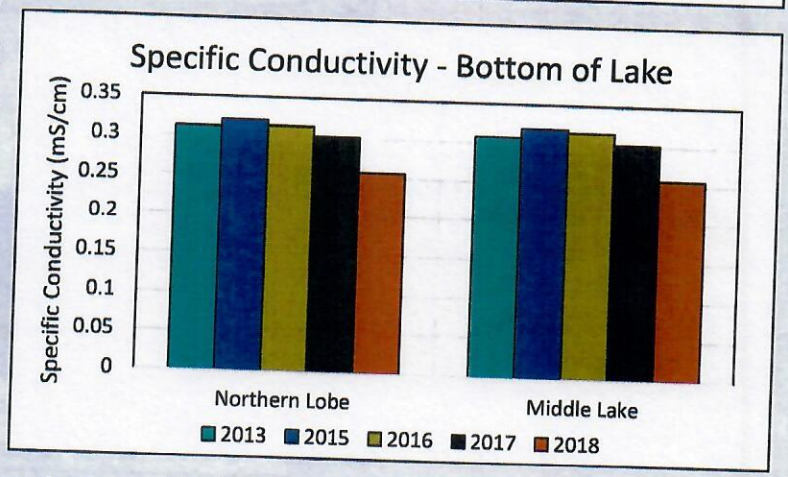
- Temperature will increase if there is an increase in impervious surfaces (pavement, roadways, roofs) in the watershed. These surfaces increase in temperature when the sun warms them, and when it rains, the stormwater absorbs the heat from these surfaces, and flows into a lake, river, or stream, thus elevating the temperature. Temperature will also increase if there is a higher concentration of suspended solids. These solids absorb energy from sunlight, thus increasing the temperature of the waterbody that they are suspended in.
- Temperature in waterbodies naturally increase and decrease seasonally as atmospheric temperatures increase and decrease.

SPECIFIC CONDUCTIVITY

Conductivity is a measure of the ability of water to pass an electrical current. Conductivity will increase or decrease depending on the quantity of positively or negatively charged ions (chloride, nitrate, sulfate, phosphate, sodium, magnesium calcium, iron, aluminum, etc.) dissolved in the water. Conductivity is also temperature-dependent, so specific conductivity corrects the conductivity measurement to 25°C.



In Paw Paw Lake, specific conductivity tends to be higher in the bottom of the lake and lower at the surface of the lake. This may be attributed to the breakdown of bottomland sediment and detritus. Specific conductivity at the lake's bottom has also remained relatively consistent the past five years, where the concentration at the surface has seen a 17 – 19% reduction in concentration.



CRITERIA FOR COMPARISON:

For inland lakes in the State of Michigan, there is not a set water quality standard for specific conductivity.

A good rule of thumb is that the higher in concentration specific conductivity is, the more dissolved ions there are. A higher concentration doesn't necessarily mean that the water quality is poor, and a low concentration doesn't mean that the lake is healthy. Just like temperature, the lake needs the right balance of ion concentrations to maintain its health.

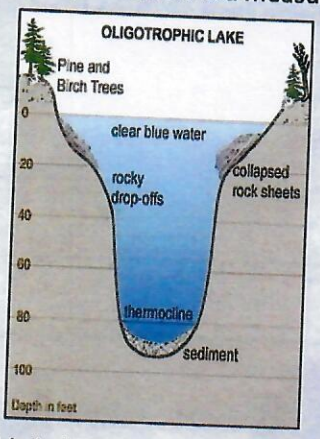
WHY DOES IT INCREASE AND DECREASE? –

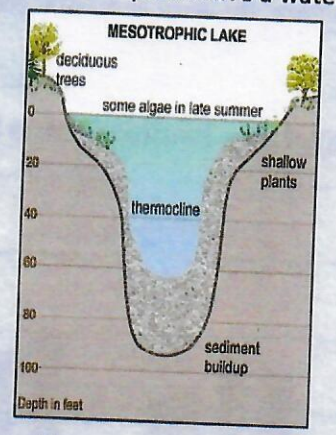
Specific conductivity is impacted by geology of the area. For example, lakes with a large amount of limestone in the surrounding area will have a higher specific conductivity due to dissolved carbonate ions. Specific conductivity will also increase if the watershed is larger, as there is more land surface area that is being drained and contributing ions to the runoff water that feeds the lake. Pollutants such as fertilizers, pesticides, road salts, and wastewater from septic fields will increase specific conductivity.

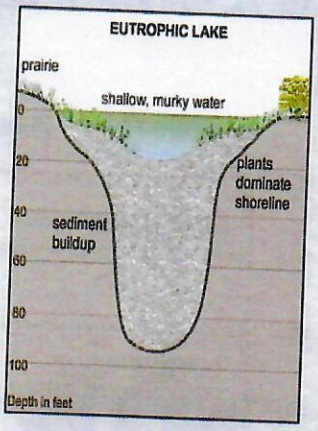
Specific conductivity will be reduced if pollutant inputs to the lake are reduced and evaporation is minimized, among other pathways.

TROPHIC STATUS INDEX (TSI)

Overall, Paw Paw Lake exhibits water quality characteristics typical of developed, inland lakes in lower Michigan. According to its 2018 trophic state index, Paw Paw Lake classifies as a mesotrophic lake. The trophic status of Paw Paw Lake has decreased from last year, which had an average TSI of 50.8, classifying the lake as mesotrophic to eutrophic. The calculations used to determine the trophic status of Paw Paw Lake take chlorophyll-A, Secchi depth, and total phosphorus measurements into consideration. In general, trophic status is a measurement of how productive a water body is.





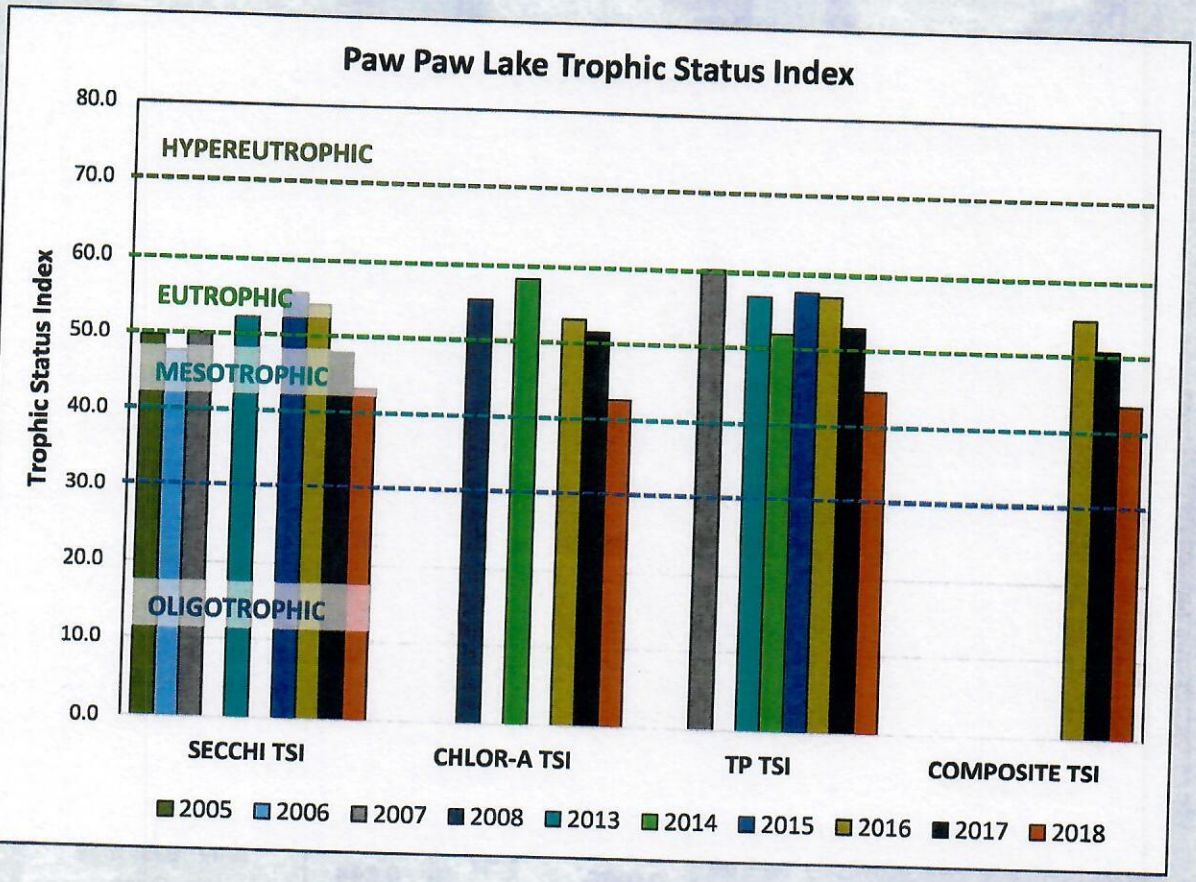


The table below summarizes levels of trophic statuses and their environmental and ecological conditions:

TROPHIC STATUS	TSI	CHLOR-A (MG/L)	SECCHI (FT)	TP (MG/L)	FISHERIES AND RECREATION
Oligotrophy – Clear water, oxygen throughout the year in bottom of lake.	<30	<0.00095	>26	<0.006	Salmonid fisheries dominate.
Bottom of shallower lakes may become oxygen depleted.	30 – 40	0.00095 – 0.0026	13 – 26	0.006 – 0.012	Salmonid fisheries in deep lakes only.
Mesotrophy – Water moderately clear; increasing chance of reduced dissolved oxygen in bottom of lake.	40 – 50	0.0026 – 0.0073	7 – 13	0.012 – 0.024	Hypolimnetic anoxia results in loss of salmonids. Walleye may predominate.
Eutrophy – Anoxic hypolimnia, excess plant and algal growth possible.	50 – 60	0.0073 – 0.0200	3 – 7	0.024 – 0.048	Warm-water fisheries only. Bass may dominate.
Blue-green algae dominate, algal scums and aquatic plant problems.	60 – 70	0.0200 – 0.0560	1.6 – 3	0.048 – 0.096	Nuisance plants, algae, and low transparency may discourage recreation.
Hypereutrophy – Light limited productivity. Dense algae and aquatic plants.	70 – 80	0.0560 – 0.1550	0.8 – 1.6	0.096 – 0.192	-
Algal scums, few aquatic plants.	>80	>0.1550	<0.8	0.192 – 0.384	Rough fish dominate; summer fish kills possible.

TROPHIC STATUS INDEX, CONTINUED:

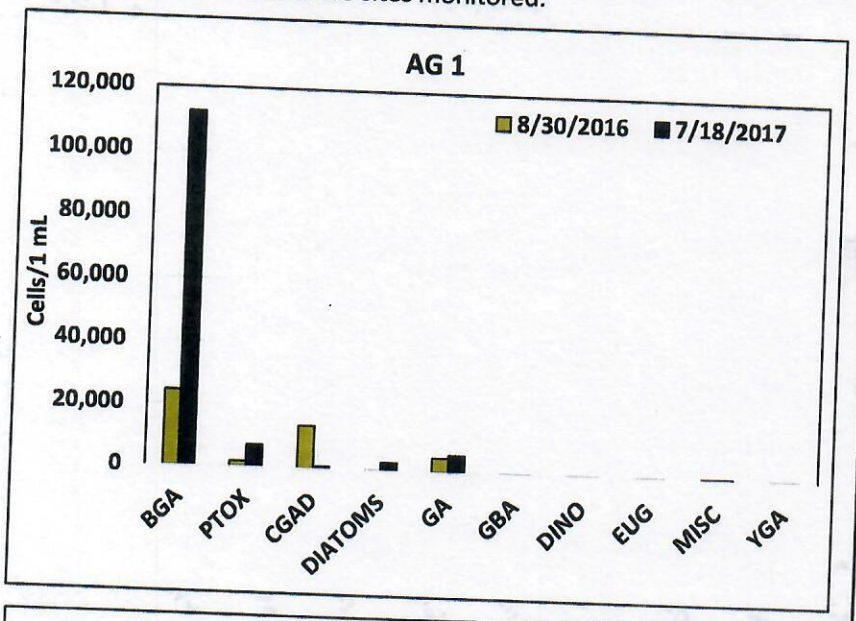
In the past three years, Paw Paw Lake's Trophic Status Index has shifted towards mesotrophy, meaning that there are less nutrients available for plant and animal uptake, making the lake less productive. The "older" a lake gets, the more eutrophic it becomes, and the more algae, aquatic plants, and productive it becomes. A lake that is extremely eutrophic, or hypereutrophic, will have excessive nutrients, minimal clarity, and will not be conducive for a variety of recreational activities. The figure below shows Paw Paw Lake's TSI over time based on Secchi depth, chlorophyll-A, total phosphorus, and all three components (titled "Composite TSI").

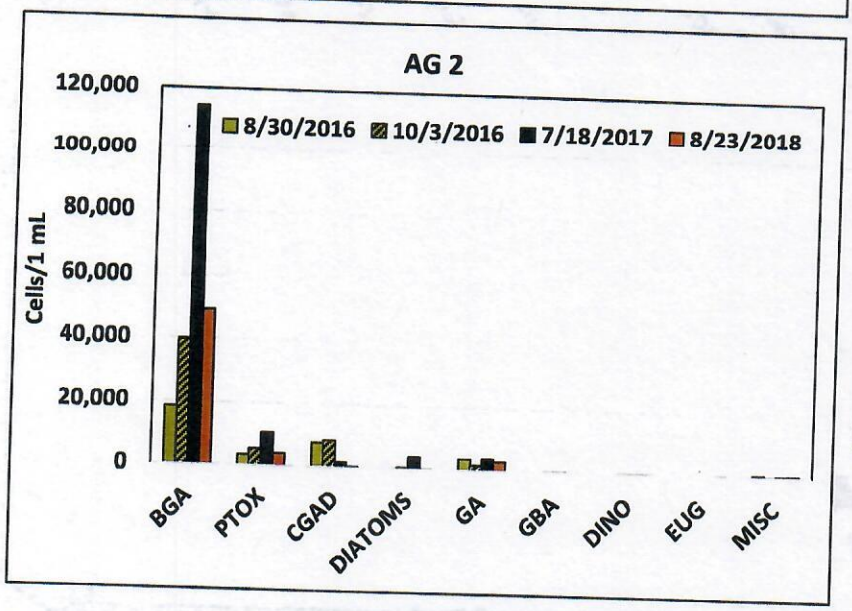


ALGAE MONITORING

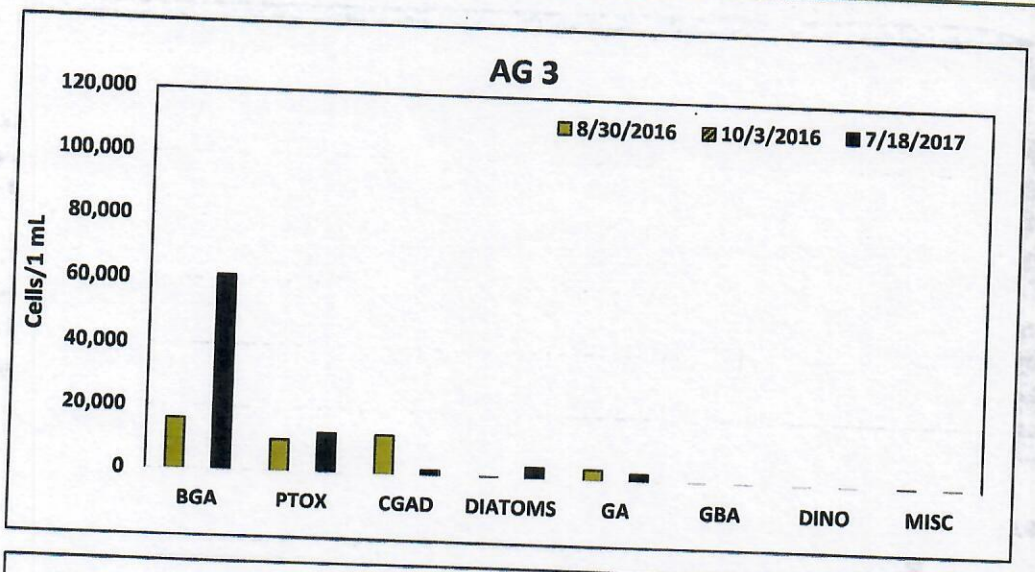
In recent years (2016 – 2018), algal population has been monitored on Paw Paw Lake. The dominant algal species for all sample locations on the lake is blue-green algae. A sub-set of blue-green algae are potentially toxigenic cyanobacteria, which have the potential to produce toxins. It is important to note that most blue-green algae do not produce toxins.

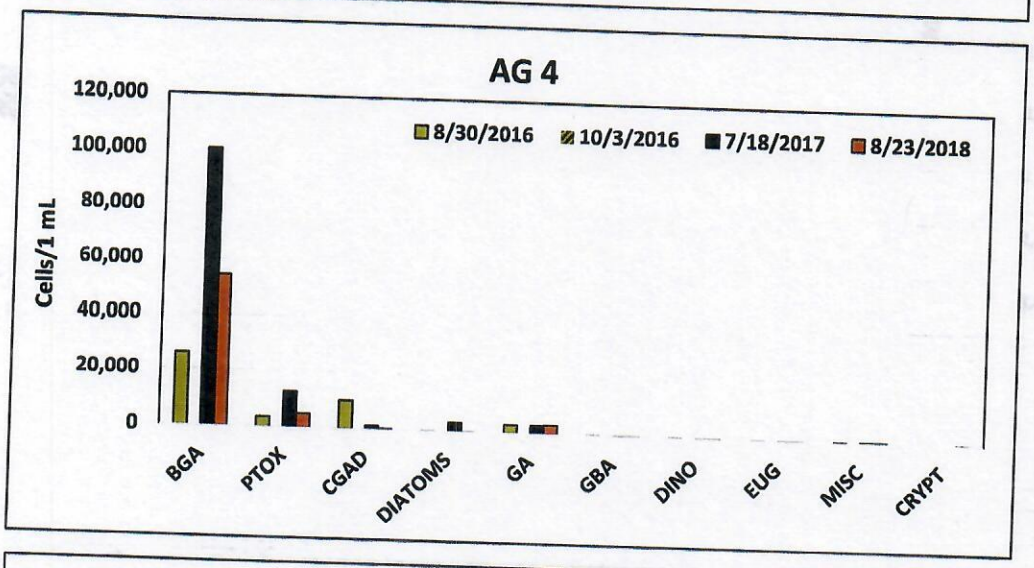
Between 2016 and 2017, the conjugated green algae and desmid population was significantly decreased and the blue-green algae population increased. Between 2017 and 2018 both blue-green algae population and potentially toxigenic cyanobacteria population decreased, and green algae population increased at two of the three sites monitored.

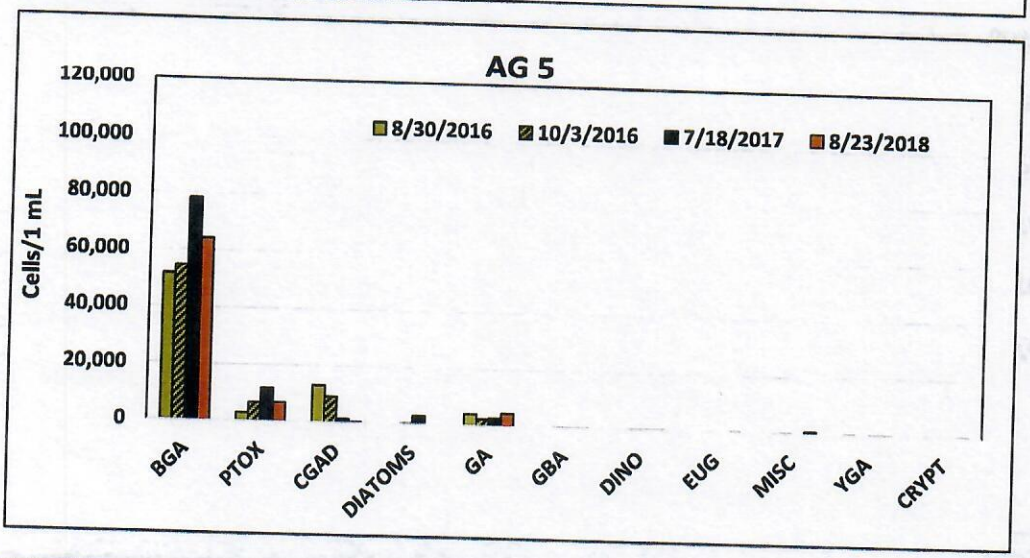




KEY	
BGA	Blue-Green Algae
PTOX	PTOX Cyanobacteria
CGAD	Conjugating Green Algae and Desmids
DIATOMS	Diatoms
GA	Green Algae
GBA	Golden-Brown Algae
DINO	Dinoflagellates
EUG	Euglenophytes
MISC	Miscellaneous
YGA	Yellow-Green Algae
CRYPT	Cryptophytes


AG 3
120,000
100,000
80,000
60,000
40,000
20,000
0
Cells/1 mL
8/30/2016
10/3/2016
7/18/2017
BGA
PTOX
CGAD
DIATOMS
GA
GBA
DINO
MISC


AG 4
120,000
100,000
80,000
60,000
40,000
20,000
0
Cells/1 mL
8/30/2016
10/3/2016
7/18/2017
8/23/2018
BGA
PTOX
CGAD
DIATOMS
GA
GBA
DINO
EUG
MISC
CRYPT


AG 5
120,000
100,000
80,000
60,000
40,000
20,000
0
Cells/1 mL
8/30/2016
10/3/2016
7/18/2017
8/23/2018
BGA
PTOX
CGAD
DIATOMS
GA
GBA
DINO
EUG
MISC
YGA
CRYPT