Phytoplankton and Zooplankton
2019 Report

Lake Rippowam, Lake Oscaleta, & Lake Waccabuc

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Table of Contents

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Phytoplankton and Zooplankton Report

Lake Rippowam, Lake Oscaleta, & Lake Waccabuc

Introduction

The Three Lakes Council maintains an outstanding water quality monitoring program to properly manage its three lakes: Lake Waccabuc, Lake Oscaleta and Lake Rippowam. This includes conducting the CSLAP Water Quality Monitoring Program with assistance from the New York State Department of Environmental Conservation (NYSDEC) and the New York State Federation of Lake Associations (NYSFOLA), as well as further water quality testing beyond these programs. This data is reviewed and used to maintain the lakes as a natural resource for the community for recreation and aesthetic value. SOLitude Lake Management was pleased to provide services to the Three Lakes Council again in 2019. Phytoplankton and zooplankton samples for each of the three lakes were collected by the client on July 30th, 2019.

Phytoplankton Monitoring

Methodology

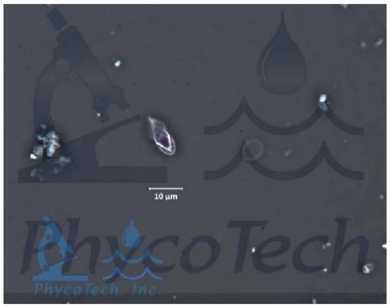
Phytoplankton samples were collected once in 2019. The sampling date aligned with the sampling events conducted in previous years in order to easily compare the data. The same historical sample sites were utilized and were established at the regular CSLAP sampling stations on all three lakes. Three Lakes Council (3LC) volunteers collected a single sample from each basin on July 30, 2019 and delivered them to SOLitude Lake Management (SLM) staff for laboratory analysis.

Phytoplankton samples were collected at a depth of 1.5 meters at each station using clean 1,000 mL HDPE or Nalgene plastic bottles. Immediately following collection, the bottles were placed in a dark cooler stocked with ice to chill the sample. The samples were returned to SOLitude Lake Management's laboratory for analysis within 24 hours. If the sample could not be examined within 24 hours, it was preserved using 0.5 mL of an iodine solution. A sub-sample was sand filtered and microscopically examined at 100X magnification using a compound microscope. Using regionally appropriate taxonomic keys, the phytoplankton was identified to genus level and enumerated. The results for each lake are discussed below and associated examination data is included in the appendix of this report. Further descriptions of the phytoplankton groups observed can also be found in the appendix along with full-sized versions of the abundance and distribution graphs and pie charts.

2019 Phytoplankton Results

Table 1: 2019 Phytoplankton Distribution						
Phytoplankton Group	**Lake Rippowam**		**Lake Oscaleta**		**Lake Waccabuc**	
	Org./mL	%	Org./mL	%	Org./mL	%
Diatoms	40	2.1%	30	6.3%	**70**	**46.6%**
Golden Algae	10	0.5%	50	10.3%		
Green Algae	880	47.1%	10	2.1%	20	13.3%
Blue-green Algae	**930**	**49.7%**	**380**	**79.2%**	60	40.0%
Euglenoids						
Protozoa						
Dinoflagellates	10	0.5%	10	2.1%		
Total Organisms	**1,870**	**100%**	**480**	**100%**	**150**	**100%**

In 2019, the phytoplankton distribution at Lake Rippowam was again the most diverse out of the three lakes. There were seven different genera observed, spread out over five phytoplankton groups. Phytoplankton density was considered high at 1,870 organisms/mL and was the highest overall abundance of the three lakes. This is typical for this site according to historical data. The only phytoplankton groups that were not represented this year were euglenoids and protozoa in the assemblage at Lake Rippowam. The most abundant group of phytoplankton observed was nuisance blue-green algae (49.7%), which was 100% the genus *Anabaena* (pictured) at 930 organisms/mL. Although blue-green algae were the dominant group represented, green algae accounted for a significant 47.1% of the total phytoplankton. One genus of green algae, *Ulothrix*, accounted for 880 organisms per mL. Trace amounts of diatoms, golden algae and dinoflagellates rounded out the assemblage at this site in late July. Water clarity at Lake Rippowam measured 1.90 meters, which is similar to the previous year's clarity, and typical for this site. It was the lowest of the three sites sampled on this date, which would be supported by the higher phytoplankton abundance. It should be stated, however, that a water clarity near 2.0 m is suitable for this site in late July.



In 2019 at Lake Oscaleta, the overall phytoplankton abundance was considered low to moderate with a total of 480 organisms/mL. Diversity was moderate as six different genera were recorded from five phytoplankton groups. All phytoplankton groups were represented except for protozoa and euglenoids. The phytoplankton group with the highest abundance was blue-green algae, consisting of 79.2% of the assemblage. All blue-green algae were represented by *Anabaena* (pictured above). Although the assemblage was dominated by nuisance blue-green algae (and a potential toxin-producer), overall abundance was non-problematic at the time of sampling (July). All other groups were trace abundance. *Mallomonas*, a golden alga (pictured to the left), was the second most dominant genus, yet only occurred at 50 organisms per mL. Water clarity at Lake Oscaleta was measured at 2.05 meters, which is considered good, considering it was late July. Typically, in mid-summer, phytoplankton densities are the highest of the growing season, which can negatively impact water clarity.

At Lake Waccabuc, phytoplankton density was the lowest of the Three Lakes in 2019. Phytoplankton density was considered low at 150 organisms/mL. Only three different groups were observed: diatoms, green algae, and blue-green algae. Overall sample diversity was low at five genera, with two each in the green algae and blue-green algae groups. The most abundant phytoplankton group was diatoms consisting of 46.6% of the assemblage (at 70 organisms/mL). Lake Waccabuc had the lowest abundance of blue-green algae, and was the only site not dominated by the nuisance group on this sampling date. *Synedra*, a ubiquitous diatom (pictured to the right), was the most common genus observed on this sampling date. A trace amount of green algae rounded out the assemblage. Water clarity at Lake Waccabuc was measured at 2.75 meters, which is considered very good, considering this lake is prone to summer phytoplankton blooms, and the sampling occurred in late July.

Phytoplankton Discussion 2013-2019

The 2019 season was the tenth season SOLitude Lake Management (formerly Allied Biological, Inc.) monitored phytoplankton at the Lake Rippowam, Lake Oscaleta, and Lake Waccabuc. The three graphs below, one for each basin, compare the phytoplankton results from 2013 through 2019. Since all samples were collected around the same time of year, utilizing the same sampling station and procedures, it should represent a consistent comparison. Full-sized versions of all three phytoplankton graphs can be found in the appendix, as well as 2019 distribution pie charts and microscopic examination data for each respective sampling location.

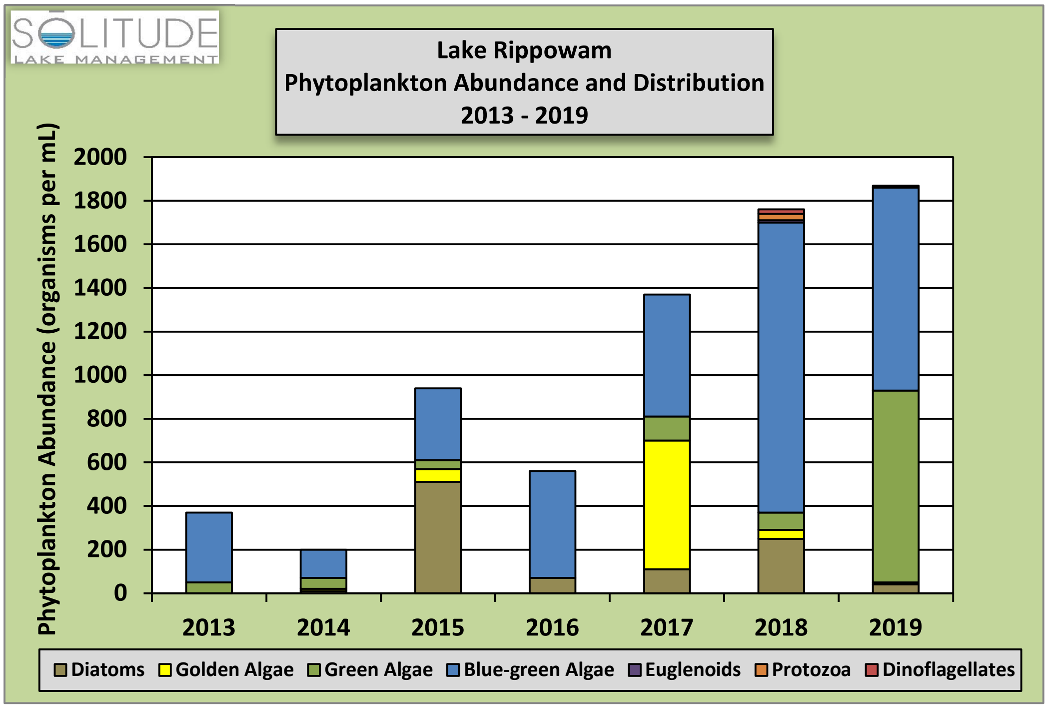


Figure 1. 2013-2019 Lake Rippowam Phytoplankton

At Lake Rippowam, phytoplankton abundance and distribution varied greatly over the years. Overall phytoplankton abundance appears to be on an increasing trend since it was lowest in 2013 and 2014 and highest in 2017 through 2019. Total phytoplankton was considered low in 2013 and 2014, moderate in 2015 and 2016, and high from 2017 through 2019. Blue-green algae is typically the dominant phytoplankton at this site, as only in 2015 (diatoms) and 2017 (golden algae) was another group dominant. Although the 2015 and 2017 assemblages were not dominated by blue-green algae, the amount present was still significant. The highest amount of blue-green algae observed at Lake Rippowam was in 2018 at 1,330 organisms/mL. In 2019, total phytoplankton was slightly higher than 2018. Although blue-green algae dominated, its overall amount decreased, as beneficial green algae displayed a significant increase this year. Previously, we have never observed such high amounts of green algae at this lake, which is encouraging. However, phytoplankton abundance and group composition is temporal.

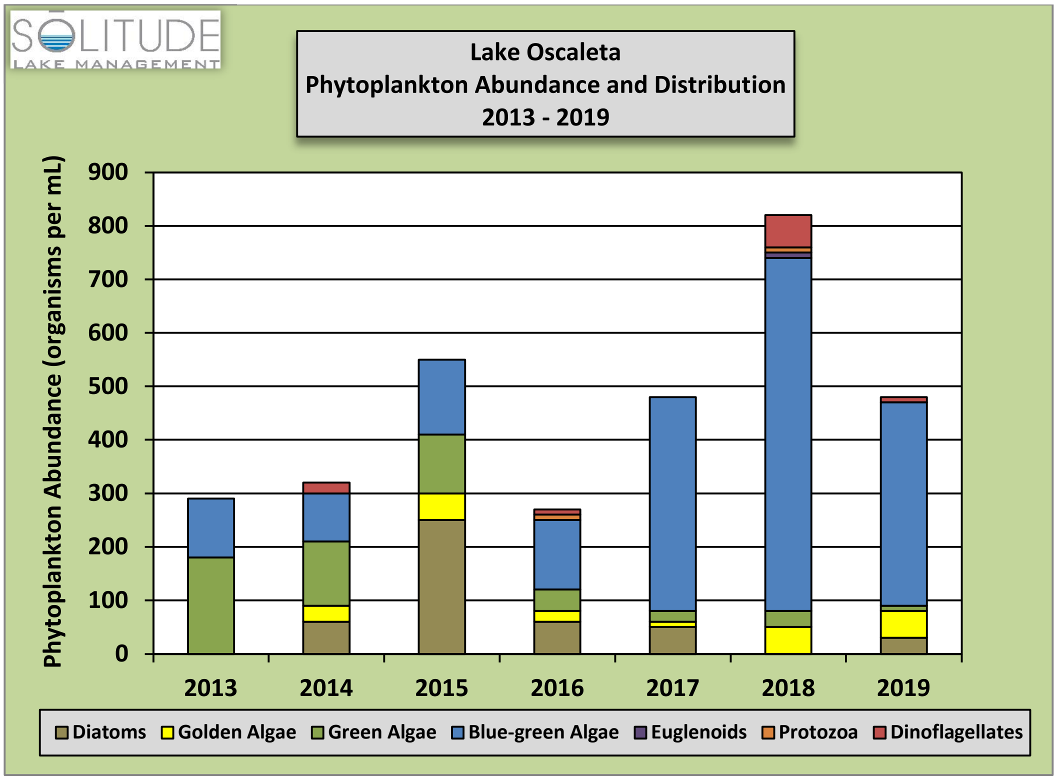


Figure 2. 2013-2019 Lake Oscaleta Phytoplankton

At Lake Oscaleta, overall phytoplankton increased from 2013 to 2015 before a steep decline in 2016, most likely due to seasonal variations and temperature fluctuations. Following 2016, the phytoplankton population has been consistently increasing, especially blue-green algae. Group dominance prior to 2016 mainly consisted of diatoms and green algae, but within the last four years blue-green algae has taken over the assemblage. The highest amount of blue-green algae was recorded in 2018 at 660 organisms/mL. This was also the first year on record that any genera of euglenoids were observed. Diatoms were present every sampling event except 2013 and 2018. Diatoms dominated the 2015 sample, which also had the second highest amount of overall phytoplankton abundance out of all seven years. Although 2015 had the second highest overall, 2017 had the second highest amount of blue-green algae with 400 organisms/mL. The blue-green algae population in Lake Oscaleta is consistently increasing, especially within the last four years. This was the case for 2019 as well, as blue-green algae accounted for nearly 80% of the total phytoplankton this year. We did see a significant decrease in overall abundance from 2018 to 2019. The 2019 abundance (low-moderate) seems to be consistent with results most previous years. Its possible that 2018 was a high phytoplankton year at the Three Lakes. This data is somewhat supported at the other two sites. The trend in blue-green algae dominance at this site needs to be closely followed as it could indicate a shift in the phytoplankton community. That said, we are examining a very limited dataset (one sampling event per year) and perhaps other indicators (chlorophyll *a* or phycocyanin data), if sampled more regularly, might be a better indicator.

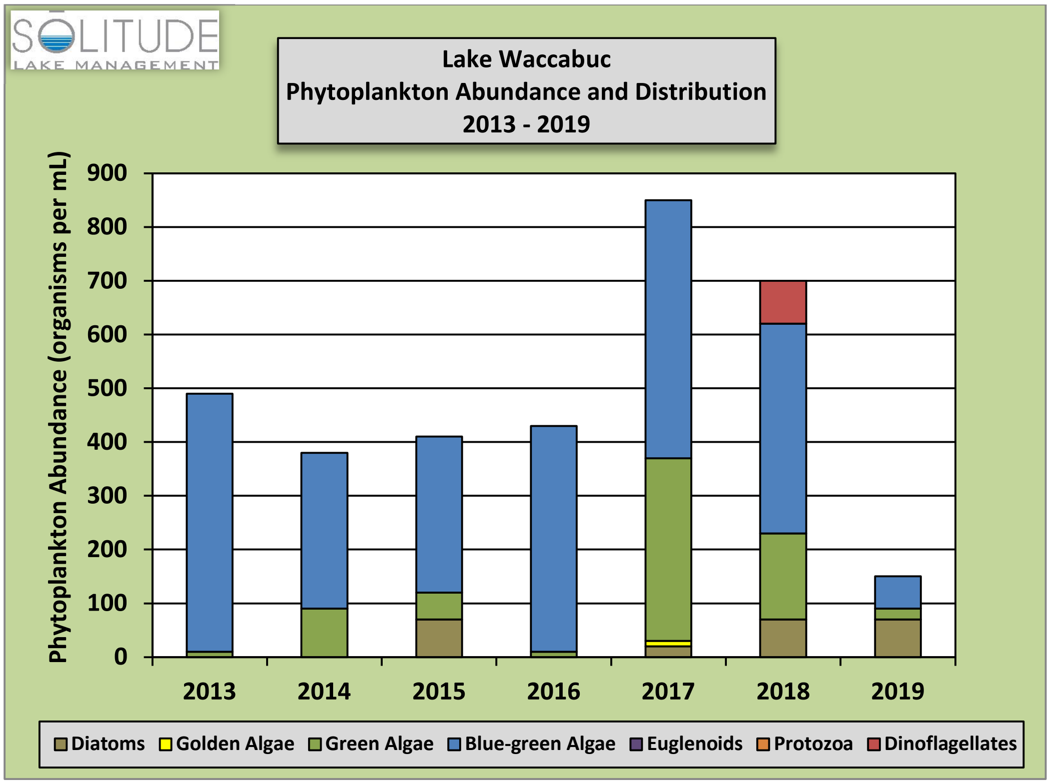


Figure 3. 2013-2019 Lake Waccabuc Phytoplankton

Based on the data in Figure 3, Lake Waccabuc contains the most consistent blue-green algae population over the past six years. Over 50% of each assemblage from the previous six years consisted of various genera of blue-green algae. In 2019, blue-green algae accounted for 40% of the assemblage. Similar to Lake Rippowam and Oscaleta, 2017 and 2018 data displays the highest amounts of total phytoplankton, specifically blue-green algae, at Lake Waccabuc. All three lakes show overall increases in phytoplankton populations overtime. Lake Waccabuc, while not having the highest amount of blue-green algae in 2018, has held the most consistent and stable population compared to the other two basins. In 2017, we observed a significant increase in green algae genera, competing with the blue-green population. This basin contains the least diverse phytoplankton community of the three lakes. The high abundances of blue-green algae are most likely outcompeting the other algal groups in combination with seasonal variation. It is typical during the warmer months to experience an increased abundance of blue-green algae. In 2019, we observed a significant decrease in overall phytoplankton and blue-green algae abundance. This was the lowest overall phytoplankton among the seven-year dataset. This year could be the outlier of the dataset. Its also interesting to note that technically blue-green algae were not dominant in 2019 (diatoms were, although it was close to a 50:50 ratio).

Zooplankton Monitoring

Methodology

Zooplankton samples were collected, by the client, with an 80 µm Nitex plankton net. At Lake Waccabuc and Lake Oscaleta, a single vertical tow was performed to a depth of 18 feet. At Lake Rippowam, two 9-foot vertical tows were composited into a single sample due to the water depth at the sampling station. Using as little site water as possible, the sides of the net were rinsed of any trapped zooplankton, concentrating the organisms into the net bottom. This concentrate was then emptied into a clean 1,000 mL HDPE sample bottle. Immediately after collection, the sample was preserved with an equal amount of 10% sucrose formalin, to achieve a 5% solution. Sucrose was added to the preservative to help maintain carapace integrity. The samples were then placed in a cooler stocked with blue ice. On arrival at SOLitude Lake Management's laboratory, the samples were stored in a dark refrigerator until being identified and enumerated.

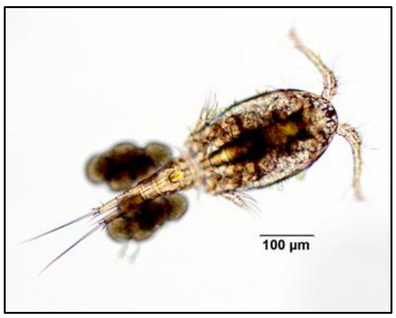
In the laboratory, each sample was manually mixed for about one minute, before a one mL subsample was removed using a calibrated syringe. The subsample was placed on a Sedgewick-Rafter counting cell and examined under a compound microscope at 100X magnification. By using calibrated guides on the microscope stage, the entire one mL sample was examined, and any zooplankton were identified and enumerated to the lowest practical taxa using regionally appropriate taxonomic keys. This procedure was repeated two more times to generate a total of three replicate counts. The counts were then averaged, and back-calculated to achieve an organism per liter density. The zooplankton examination data sheets are included in the appendix of this report. Also included in the appendix are descriptions of the zooplankton groups and individual lake distribution pie charts.

2019 Zooplankton Results

Table 2: 2019 Zooplankton Distribution

Zooplankton Group	Lake Rippowam		Lake Oscaleta		Lake Waccabuc	
	Org./L	%	Org./L	%	Org./mL	%
Rotifera	**659**	**52.5%**	150	23.1	664	25.4
Cladocera	189	15.1%	189	29.1	896	34.3
Copepoda	407	32.4%	**310**	**47.8**	**1,051**	**40.3**
Total Organisms	**1,255**	**100%**	**649**	**100%**	**2,611**	**100%**

At Lake Rippowam in 2019, zooplankton abundance was considered high at 1,255 organisms/L. A total of nine different species of zooplankton were observed in the sample. Zooplankton diversity would be considered moderate for this basin. Rotifers dominated the assemblage, accounting for just over 52% of the sample at 659 organisms/L. The most abundant species within the rotifer group was *Conochilus unicornis* with 407 organisms/L (pictured). Four other rotifer species were present, all from differing genera. Copepods were the next most abundant group of zooplankton present in Lake Rippowam, consisting of 32.4% of the assemblage (407 organisms/L). One species of adult copepod was observed: *Microcyclops rubellus* along with naupliar stages of both Cyclopoids and Calanoids. *Microcyclops rubellus* was the dominant copepod observed at 300 organisms/L. Cladocera were the least common group of zooplankton observed with a low abundance of 189 organisms/L (15.1% of the assemblage). Two different species of Cladocera, *Bosmina longirostris* and *Daphnia pulex*, were present at relatively similar amounts. *Bosmina* is a small bodied Cladocera, yet the *Daphnia* observed could be described as moderate-body size. The larger the body size of the Cladocera implies more efficient grazing on phytoplankton, which is desirable. Conversely, larger-bodied Cladocera are more susceptible to be grazed upon by fish (as they are easier to see).



For Lake Oscaleta, the total zooplankton abundance was considered moderate at 659 organisms/L. This is about one third of the total abundance observed at this site in 2018. Zooplankton diversity for this sample was moderate with eight different species recorded. The dominant group of zooplankton, accounting for 47.1% of the assemblage, were copepods with a density of 310 organisms/L. Two different species of copepods were observed in the sample: *Microcyclops rubellus* (by far the most common; pictured to the left) along with naupliar stages of both Cyclopoid and Calanoid copepods. The Cyclopoid nauplii might be juvenile stages of *Microcyclop*s. The next most abundant group of zooplankton was Cladocera with a low abundance of 189 organisms/L although considered to be nearly 30% of the assemblage. Two different Cladocera genera were observed, *Bosmina* and *Daphnia*. Rotifers were the least common group observed on this date, with 150 organisms/L (which accounted for 23.1% of the total zooplankton). Despite this, rotifers had the highest diversity of the three groups, with four different genera. These includes *Keratella*, *Notholca*, *Ascomorpha,* and *Asplanchna*. Lake Oscaleta had the lowest total zooplankton abundance out of the Three Lakes in 2019.

At Lake Waccabuc, total zooplankton abundance was considered high with 2,611 organisms/L. A total of 10 different species were observed in the sample, making the zooplankton diversity moderate-high. Copepods were the dominant zooplankton group this year (1,051 organisms per L, or 40.3%). One adult stage (*Microcyclops rubellus*) was observed along with naupliar stages of both Cyclopoid and Calanoid copepods. An even mixture of *Microcyclops* and Cyclopoid nauplii were observed, with only trace Calanoids. Cladocera abundance was suitable at 896 organisms per L (or 34.3%). Since the dominant genus observed is a moderate-bodied *Daphnia*, one could assume reasonable grazing pressure of phytoplankton populations was likely occurring at the time of the survey. This could be one factor regarding the low phytoplankton abundance on this date, which is unusual for late July at this particular site. Its somewhat unusual, but rotifer abundance was the lowest of the three groups. Rotifers accounted for 664 organisms per L, or 25.4%. Five different rotifer genera were observed. Lake

Waccabuc contained the highest number of zooplankton and highest diversity out of the three lakes.

Zooplankton Discussion 2013-2019

The three graphs below, one for each basin, compare the zooplankton results from the 2013 through 2019 sampling events. Since all samples were collected at about the same time of year, utilizing the same sampling station and procedures, it should represent a consistent comparison. Full-sized versions of all three zooplankton graphs can be found in the appendix along with the examination data and distribution pie charts.

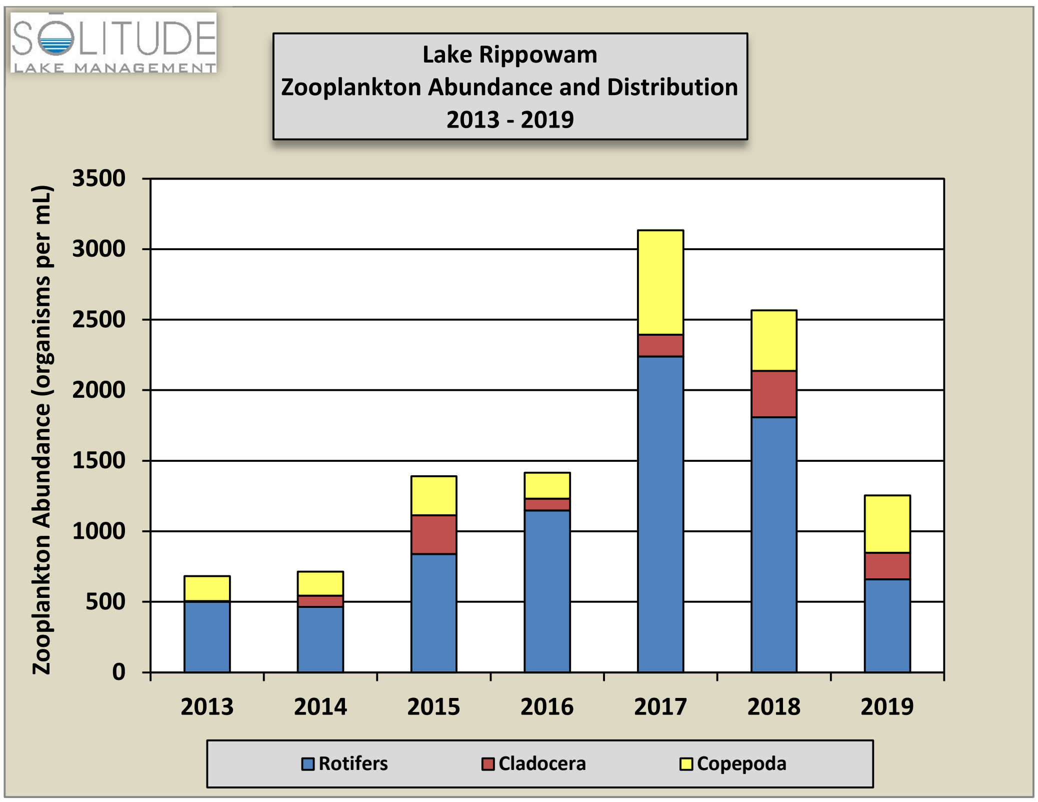


Figure 4. Lake Rippowam Zooplankton 2013-2019

The zooplankton abundance at Lake Rippowam had been consistently increasing since 2013 until 2017/2018. Zooplankton density was considered moderate in 2013 and 2014 with the majority of the assemblage being rotifers. From 2015 to 2018, zooplankton abundance was considered high. In 2019, it was considered high, although it has decreased since 2018. Rotifers have been the dominant zooplankton group every year since 2013. Copepods have continuously been the second most abundant group with the exception of 2015 where the density of copepods and cladocera were equivalent. Total zooplankton abundance reached a high of 3,134 organisms/L in 2017 before slightly decreasing to 2,565 organisms/L in 2018. Copepods and rotifers experienced this decrease, but cladocera increased from 155 organisms/L in 2017 to 330 organisms/L in 2018. Cladocera are a desirable group to have as they are highly effective feeders on phytoplankton populations. Since this lake has the least developed submersed aquatic plant (SAV) community, it could explain the rotifer dominance for all years in this dataset. SAV beds act as refuge for zooplankton, as they can use the cover to evade predaceous fish (such as alewives), which have anecdotally been reported in the Three Lakes).

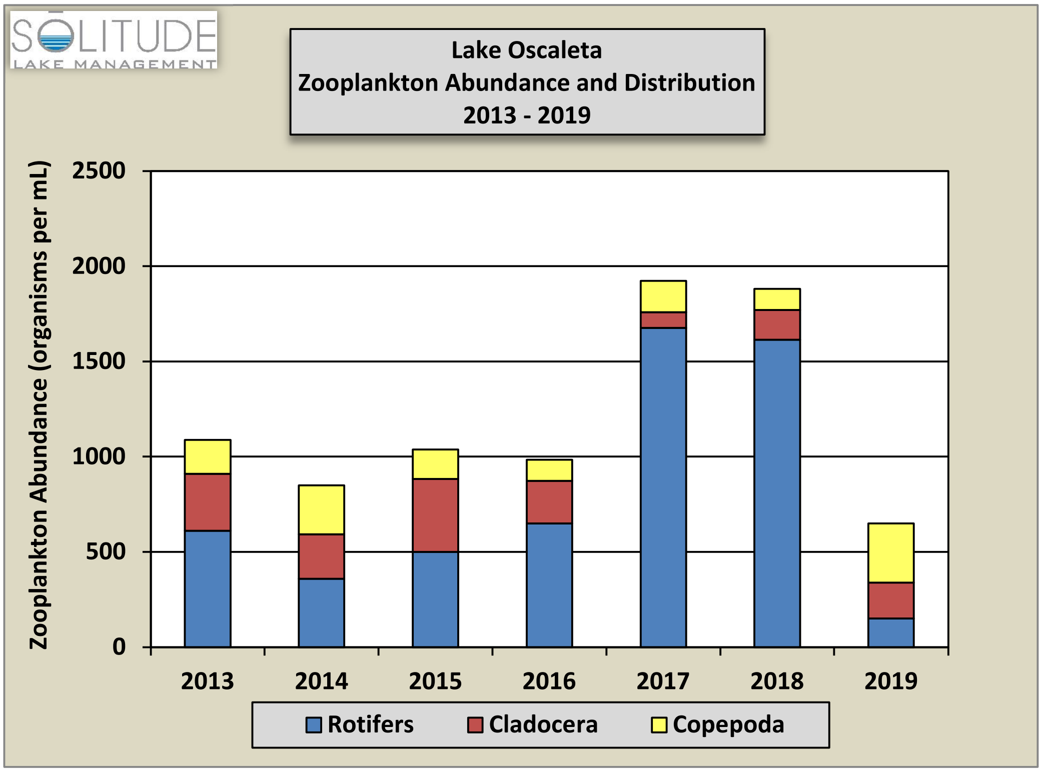


Figure 5. Lake Oscaleta Zooplankton 2013-2019

At Lake Oscaleta, high overall zooplankton results have been observed recently, reaching a high of 1,923 organisms/L in 2017 and 1,880 organisms/L in 2018. But in 2019, we have seen a significant decrease in overall zooplankton abundance. In 2019, overall abundance was considered moderate. It is interesting to note that Copepods dominated in 2019. In addition, Cladocera abundance was greater than rotifer abundance. Zooplankton density was considered moderate in both 2014 and 2016, and high all other years. Greater distribution between the three zooplankton groups are displayed from 2013 to 2016, but in 2017 and 2018 rotifers have dominated the assemblages. Cladocera and copepod densities were very low in 2017 and 2018 while rotifer abundances were high. This trend is very similar to that of Lake Rippowam, where rotifers increased significantly within the past two years. In more recent years, Lake Oscaleta has had the lowest zooplankton abundance out of the three lakes, and 2019 was no exception.

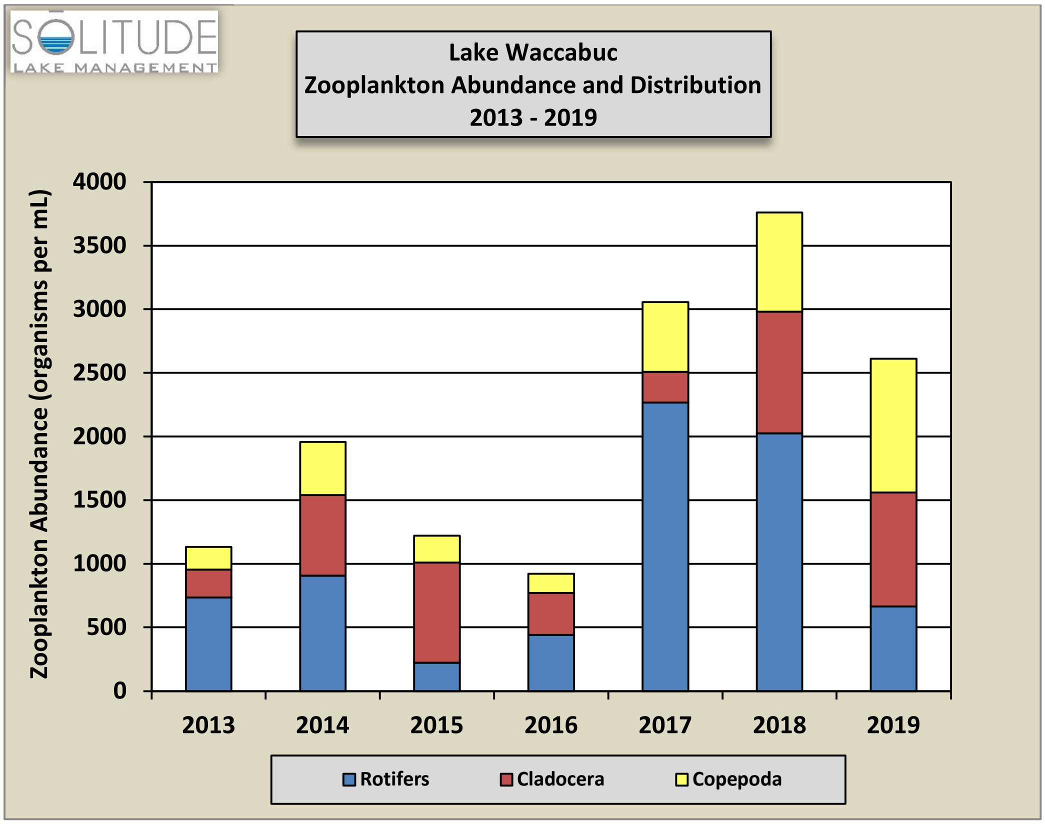


Figure 6. Lake Waccabuc Zooplankton 2013-2019

At Lake Waccabuc, zooplankton distribution has been the most diverse over the years compared to the other two lakes. Cladocera and copepods had increased abundance in comparison to Lake Rippowam and Lake Oscaleta. These two groups outnumbered rotifers in 2014, 2015, and 2016 and again in 2019. Cladocera dominated the assemblage in 2015. Rotifers were the dominant group of zooplankton in 2013, 2014, 2016, 2017, and 2018. In 2019, Copepods dominated, although Cladocera were a significant contributor to the overall abundance. Overall zooplankton abundance was considered moderate in 2016 and was high all other years. Zooplankton abundance has been the highest in the past three years, over 1,000 organisms/L higher in density than the next highest year (2014). The rotifer community has developed significantly out of the three groups since 2017. For some reason rotifers enjoyed increase abundance in 2017/2018. In 2018 (and to some extent 2019), the distribution of the three groups was more evenly distributed compared to 2017 as cladocera and copepod abundance increased. Lake Waccabuc contains the highest zooplankton abundance out of the three lakes, peaking in 2018 at 3,760 organisms/L.

Lake Profiles

Table 3: 2019 Three Lakes Profiles						
Depth (meters)	Lake Rippowam		Lake Oscaleta		Lake Waccabuc	
	Temp. (°C)	Dissolved Oxygen (mg/L)	Temp. (°C)	Dissolved Oxygen (mg/L)	Temp. (°C)	Dissolved Oxygen (mg/L)
0	30.3	9.67	30.1	10.44	29.7	9.34
1	29.0	10.16	29.2	10.87	29.0	9.21
1.5	28.7	9.47	28.8	10.20	28.8	9.37
2	28.3	10.33	28.4	9.49	28.7	9.39
3	25.8	9.88	25.8	8.09	28.1	8.88
4	20.7	0.57	22.3	6.74	25.1	5.72
4.5						
5	16.3	0.15	17.1	1.34	21.0	4.64
5.5	14.9	0.11				
6			13.7	0.21	15.6	2.34
7			11.0	0.12	12.1	0.37
8			9.7	0.11	9.9	0.16
9			9.2	0.10	9.1	0.12
10			8.9	0.10	8.3	0.11
10.5			8.5	0.10		
11					7.8	0.10
12					7.6	0.10
13					7.5	0.10
14					7.3	0.10

In 2019, temperature and dissolved oxygen profiles were measured at each lake station by the client. That data was provided to SLM for summary. Data was collected at one-meter intervals with some extra measurements at half-meter marks, most likely based on depth measurements. All three profiles have an extra measurement at the 1.5 meter depth coinciding with the depth of the phytoplankton collection. Lake Rippowam has an added measurement of 5.5-meter depths. Lake Oscaleta has an extra measurement at the 10.5 meter depth.

At Lake Rippowam, dissolved oxygen readings were slightly elevated until reaching a depth of 2.0 meters. We did observe a few spikes in the dissolved oxygen in the upper levels of the water column. The highest dissolved oxygen occurred at a depth of 2.0 meters (10.33 mg/L) which is equivalent to 135% saturation. At 4.0 meters, and the rest of the water column, the dissolved oxygen was effectively anoxic.

At Lake Oscaleta, dissolved oxygen levels were highly elevated from the surface until a depth of 1.5 meters with a percent saturation around 140%. We then observed an expected decrease in dissolved oxygen to the 4.0-meter depth. Throughout this part of the water column, we observed suitable dissolved oxygen amounts. By the 5.0-meter depth, percent saturation was down to about 20%. By the 6.0-meter depth, we observed anoxic conditions with dissolved oxygen at or below 0.21 mg/L.

At Lake Waccabuc this year, dissolved oxygen was slightly elevated at the surface. At the surface we observed about 120% saturation. We then observed a normal, expected decrease in dissolved oxygen, yet there was still suitable oxygen in the water column to support diverse aquatic biota. By the 6-meter depth, we observed 2.34 mg/L of oxygen, which is equivalent to 23.5% saturation. Below 7.0-meters, we observed anoxic conditions.

Conclusion

Summary

Phytoplankton abundance and composition varied throughout the Three Lakes in 2019. At Lake Waccabuc, we observed low overall phytoplankton abundance. Although blue-green algae still was common in the assemblage, the overall low abundance equated to non-problematic conditions. The previous few years at this site were considered bloom-like conditions. At Lake Oscaleta, we observed low-moderate overall phytoplankton, although this site was dominated by nuisance blue-green algae. At Lake Rippowam, we observed high phytoplankton abundance. Although blue-green algae dominated this assemblage, we did observe a suitable amount of green algae on this date.

Zooplankton abundance decreased at all three lakes in 2019 when compared to 2018. At Lake Waccabuc, we observed high zooplankton abundance, dominated by Copepods. At Lake Oscaleta, we observed moderate zooplankton abundance, also with Copepods dominating the community. Both of these lakes saw a decrease in rotifer abundance from 2018. At Lake Rippowam, we observed high zooplankton abundance, dominated by rotifers.

Recommendations

The Three Lakes Council has now compiled seven years of zooplankton and phytoplankton data for Lake Rippowam, Lake Oscaleta, and Lake Waccabuc, which should be considered a suitable baseline of data. Monitoring the health of a lake ecosystem requires sampling a diverse array of biological communities such as fish, aquatic plants, phytoplankton and zooplankton and is essential to provide stewardship to a delicate ecosystem. The comprehensive water quality collected via the CSLAP program is suitable to be combined with available biological data, to assist with completing the picture of the overall ecological status of the three basins. The importance of the CSLAP program can't be overstated. At the time of this report being generated, we understand that the CSLAP program might not occur due to the COVID-19 situation affecting the country. If this program is put on pause for 2020, the Three Lakes Council might want to consider alternative water quality monitoring sampling programs to prevent a hole in an otherwise excellent dataset.

SOLitude Lake Management recommends the 3LC to continue monitoring zooplankton and phytoplankton in the 2020 season. Although sampling throughout the growing season (May through September) would be more suitable to observe seasonal variation (and we have limited seasonal data). That said, at the least, continuing the same sampling format and techniques applied in 2013 through 2019, does provide value. Therefore, a single sample event should be collected in mid-July of 2020, to coincide with the SAV surveys.

We now have suitable phytoplankton and zooplankton data for all three lakes, and we have developed a rotating schedule to survey the submersed aquatic plant community among the three lakes. However, we continue to lack baseline fishery data at any of the Three Lakes, and arguably this is one of the most important recreational resources for the Three Lakes community. This may provide some insight upon the fluctuating phytoplankton and zooplankton populations within some of the basins. We strongly recommend a fish population study, at least in one basin, for 2020, and SLM supports another aquatic consultant's recommendation to conduct fishery studies at these lakes. It would be ideal to survey a single basin each year, and then use the results of these studies to develop sound, scientifically based fish management programs, as we would expect each lake would require a slightly different program. SOLitude has reached out to the 3LC regarding these surveys in the past, and in early 2020, but it needs to be a priority of the 3LC to move forward with this task. It might even be possible to manipulate the fish community to the benefit of the phytoplankton and zooplankton communities.

SOLitude Lake Management would like to take this opportunity to thank the Three Lakes Council for allowing us to provide lake management consulting services. We look forward to working with you again throughout the 2020 lake management season.

Sincerely,

Chris J. Doyle

Digitally signed by Chris J. Doyle
DN: cn=Chris J. Doyle, o=SOLitude Lake Management, ou=Biology Department, email=cdoyle@solitudelake.com, c=US
Date: 2020.04.07 14:24:11 -04'00'

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Appendix

Phytoplankton Primer

Zooplankton Primer

2018 Phytoplankton Examination Data and Pie Charts

2018 Zooplankton Examination Data and Pie Charts

2013-2019 Phytoplankton Abundance and Distribution Graphs

2013-2019 Zooplankton Abundance and Distribution Graphs

Three Lakes Profile Data and Graphs

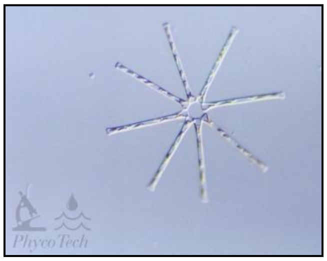
Phytoplankton Primer

Lakes typically contain three broad categories of phytoplankton (also sometimes referred to as algae). These include filamentous phytoplankton, macroscopic multi-branched phytoplankton (which appear similar to submersed plants), and unicellular phytoplankton. Each category shall be discussed in turn, sampling will focus on the unicellular phytoplankton population.

Filamentous phytoplankton are typically macroscopic (that is, visible with the naked eye), composed of long chains of cells that are attached to a substrate, typically the lake bottom, submersed or emergent vegetation, or rocks. This is called benthic filamentous algae (BFA), and rampant growth can become visible at the surface. As pieces of benthic filamentous algae break apart, it often floats on the surface as dense unsightly mats called floating filamentous algae (FFA). Typically, genera of green algae or blue-green algae develop into nuisance filamentous mats. Abundant nuisance growth of filamentous phytoplankton creates numerous negative impacts to a lake. These can include a decrease in aesthetics, a decrease in recreational uses, increased fishing frustration, and water quality degradation.

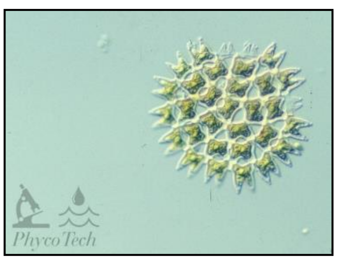
Macroscopic multi-branched phytoplankton appears to be submersed plants, especially when viewed in the water column. Physical examination reveals simple structures, no conductive tissue, and a lack of roots (instead having simplified rhizoids). Although typically only reaching heights of a few inches, under ideal conditions, this type of phytoplankton can reach lengths of several feet, and create a dense carpet on the bottom of a lake. Therefore, it typically does not reach nuisance levels in a lake, save for high use areas such as beaches and other popular swim areas. Since this phytoplankton occupies a similar ecological niche as submersed plants, it’s often included in detailed and visual aquatic plant surveys. It provides numerous benefits to a lake system, including sediment stabilization, acting as a nutrient sink, providing invertebrate and fish shelter and habitat, and is one of the first to re-colonize a disturbed area. In the Northeast, muskgrass (*Chara* sp.) and stonewort (*Nitella* sp.) are two of the most common macroscopic multi-branched phytoplankton.

Unicellular phytoplankton are typically microscopic, and consist of individual cells or colonies of cells suspended in the water column. At high enough densities (often called a bloom), they can impart a green or brown (and sometimes, even red) tint to the water column. Unicellular phytoplankton belongs to several taxonomic groups with density and diversity of these groups often varying due to seasonality. When unicellular phytoplankton density becomes elevated it can reduce water clarity (giving the water a “pea soup” appearance), and impart undesirable odors. Usually blue-green algae are responsible for these odors, but other groups or extremely elevated densities can impart them as well. In addition to decreased aesthetics, unicellular phytoplankton blooms can cause degradation of water quality, increase the water temperature (turbid water warms faster than clear water), and can possibly produce a variety of toxins (in the case of blue-green algae), depending on the type of genera present and environmental conditions. Numerous groups of unicellular phytoplankton are common in the Northeast, including diatoms, golden algae, green algae, blue-green algae, euglenoids and dinoflagellates. Each group shall be discussed in turn.



Diatoms are ubiquitous as a group, and often possess a rigid silica shell with ornate cell wall markings or etchings. The silica shells settle to the bottom substrate after they die, and under ideal conditions can become stratified. Limnologists can then study historical (and possibly even ancient) population characteristics of diatoms. Some are round and cylindrical (centric) in shape, while others are long and wing-shaped (pennales). They are usually brown in color, and reach maximum abundance in colder or acidic water. Therefore, they tend to dominate in winter and early spring. Common diatoms in the Northeast include *Fragilaria*, *Cyclotella*, *Navicula*, and *Asterionella* (pictured).

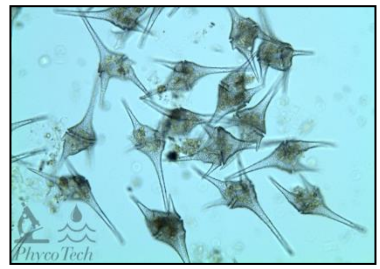
Golden Algae are typically yellow or light brown in color. Cell size is usually small oval shaped with a partially empty area, but several genera create colonies of smaller cells. Most have two flagella, and some type of scales or a rigid coating that grants it a fuzzy appearance. However, a few filamentous forms are possible as well. They typically prefer cooler water, so they dominate in the late fall, winter, or early spring. They also tend to bloom at deeper (cooler) depths. They are common in low nutrient water, and numerous forms produce taste and odor compounds. Common golden algae in the Northeast include *Dinobryon* (pictured), *Mallomonas*, and *Synura*.



Green Algae are a very diverse group of unicellular phytoplankton. There is tremendous variability in this group which varies from family to family and sometimes even genus to genus. There are flagellated single cells, multi-cell colonies (some motile), filamentous forms and attached forms, typically with distinct cell shapes light green in color. Some prefer acidic waters, and others highly eutrophic (sewage) conditions. A green algae bloom usually occurs in water with high nitrogen levels. Green algae typically dominate in mid to late summer in the Northeast. Common genera include *Chlorella*, *Scenedesmus*, *Spirogyra* and *Pediastrum* (pictured).

Blue-green algae are actually photosynthetic bacteria. Therefore, they tend to be small, simple in structure and lacking interior cell details. Blue-green algae are typically encased in a mucilaginous outer layer. Some genera are adorned with heterocysts, swollen structures capable of fixing nitrogen, a competitive advantage. These types tend to bloom in nitrogen-poor or eutrophic systems. Yet, blue-green algae are tolerant of a wide variety of water chemistries, and boast many oligotrophic forms as well. Blue-green algae often have gas vesicles which provide increased buoyancy another competitive advantage over other groups of phytoplankton, due to their propensity to shade out others by blooming at the surface. Numerous blue-green algae are documented taste and odor (T&O) producers, and under certain environmental conditions and high enough densities, can produce toxins dangerous to fish, livestock, and possibly humans. Blue-green algae typically dominate a lake system in late summer to early fall. Common blue-green algae that occur in the Northeast include *Anabaena* (pictured), *Aphanizomenon*, *Microcystis* and *Coelosphaerium.*

Euglenoids are typically motile with 0 to 3 (typically 2) flagella, one of which is longer. Euglenoids has plasticity of shape, and usually are grass green in color (although sometime they are clear or even red). Most forms have a distinct red "eyespot. They are often associated with high organic content water, and eutrophic conditions. Common euglenoids that occur in the Northeast include *Euglena* (pictured), *Phacus*, and *Trachelomonas*.



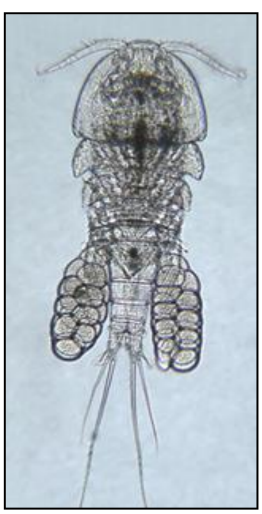
Dinoflagellates are very common in marine environments, in which they often cause toxic blooms. However, toxin production in freshwater genera is very rare. Dinoflagellates are typically single ovoid to spherical cells, but large compared to phytoplankton from other groups. They usually possess two flagella (one wrapped around the middle of the cell) which grant them rotation while they move through the water column. Cellulose plates (armored dinoflagellates) are more common, but genera without cellulose plates (naked dinoflagellates) also occur. They generally prefer organic-rich or acidic waters, and can impart a coffee-like brown tint to the water at high enough densities. Common dinoflagellates in the Northeast include *Ceratium* (pictured) and *Peridinium*.

A Zooplankton Primer

Zooplankton provides an important link in a typical lake's food web between phytoplankton and fish, especially developing and juvenile stages. In general, zooplankton feed on phytoplankton, while fish in turn feed on zooplankton. The rate of feeding efficiency is primarily based on body size, but zooplankton group, and to some effect specific genera, also plays an important role. There are three main groups of zooplankton found in freshwater systems: rotifers, cladocera, and copepods.

Rotifers are a diverse group of zooplankton, very common in lakes and marine environments alike. Rotifers are generally the smallest zooplankton of the three groups, and thus typically the least efficient phytoplankton grazers. Feeding preferences are determined primarily by mouth structures, and include generalist feeders (omnivores), which eat any small organic detritus encountered, and predators, which eat other smaller rotifers and small phytoplankton. Generalist feeders include *Filinia, Keratella, Lecane, Euchlanis*, and *Brachionus*. Predator genera include *Polyarthra* (larger species)*, Asplanchna, Synchaeta*, and *Trichocerca*.

Cladocera are less diverse, but also very common in freshwater lakes. They are sometimes called "water fleas". They spend most of their lifecycle reproducing via parthenogenesis (asexual reproduction with an all female population) only switching to less efficient sexual reproduction when environmental conditions decline. Some genera (such as *Daphnia*) can be quite large (up to 5.0 mm long, visible without magnification), and thus can be classified as highly efficient phytoplankton grazers. Most cladocera are phytoplankton grazers, although their diet includes most organic matter ingested, including bacteria and protozoa. Body size (and thus mouth size) determines feeding efficiency, but ironically the larger-bodied genera are easier to see by predaceous fish, and thus typically have reduced numbers in populations of zooplanktivorous fish. *Daphnia* are the most efficient phytoplankton feeders, while *Ceriodaphnia, Bosmina* and *Eubosmina* are less efficient. There are a few predator genera as well, including *Polyphemus* and *Leptodora*.



Copepods are almost excusive to freshwater lake systems (not streams or rivers) and estuarine and marine systems. Of the six suborders native to the United States, three are parasitic, and three are free living. One of the free living, Harpacticoida are exclusively benthic and thus often not collected in traditional plankton tows (unless the bottom sediments are disturbed). The remaining two suborders, the Calanoida and the Cyclopoida are of primary concern during lake studies. All copepods have several naupilar stages, followed by several immature stages, before reaching an adult stage. Both suborders are considered large bodied zooplankton, but have distinct feeding preferences. Calanoids are almost exclusively phytoplankton feeders and have even demonstrated selective feeding strategies. Cyclopoids have mouth parts suitable for biting and seizing prey. Their diet is primarily other crustacean zooplankton (including cannibalism on younger life stages), and phytoplankton and organic detritus ingestion (but less efficiently).

MICROSCOPIC EXAMINATION OF WATER

Sample from: Three Lakes

Collection Date: 7/30/2019	Examination Date: 7/31/2019	Amount Examined: 200 ml.
Site A: Lake Rippowam	Site B: Lake Oscaleta	Site C: Lake Waccabuc

BACILLARIOPHYTA (Diatoms)	**A**	**B**	**C**
Asterionella			
Cyclotella	10		
Cymbella			
Diatoma			
Fragilaria	10	10	
Melosira			
Navicula		20	
Nitzschia			
Pinnularia			
Rhizosolenia			
Stephanodiscus			
Stauroneis			
Synedra	20		70
Tabellaria			
Cocconeis			

CHRYSOPHYTA (Golden Algae)	**A**	**B**	**C**
Dinobryon			
Mallomonas	10	50	
Synura			
Tribonema			
Uroglenopsis			

CHLOROPHYTA (Green Algae)	**A**	**B**	**C**
Ankistrodesmus			
Chlamydomonas			
Chlorella			
Chlorococcum			
Closterium			
Coelastrum			
Eudorina			
Mougeotia			
Oedogonium			
Oocystis			
Pandorina			
Pediastrum			
Phytoconis			
Rhizoclonium			
Scenedesmus			
Spirogyra			10
Staurastrum		10	10
Sphaerocystis			
Ulothrix	880		
Volvox			
Zygnema			
Quadrigula			
Gloeocystis			
Cosmarium			
Treubaria			

CYANOPHYTA (Blue-green Algae)	**A**	**B**	**C**
Anabaena	930	380	50
Anacystis			
Aphanizomenon			10
Coelosphaerium			
Gomphosphseria			
Lyngbya			
Microcystis			
Oscillatoria			
Pseudoanabaena			
Synechocystis			
Agmenellum			
PROTOZOA			
Actinophyrs			

EUGLENOPHYTA (Euglenoids)	**A**	**B**	**C**
Euglena			
Phacus			
Trachelomonas			

PYRRHOPHYTA (Dinoflagellates)	**A**	**B**	**C**
Ceratium			
Peridinium	10	10	

SITE	**A**	**B**	**C**
TOTAL GENERA:	7	6	5
TRANSPARENCY:	1.9m	2.05m	2.75m
ORGANISMS PER MILLILITER:	**1,870**	**480**	**150**

NOTES: This was the sampling event of 2019. Algal density is considered high at site A but low at sites B and C. Algal diversity is currently moderate at sites A and B but low at site C. Lake Rippowam and Lake Oscaleta are dominated by blue-green algae, while diatoms are the most abundant group at Lake Waccabuc. Green algae and other diatoms were also observed at all sites. Trace amounts of golden algae and dinoflagellates were present at sites A and B only. Water clarity is considered good at sites A and B, whereas site C is excellent.

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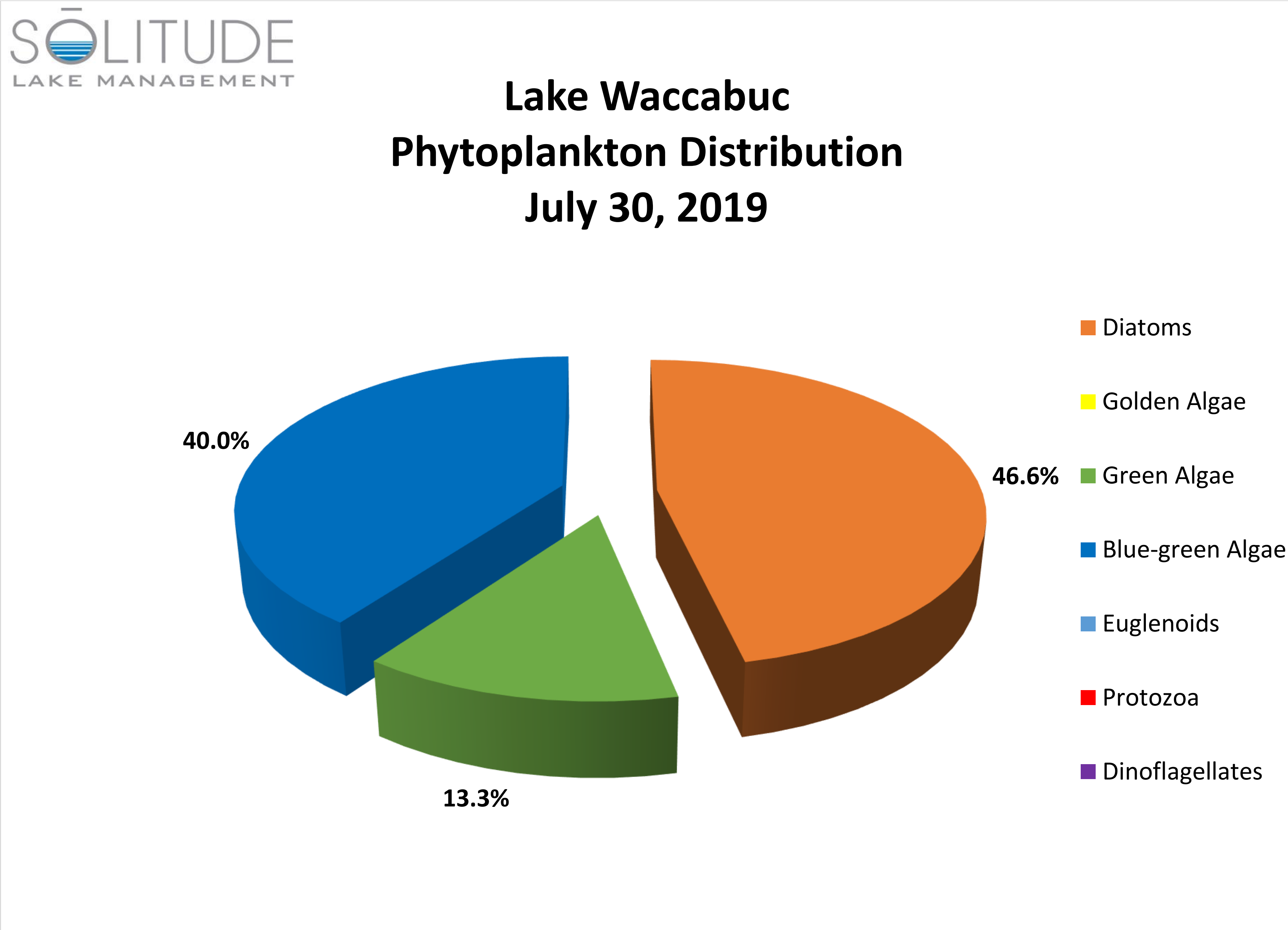
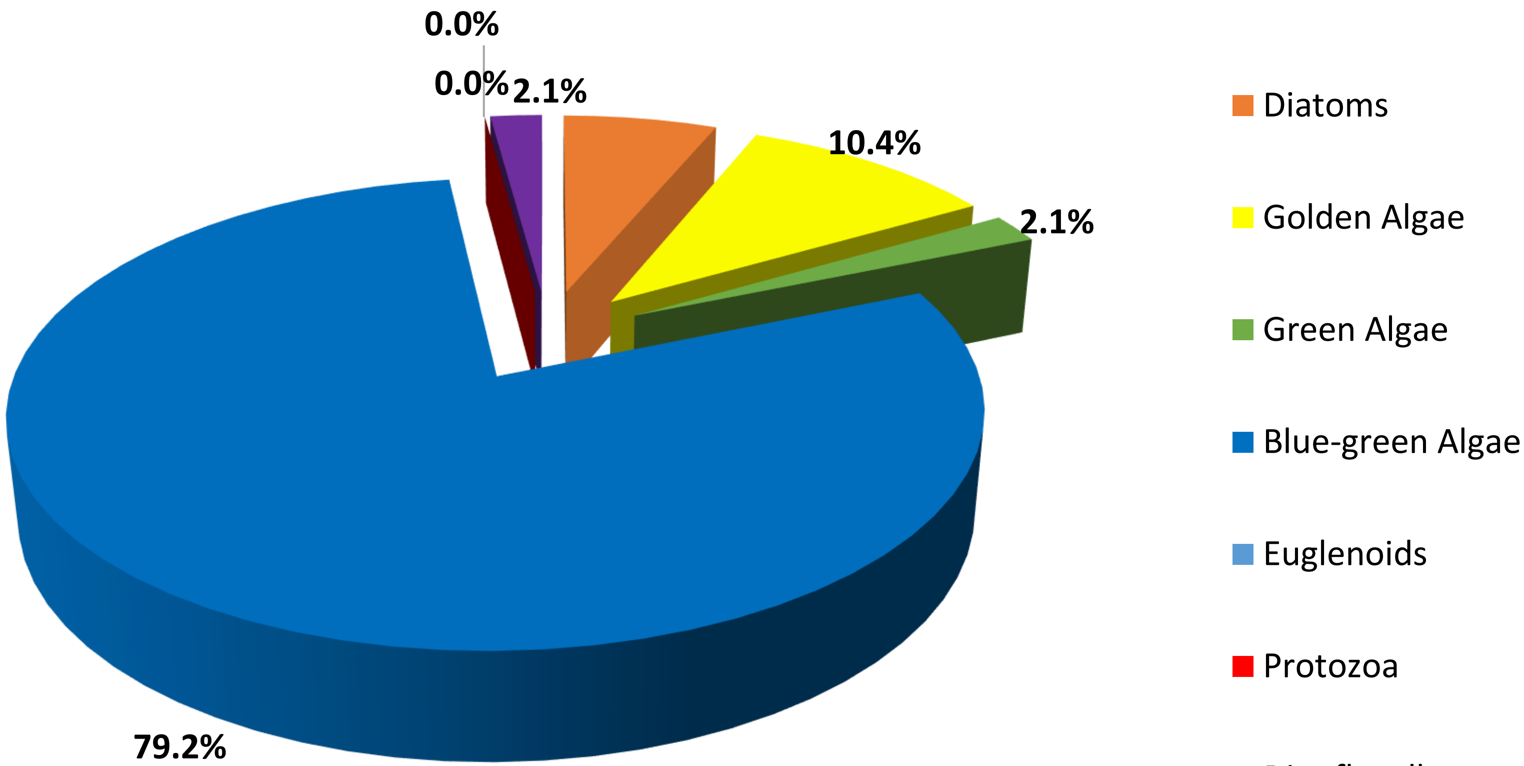
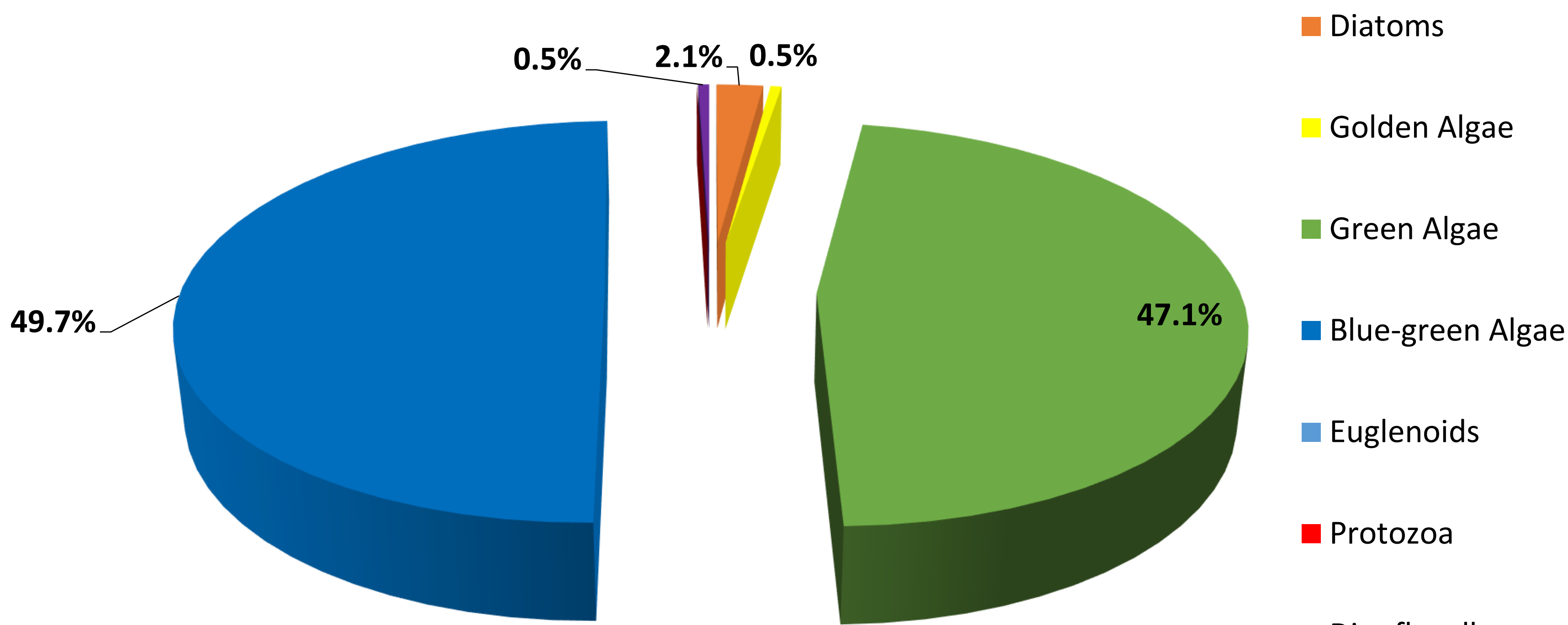
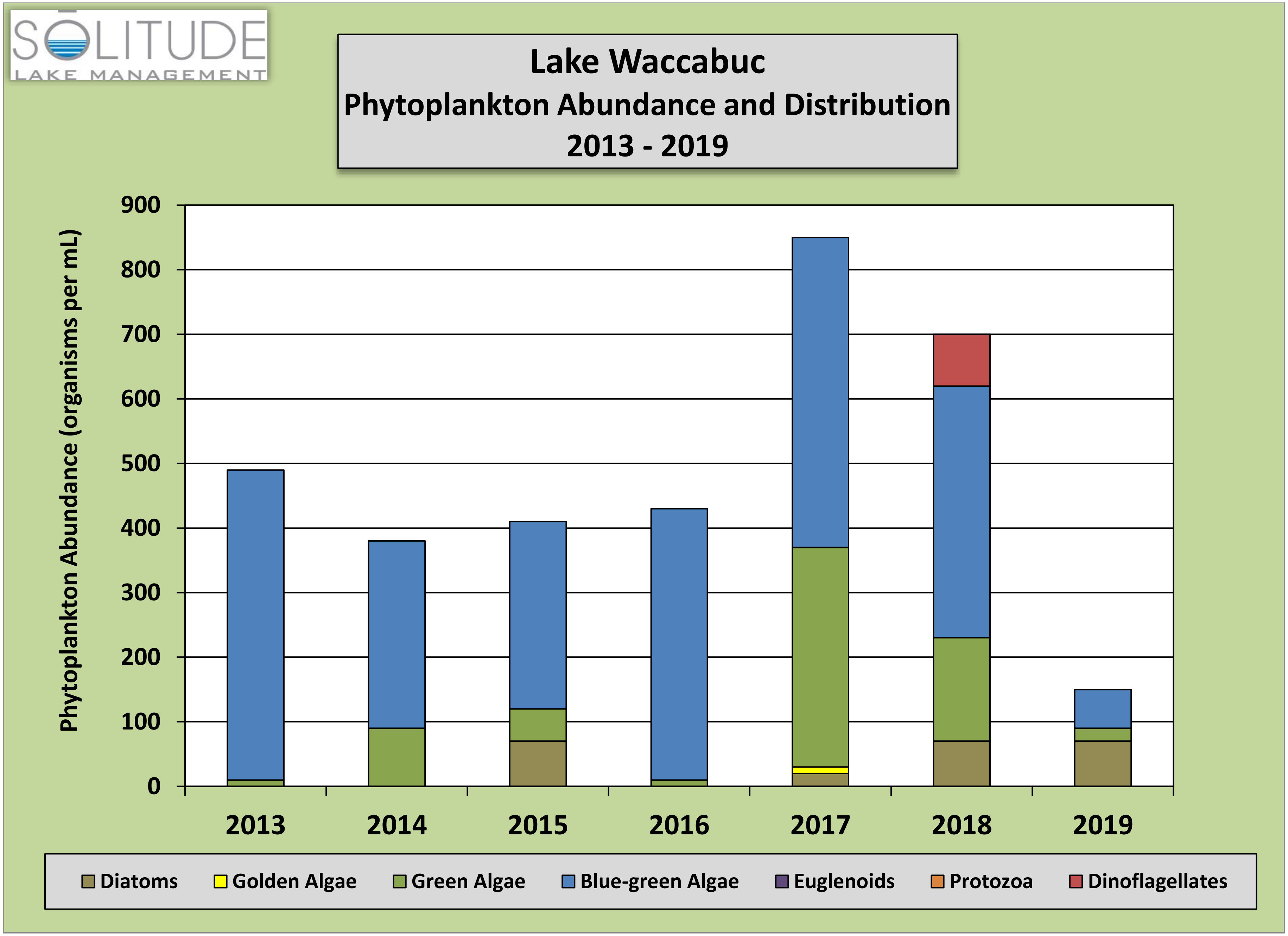

Lake Waccabuc
Phytoplankton Distribution
July 30, 2019
40.0%
46.6%
13.3%
Diatoms
Golden Algae
Green Algae
Blue-green Algae
Euglenoids
Protozoa
Dinoflagellates

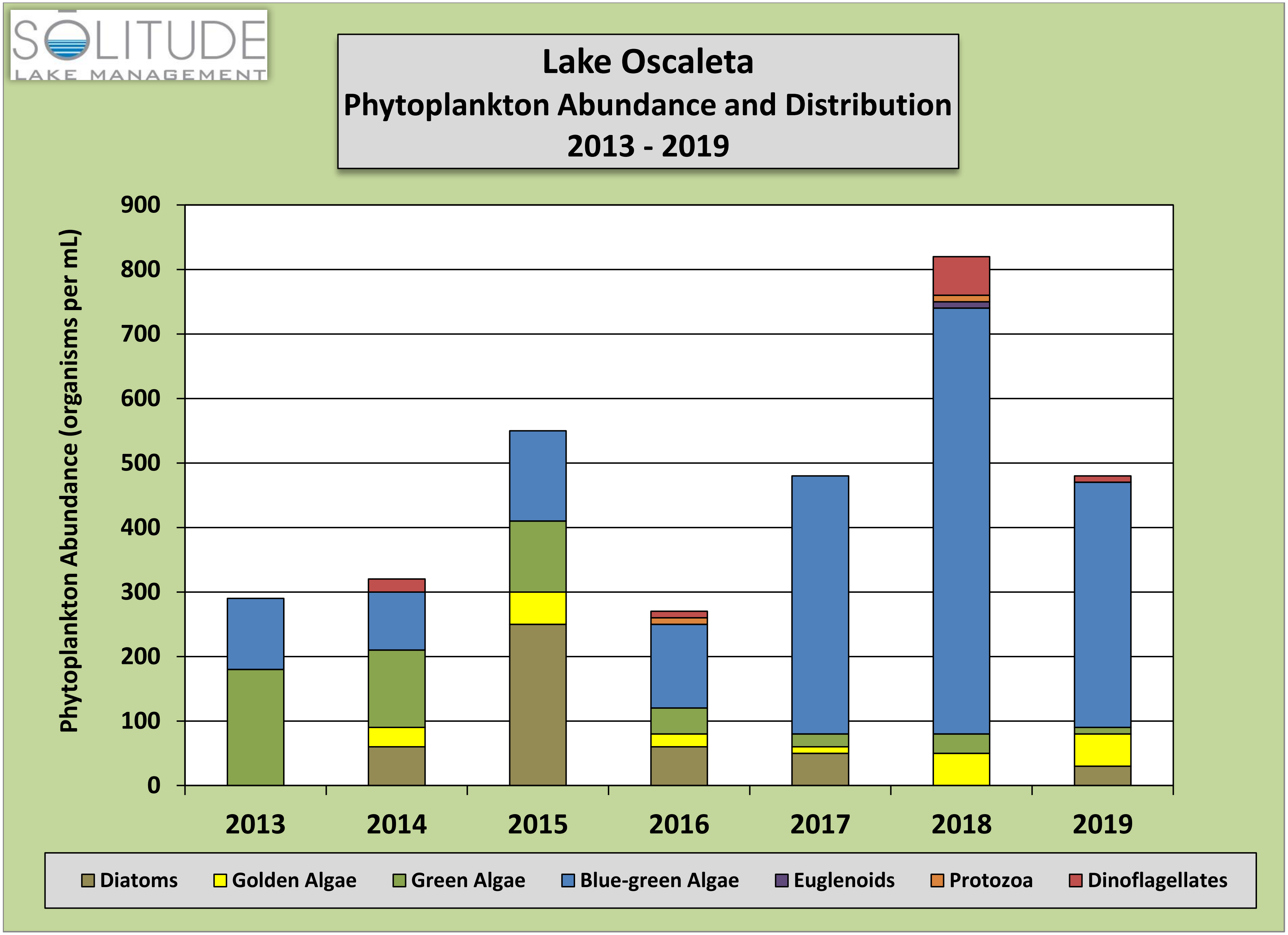
Lake Oscaleta
Phytoplankton Distribution
July 30, 2019

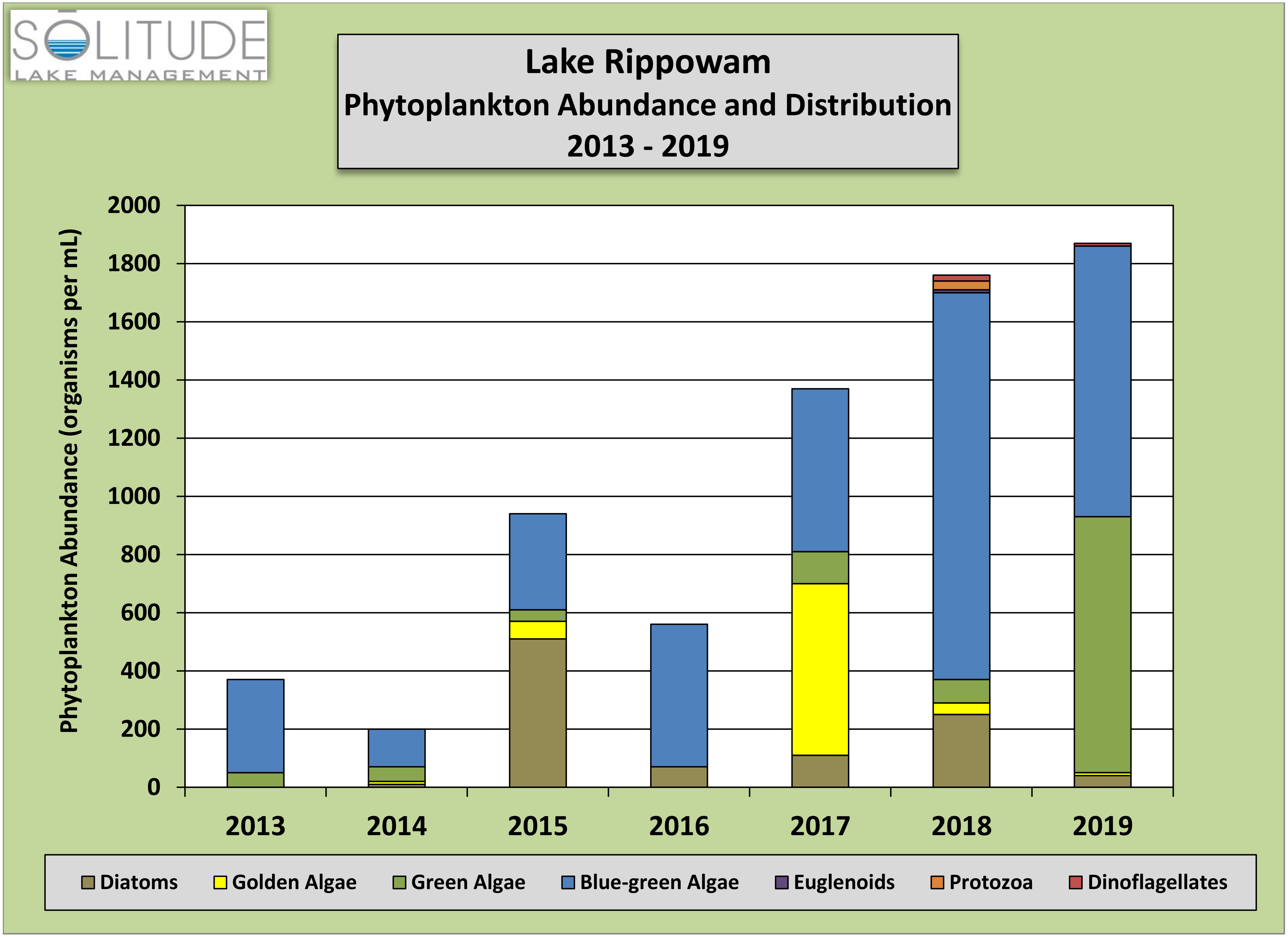


Lake Rippowam
Phytoplankton Distribution
July 30, 2019

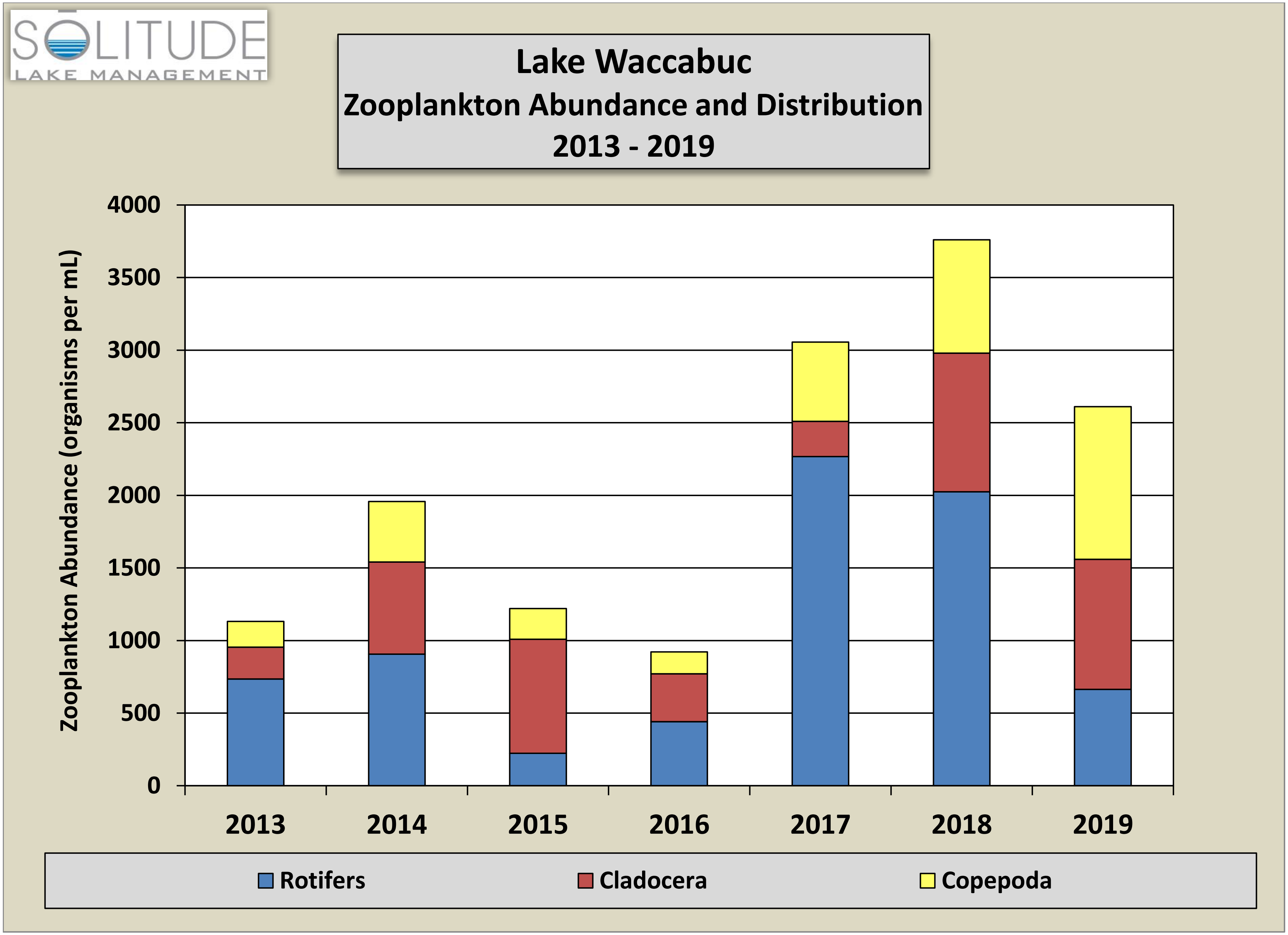



SOLITUDE
LAKE MANAGEMENT
Lake Waccabuc
Phytoplankton Abundance and Distribution
2013 - 2019
Phytoplankton Abundance (organisms per mL)
900
800
700
600
500
400
300
200
100
0
2013
2014
2015
2016
2017
2018
2019
Diatoms
Golden Algae
Green Algae
Blue-green Algae
Euglenoids
Protozoa
Dinoflagellates

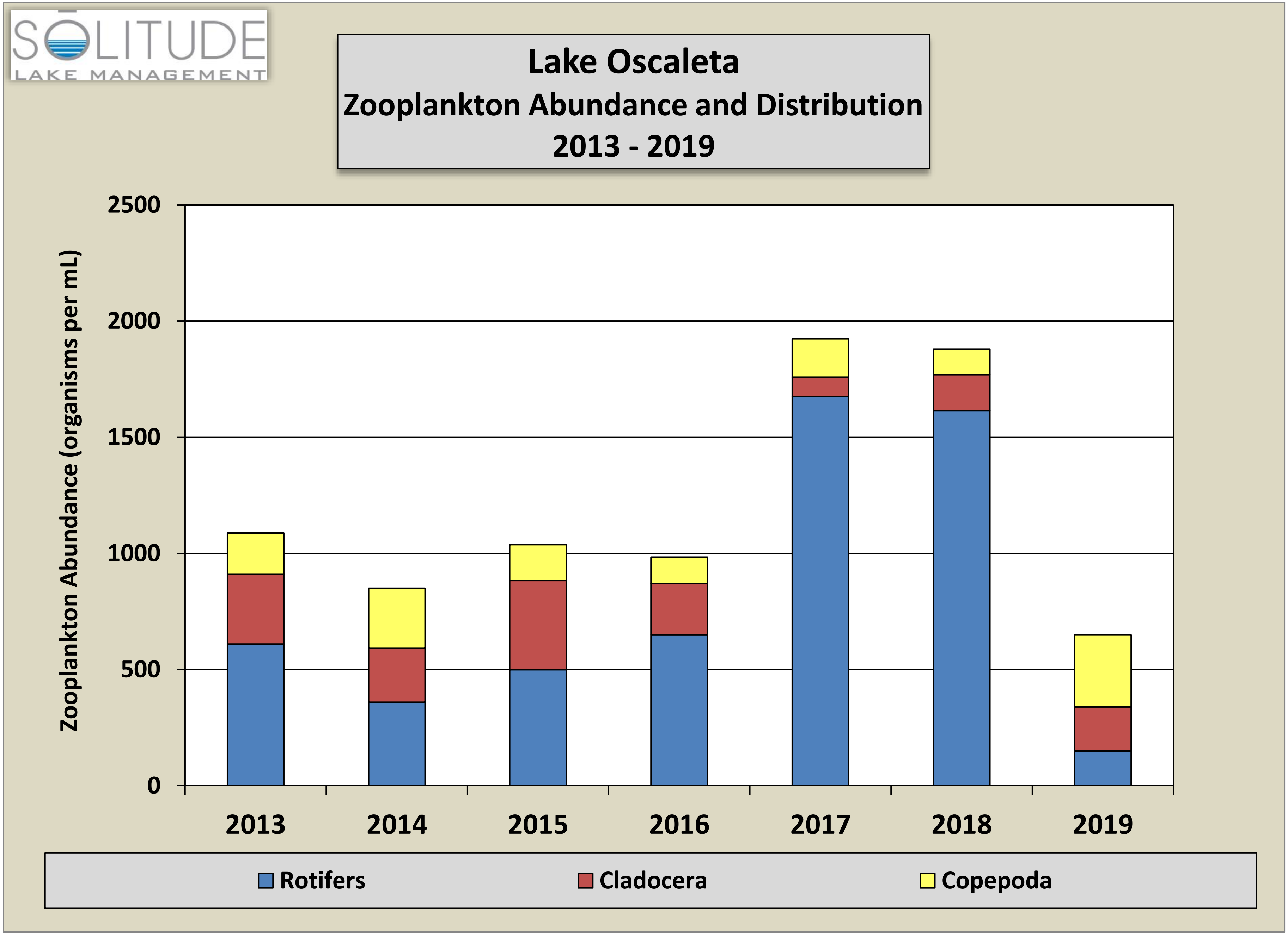

SOLITUDE LAKE MANAGEMENT
Lake Oscaleta
Phytoplankton Abundance and Distribution
2013 - 2019
Phytoplankton Abundance (organisms per mL)
900
800
700
600
500
400
300
200
100
0
2013
2014
2015
2016
2017
2018
2019
Diatoms
Golden Algae
Green Algae
Blue-green Algae
Euglenoids
Protozoa
Dinoflagellates

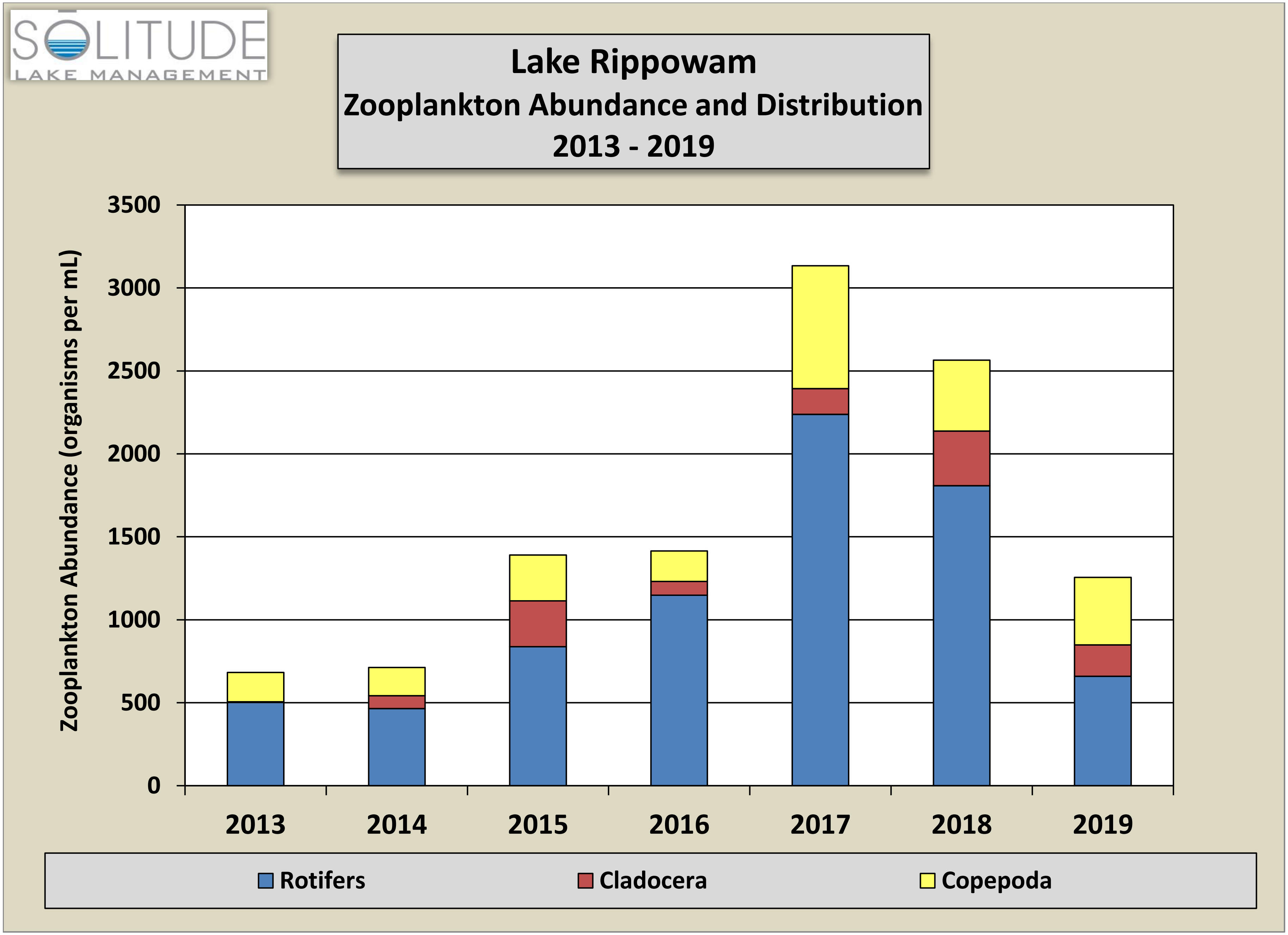


Lake Rippowam
Phytoplankton Abundance and Distribution
2013 - 2019
Phytoplankton Abundance (organisms per mL)
2000
1800
1600
1400
1200
1000
800
600
400
200
0
2013
2014
2015
2016
2017
2018
2019
Diatoms
Golden Algae
Green Algae
Blue-green Algae
Euglenoids
Protozoa
Dinoflagellates



Lake Waccabuc
Zooplankton Abundance and Distribution
2013 - 2019
Zooplankton Abundance (organisms per mL)
4000
3500
3000
2500
2000
1500
1000
500
0
2013
2014
2015
2016
2017
2018
2019
Rotifers
Cladocera
Copepoda


SOLITUDE
LAKE MANAGEMENT
Lake Oscaleta
Zooplankton Abundance and Distribution
2013 - 2019
Zooplankton Abundance (organisms per mL)
2500
2000
1500
1000
500
0
2013
2014
2015
2016
2017
2018
2019
Rotifers
Cladocera
Copepoda



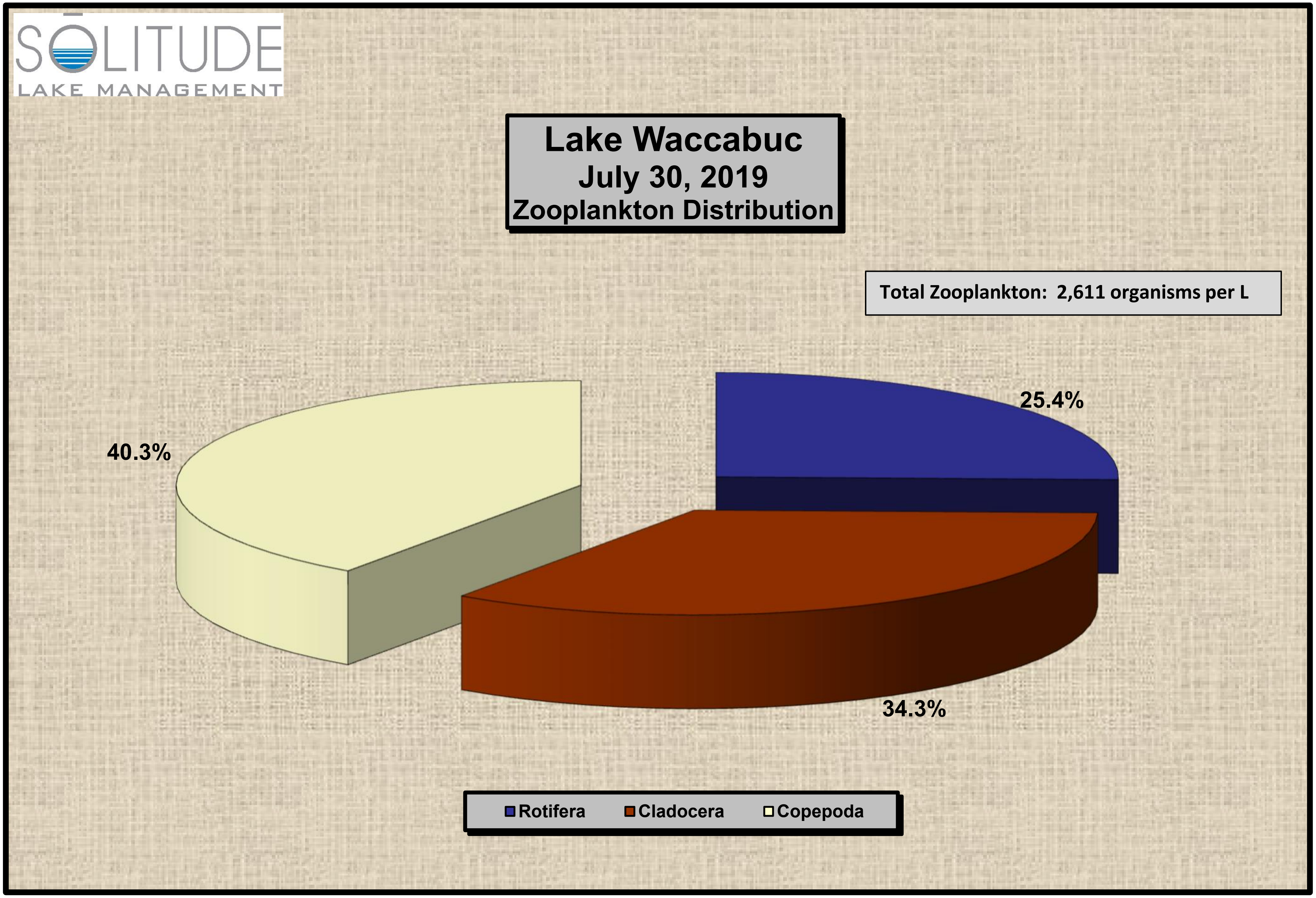
Lake Rippowam
Zooplankton Abundance and Distribution
2013 - 2019
Zooplankton Abundance (organisms per mL)
3500
3000
2500
2000
1500
1000
500
0
2013
2014
2015
2016
2017
2018
2019
Rotifers
Cladocera
Copepoda

Zooplankton Count Results

Site: Lake Waccabuc **Date: 7/30/19**

Group	Order	Family	Genus	Replicate A	Replicate B	Replicate C	Total/3 (# per mL)	x1000 mL (= 1 L)	Water sampled (L)	# organisms per L
Rotifera	**Ploima**	Brachionidae	*Keratella crassa*	20	30	14	21.33	21333	68.8	310
			Notholca acuminata	1		3	1.33	1333	68.8	19
		Gastropidae	*Ascomorpha saltans*	8	6	1	5.00	5000	68.8	73
		Synchaetidae	*Polyarthra remata*	1			0.33	333	68.8	5
		Trichocercidae	*Trichocerca cylindrica*	9	8	12	9.67	9667	68.8	141
	Flosculariacea	Conochilidae	*Conochilus unicornis*	9	11	4	8.00	8000	68.8	116
									Total:	**664**
Cladocera	**Cladocera**	Bodminidae	*Bosmina longirostris*	18	28	19	21.67	21667	68.8	315
		Daphniidae	*Daphnia pulex*	43	41	36	40.00	40000	68.8	581
							0.00	0	68.8	0
									Total:	**896**
Copepoda	**Cyclopoida**	Cyclopoidae	*Microcyclops rubellus*	39	38	27	34.67	34667	68.8	504
			Cyclopoid nauplii	36	39	36	37.00	37000	68.8	538
	Calanoida		*Calanoid* nauplii		2		0.67	667	**68.8**	10
									Total:	**1051**

Total Organisms per L	Rotifera	%	Cladocera	%	Copepoda	%
2611	664	25.4%	896	34.3%	1051	40.3%

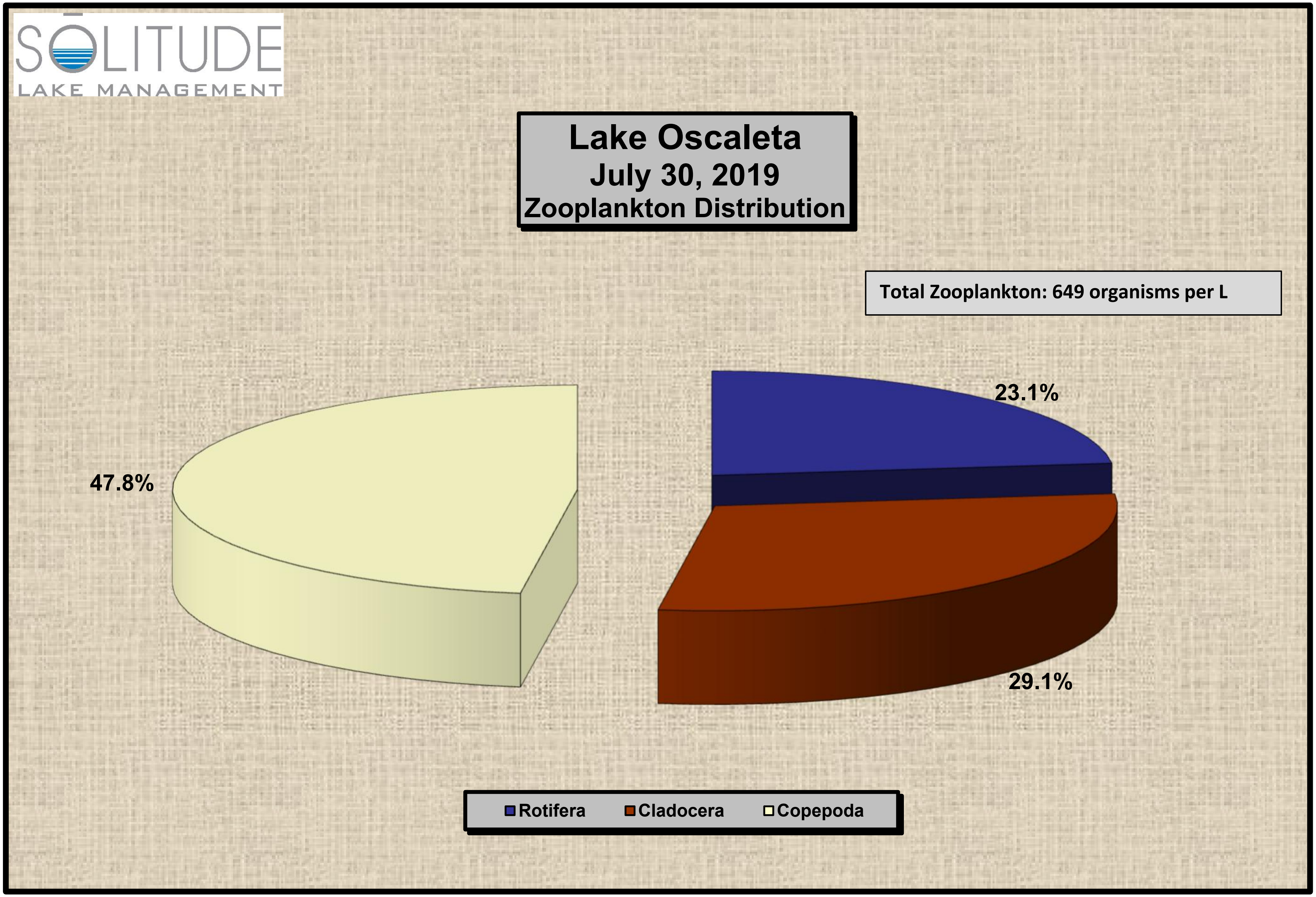

Lake Waccabuc
July 30, 2019
Zooplankton Distribution
Total Zooplankton: 2,611 organisms per L
25.4%
40.3%
34.3%
Rotifera
Cladocera
Copepoda

Zooplankton Count Results

Site: Lake Oscaleta **Date: 7/30/19**

Group	Order	Family	Genus	Replicate A	Replicate B	Replicate C	Total/3 (# per mL)	x1000 mL (= 1 L)	Water sampled (L)	# organisms per L
Rotifera	**Ploima**	Brachionidae	*Keratella crassa*	7	6	4	5.67	5667	68.8	82
			Notholca acuminata	1			0.33	333	68.8	5
		Gastropidae	*Ascomorpha saltans*	5	2	4	3.67	3667	68.8	53
		Asplanchnidae	*Asplanchna priodonta*			2	0.67	667	68.8	10
									Total:	**150**
Cladocera	**Cladocera**	Bodminidae	*Bosmina longirostris*	2	6	3	3.67	3667	68.8	53
		Daphniidae	*Daphnia pulex*	11	8	9	9.33	9333	68.8	136
									Total:	**189**
Copepoda	**Cyclopoida**	Cyclopoidae	*Microcyclops rubellus*	13	15	19	15.67	15667	68.8	228
			Cyclopoid nauplii	3	5	3	3.67	3667	68.8	53
	Calanoida		*Calanoid* nauplii	4	2		2.00	2000	**68.8**	29
									Total:	**310**

Total Organisms per L	Rotifera	%	Cladocera	%	Copepoda	%
649	150	23.1%	189	29.1%	310	47.8%


Lake Oscaleta
July 30, 2019
Zooplankton Distribution
Total Zooplankton: 649 organisms per L
23.1%
47.8%
29.1%
Rotifera
Cladocera
Copepoda

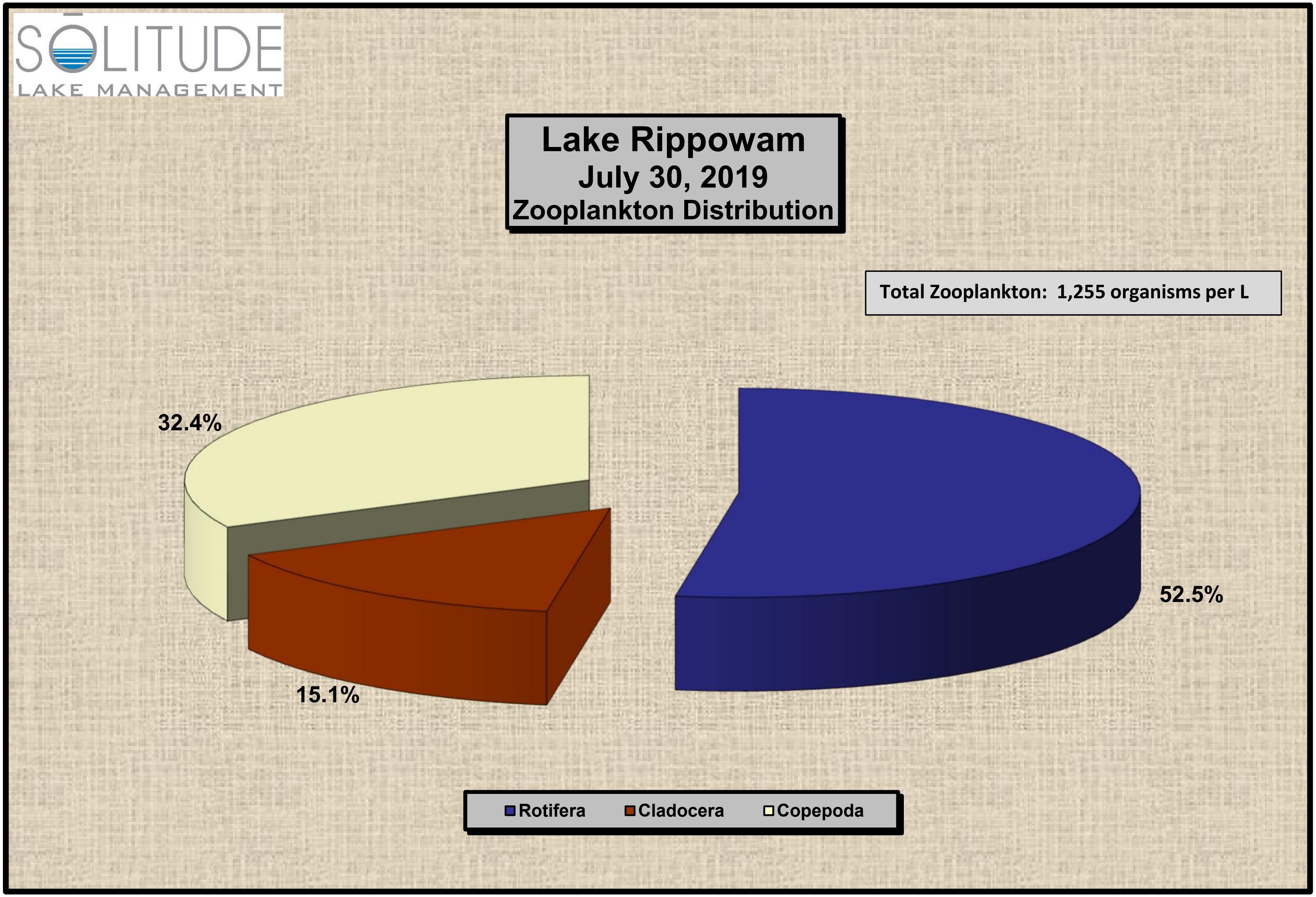
Zooplankton Count Results

SOLITUDE LAKE MANAGEMENT

Site: Lake Rippowam **Date: 7/30/19**

Group	Order	Family	Genus	Replicate A	Replicate B	Replicate C	Total/3 (# per mL)	x1000 mL (= 1 L)	Water sampled (L)	# organisms per L
Rotifera	**Ploima**	Brachionidae	*Keratella crassa*	1	5	4	3.33	3333	68.8	48
			Notholca acuminata	4		2	2.00	2000	68.8	29
		Gastropidae	*Ascomorpha saltans*	9	11		6.67	6667	68.8	97
		Trichocercidae	*Trichocerca cylindrica*	5	3	8	5.33	5333	68.8	78
	Flosculariacea	Conochilidae	*Conochilus unicornis*	25	28	31	28.00	28000	68.8	407
									Total:	**659**
Cladocera	**Cladocera**	Bodminidae	*Bosmina longirostris*	6	4	6	5.33	5333	68.8	78
		Daphniidae	*Daphnia pulex*	7	8	8	7.67	7667	68.8	111
									Total:	**189**
Copepoda	**Cyclopoida**	Cyclopoidae	*Microcyclops rubellus*	17	21	24	20.67	20667	68.8	300
			Cyclopoid nauplii	6	4	2	4.00	4000	68.8	58
	Calanoida		*Calanoid* nauplii	4		6	3.33	3333	**68.8**	48
									Total:	**407**

Total Organisms per L	Rotifera	%	Cladocera	%	Copepoda	%
1255	659	52.5%	189	15.1%	407	32.4%


Lake Rippowam
July 30, 2019
Zooplankton Distribution
Total Zooplankton: 1,255 organisms per L
32.4%
15.1%
52.5%
Rotifera
Cladocera
Copepoda

Three Lakes

Date:	7/30/2019
Biologist:	3LC

Lake Rippowam

Depth (Meters)	Temp. (ºC)	Dissolved Oxygen (mg/L)
0	30.3	9.67
1	29.0	10.16
1.5	28.7	9.47
2	28.3	10.33
3	25.8	9.88
4	20.7	0.57
5	16.3	0.15
5.5	14.9	0.11

Total Depth (m):	5.6
Secchi (m):	1.90

Lake Oscaleta

Depth (Meters)	Temp. (ºC)	Dissolved Oxygen (mg/L)
0	30.1	10.44
1	29.2	10.87
1.5	28.8	10.20
2	28.4	9.49
3	25.8	8.09
4	22.3	6.74
5	17.1	1.34
6	13.7	0.21
7	11.0	0.12
8	9.7	0.11
9	9.2	0.10
10	8.9	0.10
10.5	8.5	0.10

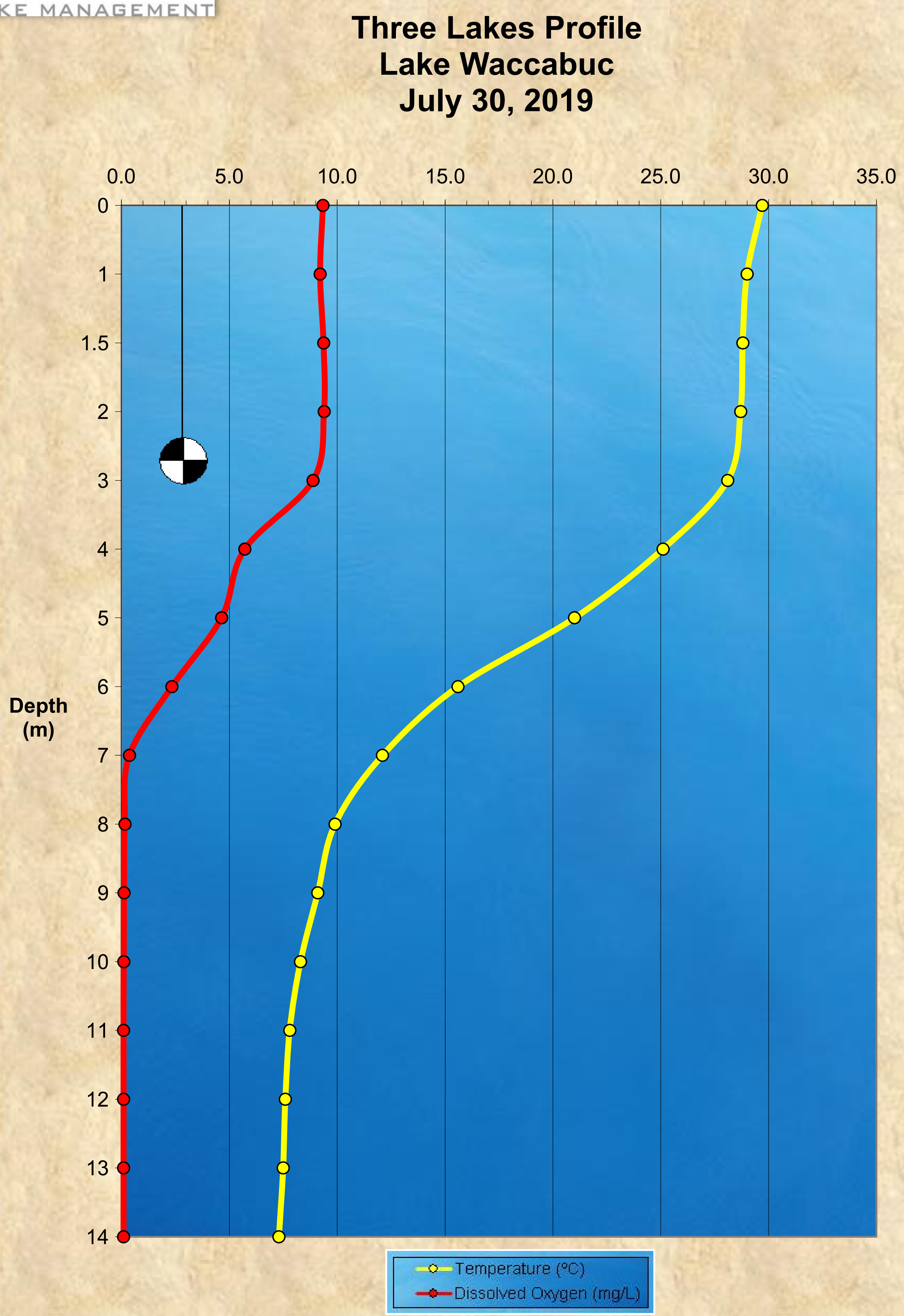
Total Depth (m):	10.6
Secchi (m):	2.05

Lake Waccabuc

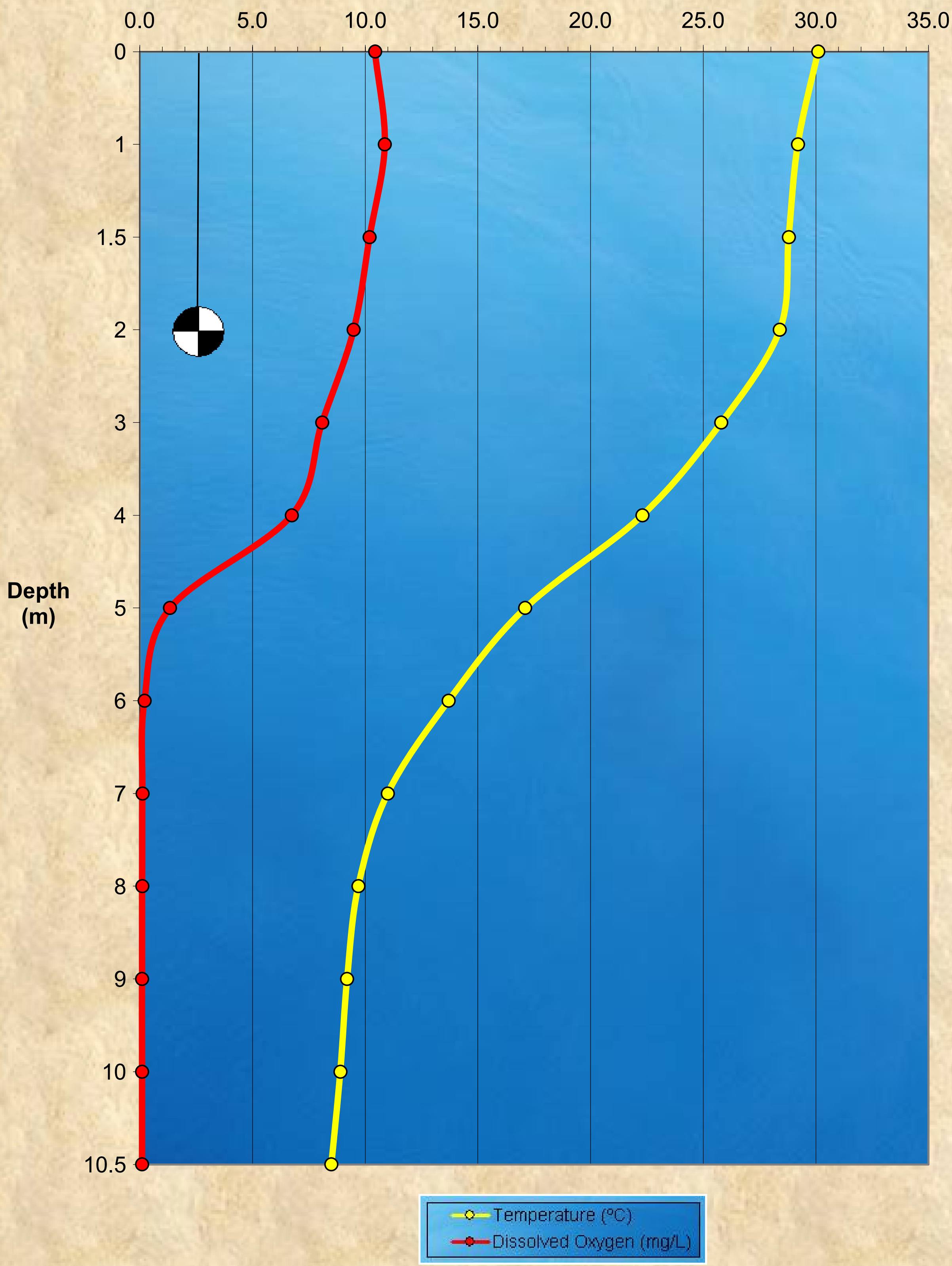
Depth (Meters)	Temp. (ºC)	Dissolved Oxygen (mg/L)
0	29.7	9.34
1	29.0	9.21
1.5	28.8	9.37
2	28.7	9.39
3	28.1	8.88
4	25.1	5.72
5	21.0	4.64
6	15.6	2.34
7	12.1	0.37
8	9.9	0.16
9	9.1	0.12
10	8.3	0.11
11	7.8	0.10
12	7.6	0.10
13	7.5	0.10
14	7.3	0.10

Total Depth (m):	14.3
Secchi (m):	2.75

Notes:


Three Lakes Profile
Lake Waccabuc
July 30, 2019
0.0
5.0
10.0
15.0
20.0
25.0
30.0
35.0
0
1
1.5
2
3
4
5
6
7
8
9
10
11
12
13
14
Depth
(m)
Temperature (°C)
Dissolved Oxygen (mg/L)

Three Lakes Profile
Lake Oscaleta
July 30, 2019



Three Lakes Profile
Lake Rippowam
July 30, 2019