

Report on 2021 Conesus Lake *In-Lake* Monitoring:

I. Zooplankton Distribution, Abundance and Biomass

by

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II. Follow-up Study of Eurasian Watermilfoil Biomass in the Cottonwood Gully, Sutton Point Gully, Graywood Gully and North Gully, Macrophyte Beds

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I. Zooplankton Distribution, Abundance and Biomass

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I. Zooplankton Study Summary

- The main goal of the 2021 *in-lake* monitoring program was to document the diversity and abundance of the Conesus Lake zooplankton community, which was last surveyed in 2014. We were especially interested in determining whether the once thriving population of large herbivorous *Daphnia* had recovered from near extirpation due to invasive alewife predation.
- In eight sampling dates between June 15 to October 7, only one specimen of *Daphnia* was collected. A species of large calanoid copepods in the genus *Skistodiaptomus* that was present in the lake prior to alewife colonization was also not encountered. Furthermore, several species of moderately- sized cyclopoid copepods (*Diacylops thomassi*, *Mesocyclops edax* and species of *Microcyclops*) are now primarily represented by smaller specimens, and their biomass has declined significantly, most likely due to alewife predation.
- The dominant crustacean in Conesus Lake was the water flea, *Bosmina longirostris*, which due to its small size generally escapes predation by alewife. The *Bosmina* population on average was more than 200 thousand individuals m⁻³, representing about 60% of the zooplankton biomass. Overall, at an average length of 0.35 mm length and a biomass of 115 thousand µg.m³, the crustacean component of the zooplankton community in Conesus Lake has not changed significantly from that described in 2009 and 2014 by Makarewicz and Colleagues.
- The other major herbivorous zooplankton group in Conesus Lake is the Phylum Rotifera, and rotifer abundance in 2021 was also very low. Specifically, we report a trend of rotifer community losses of more than 60% since 1999, the year that abundant populations of the invasive zebra mussel became fully established in Conesus Lake. Zebra mussels have been shown to feed on Rotifers and may also compete with Rotifers for phytoplankton food.
- A study of crustacean and Rotifer vertical distribution showed that during the period of lake stratification (June-October) most of the zooplankton community is located in the upper mixed layer of the lake (surface to ~9 m) at or above the thermocline. Few or no individuals of most groups were found in the cold, hypoxic region below the thermocline. In October, as the mixed layer deepened, the vertical distribution of zooplankton deepened accordingly.
- The alewife and zebra mussel invasions have reduced the populations of large crustacean zooplankton and the abundance of the smaller Rotifers in Conesus Lake. These changes resulted in higher phytoplankton biomass, changed the open water food web and increased water turbidity, making the already productive lake even “greener”. In terms of lake management, we recommend that priority should be given to preventing invasion of the lake by other zooplanktivores, such as the spiny water flea (*Bythotrephes longimanus*), as they would further reduce the already impoverished zooplankton community and adversely affect the balance of the lake ecosystem.

II. Introduction

Zooplankton Community

The two principal groups of lake zooplankton are in the sub-Phylum Crustacea (Phylum Arthropoda) and in the Phylum Rotifera. The dominant crustacean herbivores in temperate lakes are the water fleas (taxonomic Order Cladocera), particularly the families Daphnidae and Bosminidae. The genus *Daphnia* is comprised of the largest of the herbivorous zooplankton, ranging in size from 1mm-3mm. *Bosmina* are much smaller than *Daphnia* and are usually smaller than 0.3-0.5 mm. Copepods also make up a large portion of the zooplankton community in lakes. Planktonic copepods are primarily of two different types: calanoid copepods and cyclopoid copepods. They are usually between 0.5mm-1.2mm. Copepods can be omnivorous, herbivorous, and some larger species are carnivores of other zooplankton. Rotifers are famously known as “the smallest animals”. They are typically between 0.1 – 0.2 mm in length, though some well-known species in the genus *Asplanchna* reach lengths of 1.0 mm. Species in the genera *Keratella*, *Polyarthra*, *Conochilus* and *Asplanchna* that are present in Conesus Lake are some of the most ubiquitous zooplankters in lakes world-wide.

Herbivorous zooplankton are the primary consumers of phytoplankton in freshwater lake ecosystems. Rotifers all possess a crown of cilia called a corona that helps guide food to their mouth. Crustaceans do not have cilia, instead using a variety of appendages with long bristles to create water currents and concentrate and capture their phytoplankton food. The feeding characteristics of zooplankton are largely determined by the size of the animal. Larger animals typically have higher feeding rates and have the capacity to capture and ingest larger phytoplankton. While Rotifers typically dominate lake zooplankton communities numerically, Crustaceans, by their larger size and greater filtering potential, have a more prominent role in regulating phytoplankton biomass, energy and nutrient distribution in the ecosystem (Chislock, 2012). The Crustacean zooplankters, particularly larger individuals, are in turn a major food source for many smaller fish species and for the juvenile of larger species. They are thus a crucial link to the top predators in the food webs of lakes.

The zooplankton community of Conesus Lake has been well studied, starting with the comprehensive work of H.D. Chamberlain (1975), who described the zooplankton of Skaneateles, Owasco, Hemlock and Conesus Lake. Subsequent studies by SUNY Brockport professor J.C. Makarewicz and Colleagues starting in the 1980's and as recently as 2014 have thoroughly characterized the Conesus Lake zooplankton community and documented significant changes in species composition and dominance. Chamberlain (1975) showed that the large *Daphnia pulex* was the dominant cladoceran occurring in each of 50 sampling dates in 1973 and reaching densities of 36 individuals·L⁻¹ in the summer. During the late 1970's the small baitfish known as the alewife (*Alosa pseudoharengus*) was accidentally introduced and became established in Conesus Lake. Alewife are obligate planktivores that feed primarily on species larger than 0.7 mm. Consequently, by the mid 1980's, the *Daphnia pulex* had all but disappeared and the dominant Cladocera were the much smaller *Bosmina longirostris*. Two species of smaller *Daphnia* (*D. retrocurva* and *D. galeata mendotae*) were still present but not dominant by 1985 (Makarewicz and Forest, 1986) , but they declined even further in subsequent years to the point that specimens are now rarely encountered. In addition to the Cladocera, a large calanoid copepod (*Skistodiaptomus* sp) also disappeared, and *Mesocyclops edax*, the largest cyclopoid copepod in the lake, experienced major declines in abundance. The loss of *D. pulex* and other large herbivorous zooplankton caused significant changes in the phytoplankton community of Conesus Lake. These changes have been documented by Makarewicz (2000, 2016) and included increases in abundance and biomass of phytoplankton and decreased lake water clarity, both trends that persist.

The goal of the present study was to document the diversity and abundance of the Conesus Lake zooplankton community, which was last surveyed in 2014. We were especially interested in determining whether efforts to manage alewife populations by stocking large predatory walleye had been successful in replenishing some of the larger species of zooplankton that all but disappeared in the 1980's.

III. Methods

To determine the species composition, size and biomass of the zooplankton, samples were collected on eight separate dates between June 15th and October 7th, 2021. On each date, a 0.25 m diameter, 80-micron porosity plankton net was lowered, cod-end first, to a depth of 10 m. The net was then towed vertically at a steady pace to the surface. The net opening was equipped with a General Oceanics flowmeter that we could use to determine distance towed in accordance with manufacturer guidelines. Once at the surface, samples were concentrated in the cod end of the plankton net and transferred using a standard turkey baster to a jar provided with 95% ethanol. The final fixative concentration was 50%. From each sample, multiple (n=2-4) 1-mL subsamples were withdrawn from a well-mixed bottle using a 1 mL volumetric pipettor. The pipette tips were cut to enlarge their opening. This modification reduced the volume of the tip by about 2% and all counts were corrected for the appropriate sample volume. All zooplankton were counted under a compound microscope at a magnification of 100X; genus/species identifications were confirmed at 400X. Crustacea taxonomy followed the image-based key of Haney et al. (2013). Rotifers were also identified using Stemberg's (1979) *Key to the Rotifers of the Laurentian Great Lakes*. We were unable to reliably distinguish between various species of rotifers in some of the most speciose genera (i.e., *Keratella spp.*, *Ploesoma spp.*, *Polyarthra spp.* and *Trichocerca spp.*). For these taxa we report numbers for the whole genus.

Size measurements were used calculate the biomass of each species or genus on each sampling date. For the abundant species in our samples, measurements were made on the first 20 individuals encountered in each sample. Calculations of dry weight followed the procedures and used conversion constants recommended by the EPA in the Standard Operating Procedure for Zooplankton Analysis (LG 403, Revision 7/2016). We did not count the necessary specimens to generate direct estimates of biomass for some of the rarer species. Instead, for those taxa we estimated biomass by multiplying their abundance times the length to dry weight conversions reported by Makarewicz and Lewis (2014). The conversion factors were taken from dates in 2014 that corresponded to our own collection dates.

To study the vertical distribution of rotifers and some of the abundant crustaceans, samples of known volume were collected from discrete depths on 8/5, 9/5, 10/7 and 10/28 using a 2.2 L Van Dorn sampler. Triplicate collections were made from depths of 1, 3, 5, 9 and 13 m. For each depth, the Van Dorn samples were combined to achieve a volume of 6.6 L. The sample was then concentrated to a volume of 50-125 mL using an 81-micron mesh sieve and transferred to a known volume of 95% ethanol to achieve a final fixation at 45-50% ethanol. To determine the abundance of zooplankton at each depth, we analyzed 3-4 subsamples using a Sedgewick-Rafter chamber at a magnification of 100x as described above. Because of the smaller sample volume, sample sizes for the profiles were small, from a low of 48 individuals on 10/28 to a high of 416 on 9/5. Because such limited sample sizes would be unlikely to provide reliable estimates of concentration, the results of the vertical profiles are reported in terms of relative abundance.

IV. Results and Discussion

Crustacean Community Trends

Eight species of crustaceans were recorded, including four cladocerans and at least four species of cyclopoid copepods (**Table 1**). Copepod nauplius larvae and copepodites (juveniles copepods) were also collected but could not be assigned to more specific taxonomic categories. The peak abundance of crustaceans (not including nauplius larvae) was in mid-July with an average of more than 250 thousand individuals \cdot m⁻³ in the upper 10 m (**Fig. 1**). Abundance declined in early September, but increased once again in October as the lake entered its fall bloom period (See **Table 2** for trends in water clarity that track phytoplankton biomass). A similar pattern of abundance was seen in Conesus Lake in previous surveys by Makarewicz and Colleagues (e.g., 1986, 2014). Crustacean abundance in 2021 was generally higher than the long-term median (**Fig. 1**), but this difference can be explained by the fact that previous studies sampled to greater depths, where zooplankton are less abundant or nearly absent. Total biomass followed the same seasonal pattern.

Only one specimen of *Daphnia* (identified as *D. retrocurva*) was found in our collections (**Table 1**). The large (>1.0 mm) *Daphnia pulex* that were dominant in Conesus Lake prior to the arrival

of the alewife are now extremely rare or gone. Similarly, a large species of calanoid copepod (*Skistodiaptomus* sp.) that was common before the alewife invasion and was recorded by Makarewicz and Lewis in 2014 was not seen in any of our samples (See **Table 3** for historical zooplankton community trends).

As in previous studies of the post-alewife Conesus Lake ecosystem, the most abundant crustacean was *Bosmina longirostris* (**Table 3**) and the seasonal trends in its population dynamics dominate the Crustacea numbers (**Fig. 1**). At an average size of 308 μm , *Bosmina* is too small to be captured efficiently by alewife. Only one specimen of *Daphnia* (identified as *D. retrocurva*) was found in our collections (**Table 1**). The large (>1.0 mm) *Daphnia pulex* that were dominant in Conesus Lake prior to the alewife invasion are now extremely rare or gone. The average length of Crustaceans in Conesus Lake for 2021 was 0.35 mm (**Table 3**). This number is essentially unchanged since the first post-alewife studies of zooplankton in 1988. Compared to data from 2009 and 2014, crustacean biomass in 2021 was 15% higher, but that difference can be explained by differences in the depth of sampling between the earlier studies (0-15 m) and the present study (0-10 m).

Rotifer Community Trends

Eighteen different types of rotifers were recorded in 2021 (**Table 1**). Diversity at the species level was undoubtedly higher than this number, as we could not reliably distinguish among several species within the genera *Keratella* (n=4), *Ploesoma* (n=2), *Polyarthra* (n=4) *Trichocerca* (n=2) and *Synchaeta* (n=2) that were among the total of thirty species reported by Makarewicz and Lewis (2014). Peaks in abundance occurred in mid-July and in early October 2021, when rotifer densities exceeded 300 thousand individuals $\cdot \text{m}^{-3}$ (**Fig. 2**). As with the crustaceans, there was a significant decline in abundance during mid-summer, especially in August. A similar seasonal pattern in rotifer abundance can be seen in the historical data, although the peaks and lows occur earlier in the season (**Fig. 2**). The two most abundant rotifer groups in 2021 were the genera *Keratella* and *Polyarthra*, which on average account for nearly 70% of rotifer numbers and 54% of the biomass and dominate seasonal trends in rotifer population dynamics (**Fig. 2**) much as *Bosmina* dominated crustacean trends. A third rotifer

taxon that is important to both numerical abundance and biomass is *Asplanchna priodonta*, which in terms of size and biomass is on average about 5 and 7 times bigger than other rotifers.

The average rotifer abundance for the season was 221 thousand individuals · m⁻³. Compared to the historical record, this average is consistent with numbers reported in 2004, 2009 and 2014 (**Table 3**) but much lower than pre-2000 averages. We conducted a more focused analysis of rotifer community trends by comparing average abundance from 1985-1999 (6 years) to data from 2004-2021(4 years). The results, shown in **Fig. 3**, reveal an average statistically significant loss in rotifer numbers (ANOVA p<0.007) of more than 60% after 1999. The collapse of the rotifer community coincides with the establishment of widespread adult populations of zebra mussels in Conesus Lake (Bosch personal observation). MacIsaac and Colleagues (1995) have shown that by the time zebra mussels are fully grown they feed as effectively on rotifers as they do on phytoplankton. Studies from a variety of fresh water systems, including Lake Erie, Lake Champlain and the Hudson River, have shown that the diversity and abundance of rotifers declined after the arrival of zebra mussels (e.g., Pace *et al.*, 1998; Carling *et al.*, 2004). We now have strong evidence that a similar scenario played out in Conesus Lake.

Vertical Distribution

To our knowledge, the vertical distribution of zooplankton in Conesus Lake has not been thoroughly studied. This is information that could be useful in monitoring the zooplankton community. For this study, discrete depth sampling was accomplished by collecting samples from of 1,3, 5, 9 and 13 m using a 2.2 L horizontal Van Dorn water sampler. Crustacea distribution was studied on August 5th while rotifer distribution was studied on August 5th, September 5th, October 7th and October 28th. Because of the small sample size, the results are reported as % relative abundance at each depth. Temperature and oxygen profiles of the water column were obtained so that patterns of distribution could be considered in the context of water column stratification.

The August 5th data for *Bosmina*, *Ceriodaphnia* and copepod nauplius larvae are shown in **Fig 4**. *Ceriodaphnia* and nauplii were found only in the upper 5m of the water column. *Bosmina* were found primarily in the upper 9 m with less than 2% of the 307 individuals collected living at 13

m. A temperature profile obtained for August 5th showed that crustacean distribution was associated with the mixed layer. Only a few individual *Bosmina* were found below the thermocline. A second species that we found was more abundant in deeper water was the large cyclopoid *Mesocyclops edax*. However, a small sample size does not permit any general conclusions about the distribution of this species.

Rotifer distribution on all dates was also principally relegated to the mixed layer (**Fig. 5**) above the thermocline. Less than 5% of individuals were found below thermocline on 8/5 and 9/5 (see temperature profiles on Fig. 5, bottom right panel). The thermocline deepens in September and October, extending the mixed layer into deeper waters, and on those dates the vertical distribution of rotifers deepened accordingly.

From these results we conclude that the bulk of the zooplankton is to be found in the mixed layer and not in the deeper deoxygenated region of the lake (See oxygen and temperature profiles for the season in **Fig. 6**). Any future monitoring of the zooplankton should be targeted to a depth of 10 m, encompassing the mixed layer. Net sampling that integrates deeper waters would tend to underestimate the abundance and biomass of the community, the bulk of which is found in the epilimnion.

V. Conclusions

The invasion of Conesus Lake by the alewife in the late 1970's and by zebra mussels in the mid 1990's significantly altered the lake's zooplankton community. Alewife size-selective predation removed multiple species of large Crustacea zooplankton, in turn reducing the intensity of herbivory on the phytoplankton and restructuring the central food web of the open waters. The lake has also experienced major loss (>60%) in rotifer abundance, presumably due to feeding by the invasive mussel. In short, the zooplankton and by extension the open water food web of Conesus Lake has been altered dramatically by invasive species. We conclude that efforts to prevent invasion of the lake by other zooplanktivores, such as the spiny water flea (*Bythotrephes longimanus*) should be intensified, as any new invaders would likely further compromise an already impoverished zooplankton community, which would likely have adverse effects on the balance of the lake ecosystem.

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TABLES

Table 1. Summary of zooplankton species composition in Conesus Lake compiled for 8 dates from June 15 to October 7, 2021. Biomass (dry wt.) was calculated from measurements of individual size averaged for the whole collection period (shown on table). For species that were rare, average biomass measurements were taken from Table 8 in Makarewicz (2014). Data for the individual sampling dates are shown in Appendix 1.

		Average Values June 15 to October 7 2021				
Sub Phylum Crustacea		Abundance	Perecent	Biomass	Percent	Weighted
Order Cladocera		# /m ³	Abundance	µg/m ³	Biomass	Size µm
<i>Bosmina longirostris</i>		119,127	28.97	90,417	62.67	308
<i>Ceriodaphnia sp.</i>		20,497	4.98	7,424	5.15	295
<i>Daphnia retrocurva</i>		19.6	0.005	8	0.01	
<i>Diaphanosoma sp.</i>		39.3	0.01	38	0.03	
Total Cladocera		139,683	33.96	97,888	67.85	
Order Cyclopoida						
<i>Cyclopoid copepodites</i>		2,645	0.64	264	0.18	356
<i>Diacyclops thomasi</i>		4,304	1.05	1,834	1.27	532
<i>Mesocyclops edax</i>		7,404	1.80	9,885	6.85	708
<i>Mesocyclops sp.</i>		78.6	0.02	132	0.09	
<i>Microcyclops spp.</i>		9,765	2.37	5,213	3.61	562
Total Cyclopoida		24,196	5.88	17,328	12.01	
Total Crustacea		163,879	39.85	115,217	79.86	
Copepoda Nauplii						
Copepod Nauplii		22,702	5.52	9,081	6.29	205
Total Nauplii		22,702	5.52	9,081	6.29	
Phylum Rotifera						
<i>Ascomorpha species</i>		2,523	0.61	55	0.04	
<i>Asplanchna priodonta</i>		9,891	2.41	9,449	6.55	510
<i>Asplanchna sp.</i>		1,283	0.31	119	0.08	
<i>Branchionus rubens</i>		133	0.03	4	0.003	130
<i>Collotheca sp.</i>		464	0.11	39	0.03	
<i>Conochilis unicornis</i>		21,074	5.12	252	0.17	
<i>Gastropus sp.</i>		303	0.07	9	0.01	
<i>Kellicottia bostonensis</i>		195	0.05	0.8	0.001	
<i>Kellicottia longispina</i>		1,672	0.41	11	0.01	
<i>Keratella species</i>		72,476	17.62	198	0.14	111
<i>Keratella quadrata</i>		2,653	0.65	215	0.15	152
<i>Monostyla commuta</i>		47	0.01	0.6	0.0004	
<i>Ploesoma species</i>		11,324	2.75	422	0.29	155
<i>Polyarthra total spp</i>		77,647	18.88	7,141	4.95	150
<i>Pompholyx campanata</i>		473	0.12	7	0.005	
<i>Pompholyx sulcata</i>		795	0.19	11	0.01	
<i>Synchaeta sp.</i>		531	0.13	51	0.04	
<i>Trichocerca species</i>		17,759	4.32	888	0.62	119
Total Rotifera		221,243	53.80	18,872	13.08	
Order Veneroida						
<i>Dreissena veligers</i>		3434	0.83	1,099	0.76	
Total veligers		3434	0.83	1,099	0.76	
Total Zooplanktor		411,258	100.00	144,268	100.00	

Table 2. Measures of water column clarity through most of the phytoplankton growing season. The trends show a drop in water clarity during the last two weeks of July, as indicated by shallow Secchi depths (m), high light attenuation coefficients (k) and high turbidities (NTU).

Date	Secchi Depth (m)	Avg Light Att. Coeff. (k)	Turbidity (NTU) 1m	NTU 3 m	NTU 5 m	NTU 7 m	NTU 10 m
22-May	2.5		1.65				
2-Jun	3.2	0.403 ± 0.062	1.20				
11-Jun	3.7		1.60	1.75			
15-Jun	2.8	0.269 ± 0.167	1.35	1.25	2.35	2.30	1.30
18-Jun	2.65	0.415 ± 0.180	1.55	1.75	1.45	1.45	1.75
24-Jun	ND	0.421 ± 0.113	2.65	2.60	2.45	2.15	1.65
1-Jul	2.1		1.50	3.40	2.40	1.90	1.70
9-Jul	2.6	0.441 ± 0.119	2.05	2.00	2.15	1.75	1.70
15-Jul	1.8		3.30	2.95	2.50	1.90	1.75
20-Jul	1.55	0.628 ± 0.194	3.55	3.50	3.90	4.60	3.00
22-Jul	1.65	0.753 ± 0.149	4.00	3.60	3.10	2.80	2.30
27-Jul	1.5		3.45	3.55	2.80	1.90	1.85
5-Aug	2.4		2.30	1.75	1.70	1.70	
16-Aug	ND		1.50	2.00	1.75	1.55	
2-Sep	1.48		2.75	2.55	2.55	5.00	
9-Sep	2.75	0.611 ± 0.120	1.60	2.00	1.55	2.80	
7-Oct	2.3	0.648 ± 0.061	1.80	2.00	1.90	1.60	
28-Oct	1.1	1.27 ± 0.264	4.40	4.30	4.60	4.30	

Table 3. Long-term trends in Crustacean biomass and Rotifer abundance in Conesus Lake. Most Data through 2014 are taken from various reports by Makarewicz and colleagues and especially from Makarewicz and Lewis (2014). Notable trends include the extirpation of large calanoid copepods and *Daphnia* species primarily by alewife predation, the decline in rotifer abundance coinciding with the establishment of zebra mussels by 1999, and the increase in Cladocera (specifically *Bosmina longirostris*) coupled with the decline in cyclopoid copepods in 2021.

Zooplankton Biomass Indicators (mg/m ³)											
	1972	1985	1988	1991	1993	1996	1999	2004	2009	2014	2021
Crustacea	228	182	99	99	71	216	81	57	105	102	115
Calanoida	30	7	0	0	0	0.1	0	0	0	0.04	0
Cyclopoida	52	113	15	40	31	122	39	28	61	68	17
Cladocera	146	62	84	59	40	94	42	29	44	34	65
<i>Daphnia</i> spp.	87	23	3	0	1	3	0.1	1	1	0.01	0.01
<i>Bosmina longirostris</i>	NA	11	61	NA	27	NA	NA	24	34	32	64
<i>Ceriodaphnia</i> sp.	NA	0.7	4	NA	1	NA	NA	8	11	2	3
Crustacea Length (mm)	1.03	0.47	0.29	0.28	0.32	0.34	0.29	0.20	0.36	0.38	0.35
Rotifer density (ind/L)	NA	567	1235	795	461	846	855	310	139	400	202

Figures

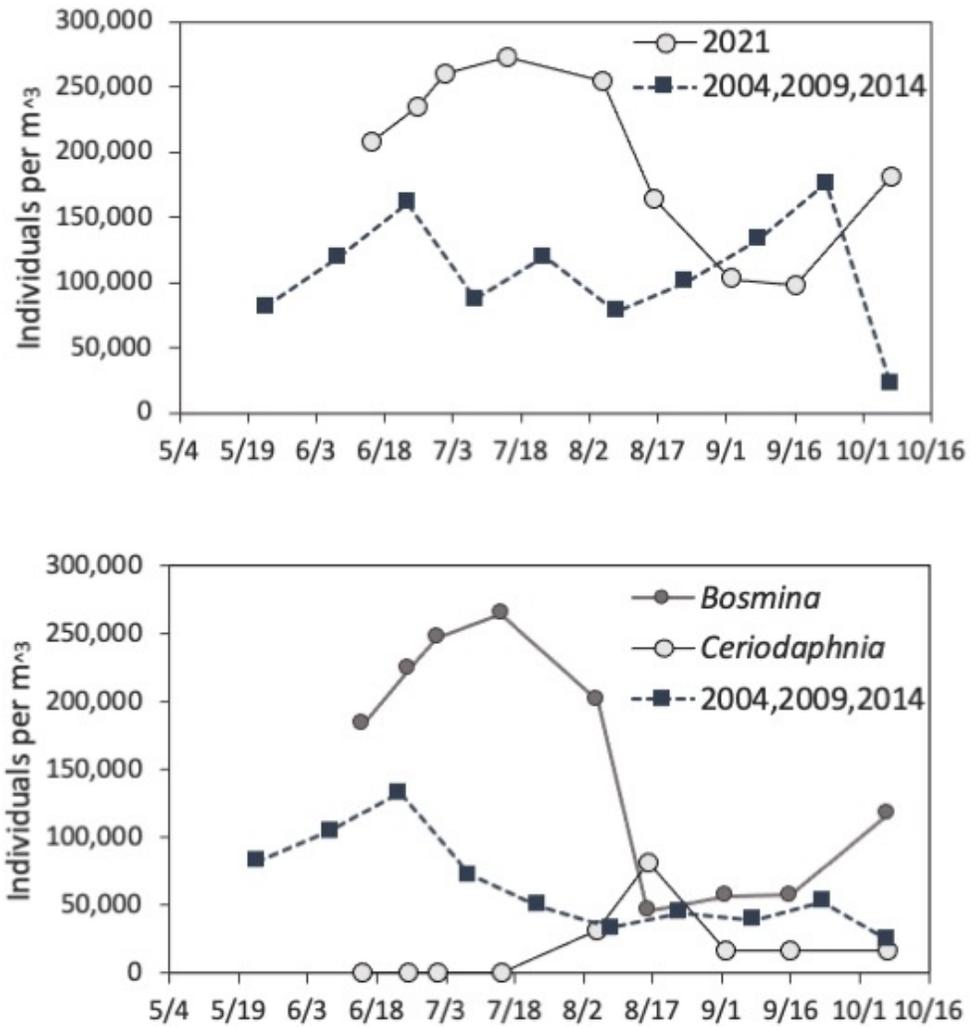


Figure 1. (Top) Crustacea seasonal trends for all species (nauplii larvae not included) in 2021 compared to the median for the years 2004, 2009 and 2014 sampled by Makarewicz and Colleagues. (Bottom) Seasonal abundance for *Bosmina* and *Ceriodaphnia* in 2021 compared to median values of *Bosmina* abundance in 2004, 2009 and 2014.

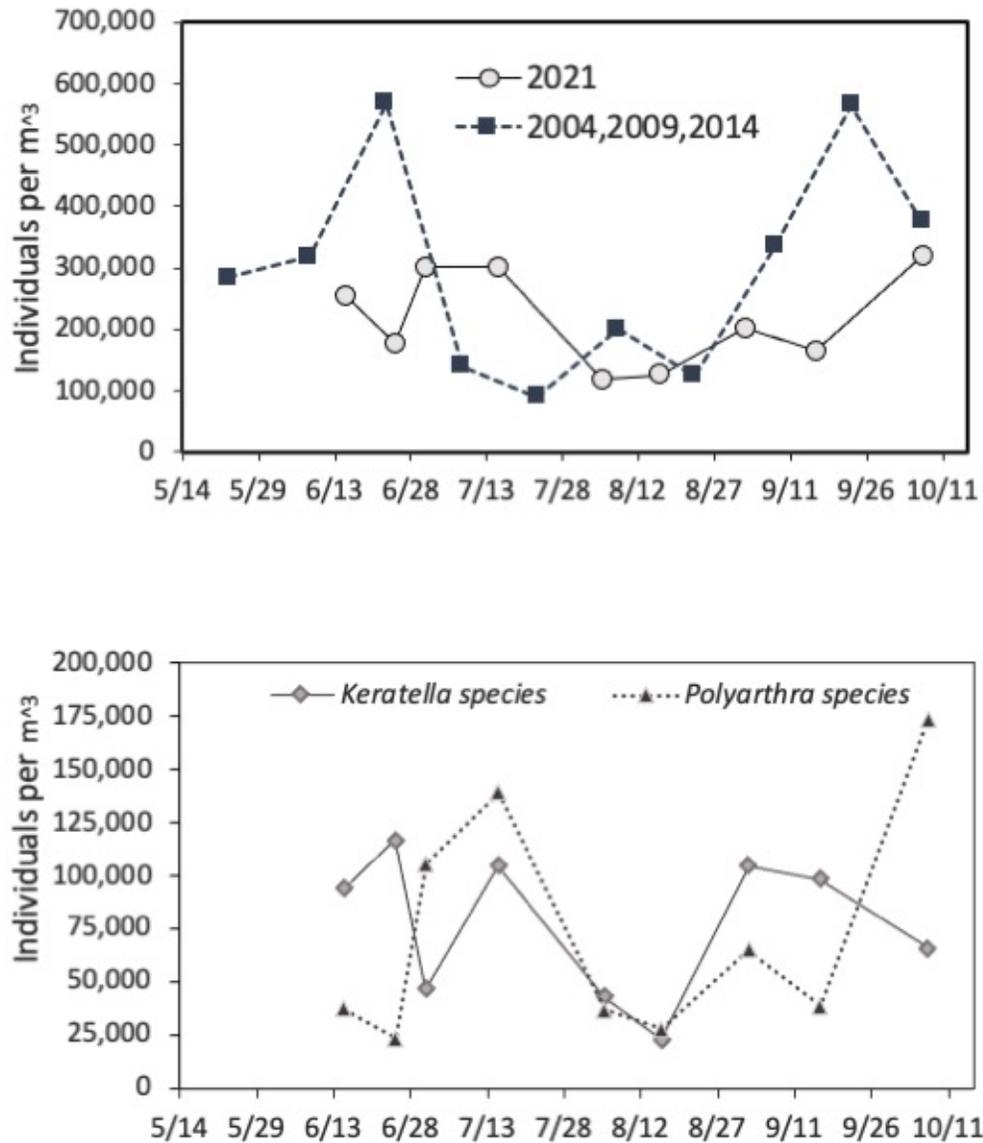


Figure 2. (Top) Rotifer seasonal trends for all species in 2021 compared to the median for the years 2004, 2009 and 2014 sampled by Makarewicz and Colleagues. Both sets of data show a decline in abundance from about mid-July to mid-August. (Bottom) In 2021, August decline in populations is accounted for by drops in abundance of species in the genera *Keratella* and *Polyarthra*, which are the two most abundant rotifer groups in Conesus Lake.

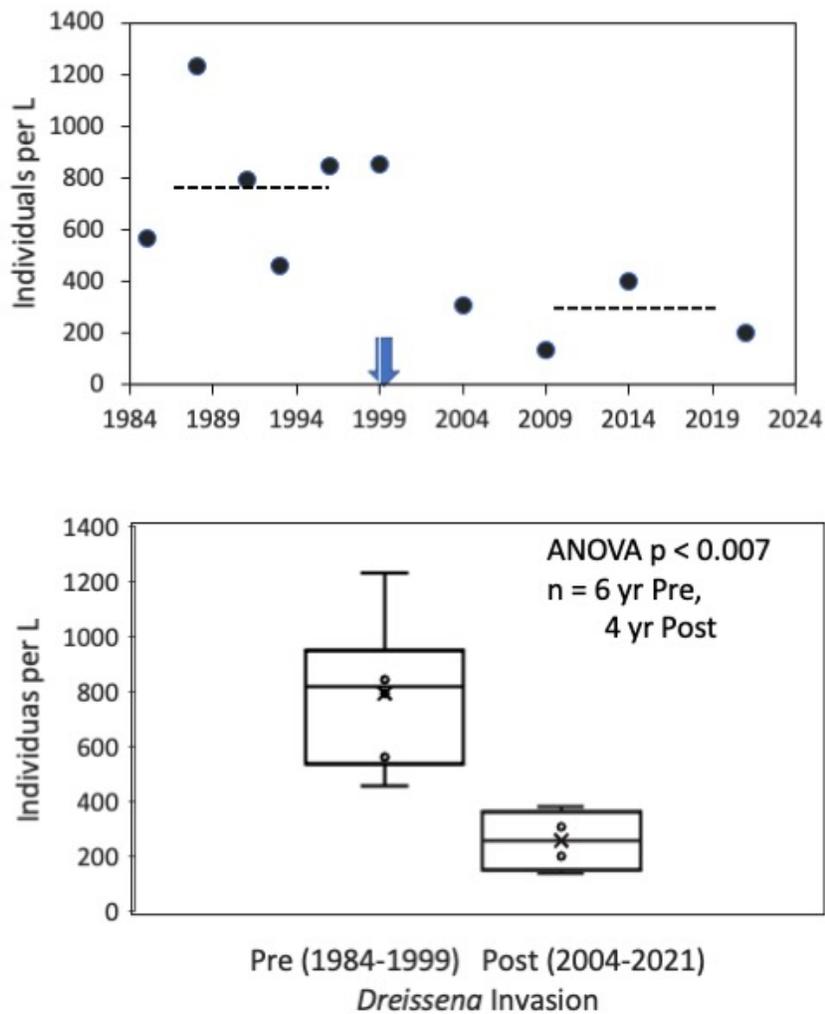


Figure 3. Historical analysis of Rotifer abundance showing a significant downturn after 1999, the year that zebra mussel adult populations became prominent in Conesus Lake. (Top) Numbers of individuals per liter averaged for whole sampling seasons (n= 10 years) with arrow showing the year when zebra mussel populations first peaked. Dashed lines indicate the mean abundance. (Bottom) Box plots comparing mean abundance up to 1999 to mean abundance after 1999. The means were significantly different (ANOVA $p = 0.007$).

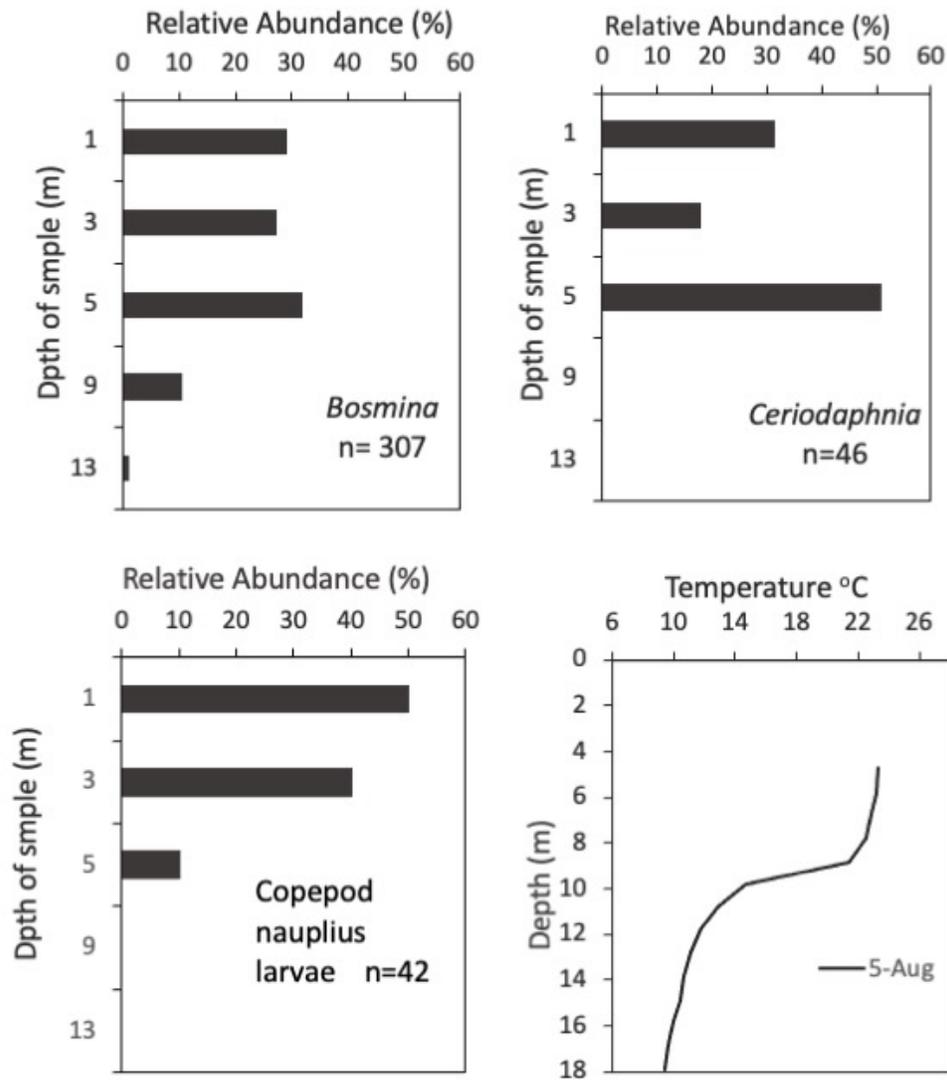


Figure 4. Relative depth distribution of various crustacean groups in relation to the stratified water column on August 5th, 2021. (Top) The dominant cladocerans, *Bosmina longirostris* and *Ceriodaphnia sp.*, are found almost exclusively in the epilimnion. (Bottom) copepod nauplius larvae were found only in the upper 5 m on this date. All three groups were absent from the colder waters of the hypolimnion as indicated by the temperature graph (bottom right).

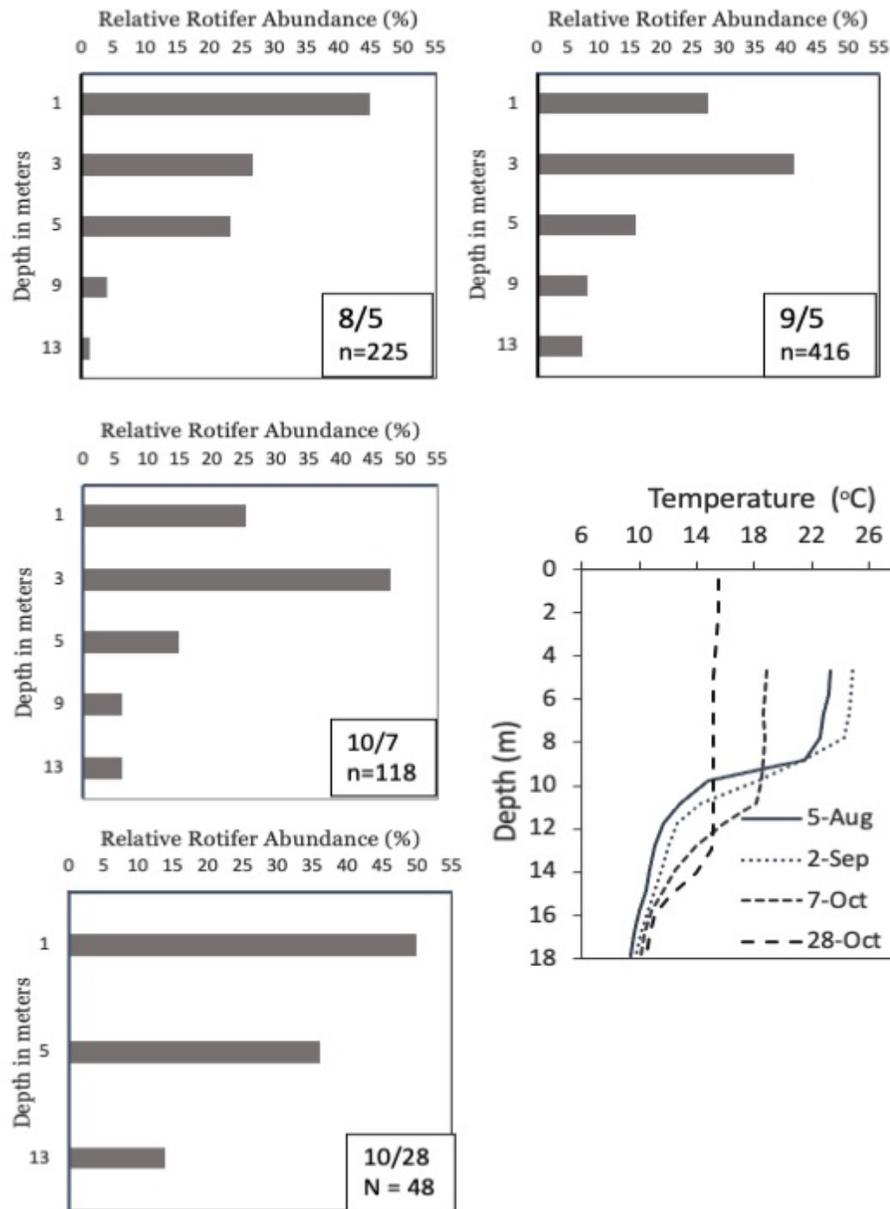


Figure 5. The relative depth distribution of rotifers in the stratified water column, from August to end of October, seems to be constrained to the mixed layer and only extends to 13 m as the thermocline deepens in October (see temperature graph bottom right). Despite this deepening phenomenon, 95% of the rotifer population on average was found in the mixed layer samples (1,3,5 and 9m).

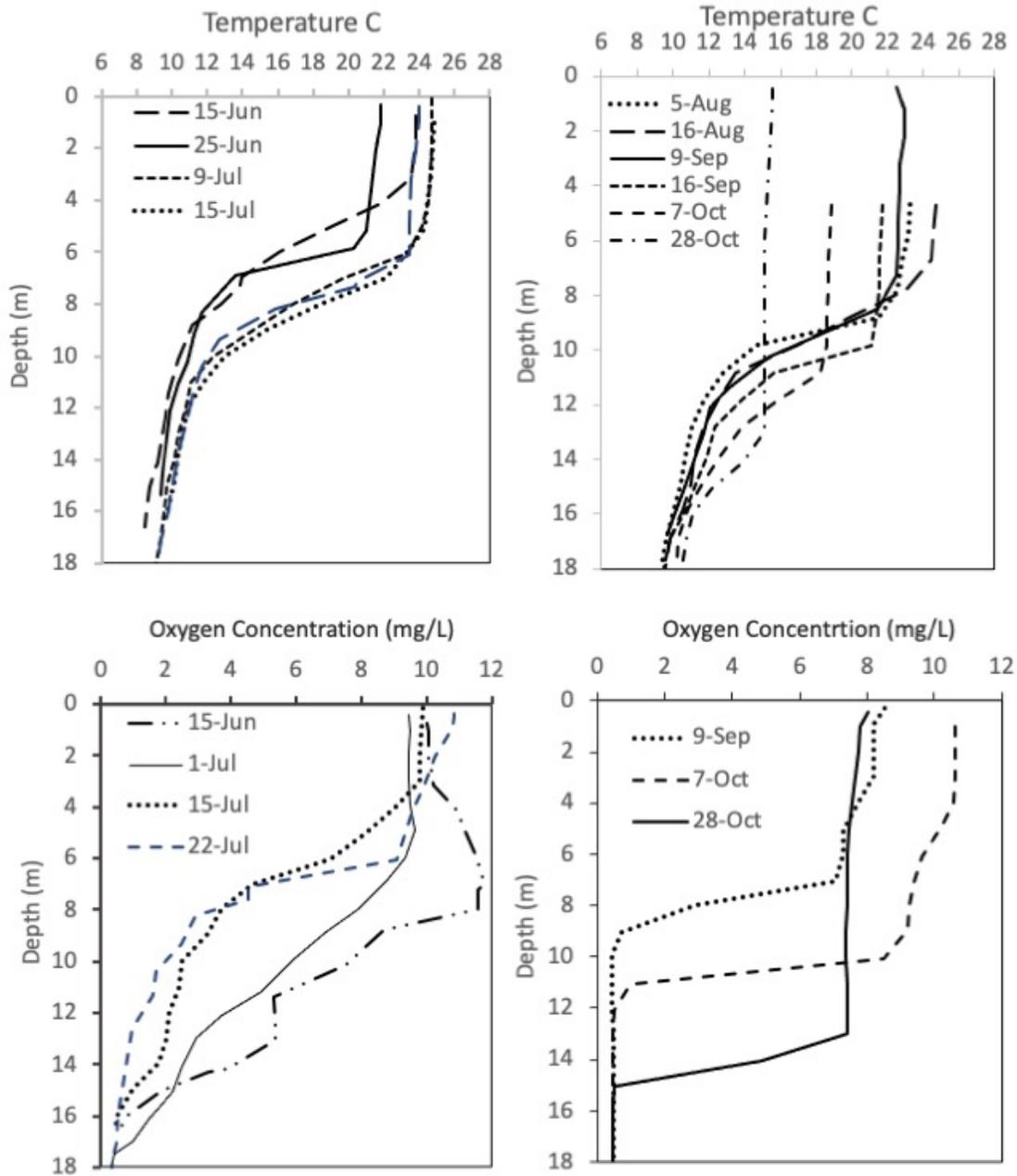


Figure 6. Temperature (top) and oxygen (bottom) graphs illustrate the summer stratification and definition of the mixed layer, where most zooplankton were distributed in this study. The low oxygen concentrations below the thermocline would be inhospitable to most active zooplankters. As stratification breaks down and oxygen is supplied to greater depths, the zooplankton are also distributed into deeper waters (see Figure 4).

**II. Follow-up Study of Eurasian Watermilfoil Biomass
in the Cottonwood Gully, Sutton Point Gully,
Graywood Gully and North Gully,
Macrophyte Beds**

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I. Summary

- We sampled to determine the biomass of the milfoil dominated beds at Sutton Point Gully and Cottonwood Point Gully, that had failed to develop significantly in 2020. The North Gully and Graywood Gully macrophyte beds were sampled to provide a reference as beds that had developed normally in 2020.
- The results for the two reference beds indicated that 2021 was a year of vigorous milfoil growth.
- At the Sutton Point Gully bed, the milfoil had returned into the northern portion of the normal bed and attained densities that were near the high ever recorded for the site. The southern portion of the bed remained dominated by other species, primarily eelgrass (*Vallisnaria americana*). While this bed had certainly not reacquired its full range, it is clear that it is on a trajectory to recover its normal habitat.
- The Cottonwood Gully bed remained sparse, with biomass comparable to 2020. But it is clear from our mapping of the bed that the milfoil had once again started to spread into its normal range. We conclude that this bed is on a slower trajectory toward milfoil recovery than the Sutton Point Gully bed, but it will eventually regain its more typical density and coverage.
- We find no conclusive evidence that milfoil may be on a major decline in Conesus Lake. In fact, the opposite may be true, especially in the central and northern regions of the lake.

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Table 1. Quadrat biomass of milfoil dominated areas in Conesus Lake macrophyte beds.

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II. Introduction

- In 1999, Bosch and colleagues (1999) identified *Myriophyllum spicatum*, commonly known as Eurasian watermilfoil, as the overwhelmingly dominant macrophyte in Conesus Lake. Mapping of regions where the largest macrophyte beds were located showed that the densest watermilfoil dominated beds were located in the proximity of streams, where ample shallow habitat and consistent delivery of nutrients from stream runoff would promote growth of macrophytes (Bosch *et al.*, 1999). Since the 1999 study, the watermilfoil-dominated macrophyte beds have been studied frequently (e.g., Bosch *et al.*, 2009; Bosch and students, 2012). The most recent comprehensive study of the milfoil beds was completed in 2020 (Bosch and Colleagues 2021). The study concluded that Eurasian watermilfoil biomass in some of the Conesus Lake beds appears to be on the decline relative to historical values but other beds were at average or above average biomass. For example, the Sand Point and North Gully Cove beds had above average biomass in 2020, but there was very limited bed development and growth at the Sutton Point and Cottonwood Gully locations and in fact, throughout most of the south basin of the lake. According to the authors, no single factor could account for the spatial differences that were observed, but it is possible that the declines may have been part of natural growth cycles of milfoil dominance that had been observed in the past. Eurasian watermilfoil has been known to overwinter as metabolically active plants, or as quiescent degraded shoots, but occasionally it has been reported that whole beds can die-off, overwintering only as roots. In that case, the bed does not replenish itself during the first year of re-growth and it may be a year or more before regrowth restores full biomass (Bosch, personal observations).

In August 2021 we conducted a limited study of the macrophyte beds at Sutton Point and Cottonwood Gully, where growth was very limited in 2020. The Graywood Gully and North Gully macrophyte beds were used as reference for normal growth. Our goal was to determine if these beds had continued to regrow to their original dimensions. Alternatively, the losses of milfoil in these and other regions of the South Basin might represent a general trajectory of decline rather than be part of a normal multi-year growth cycle.

III. Methods

SCUBA diver and snorkeling study of the Sutton Point, Cottonwood Gully, North Gully and Graywood Gully macrophyte beds were conducted between August 9-20th, 2020. Quantitative quadrat samples were collected by SCUBA divers along the same three transect lines and depths surveyed in previous years. The methods used to quantify macrophyte biomass are described in a previous technical report (Bosch *et al.*, 2012). A more detailed account can be found in the published studies of the U.S.D.A. Watershed Study (Bosch *et al.* 2009).

To determine aquatic plant biomass, replicate quadrat samples (usually 3 at each depth) were collected at depths of 1, 2, and 3 m along three transects that were approximately the same as those used in previous studies. There was little or no growth at 4 m so no samples were collected at those depths. A 0.5m x 0.5m quadrat constructed from PVC pipe was placed on the bottom and all shoot biomass was harvested by hand. Each sample was placed in a numbered plastic collection bag and taken to the laboratory for species sorting and zebra mussel removal. Plant species within each sample were blotted dry with paper towels and weighed separately to the nearest 0.1g with an electronic scale. The blotted dry weights were used for all analysis in this study.

The surface area of the macrophyte beds and the milfoil-dominated area of the beds were mapped at each site using global positioning systems (GPS). To record points, a Garmin was used by an individual aboard a boat while a swimmer indicated points to be mapped around the perimeter of milfoil dominated areas in each bed. The waypoint data was downloaded from the Garmin onto an Excel spreadsheet then uploaded into Google Earth. Georeferenced maps of the perimeter of the beds were generated using all of the waypoints collected. The Google Earth Path function was used to determine the surface area of each bed. This procedure was conducted in triplicate to estimate the error of this methodology. Standing crop in Kg total weight was calculated for each site by multiplying the average quadrat biomass for the 2-3 m samples dominated by watermilfoil times the surface area of the milfoil dominated region.

IV. Results and Discussion

Biomass data for the milfoil-dominated beds at Cottonwood Gully and Sutton Point Gully and that for the two reference sites studied in 2021 are shown in **Table 1**. Several interesting trends stand out in this comparison. First of all, there was no growth of milfoil at 1 m in any of the sites. Similarly, very few plants were ever observed at depths of 4 m, so we did not sample at those depths. Historically Conesus Lake has had significant growth of macrophytes at 4 m and even deeper. The absence of growth at the greater depths in recent years is an indication that the lake has become more turbid and that plants simply do not receive enough light to grow at those depths. A second important interesting trend is the high biomass found at the two reference sites. In 2021 we observed that these two beds in particular were very dense with milfoil. In fact, if we examine the long term data set for these two sites we can see that 2021 was a record year for milfoil biomass density in both (See **Tables 2 and 3**).

The Sutton Point Gully milfoil bed, which had been sparse in 2020 was found to also have localized areas of high density in 2021, particularly toward the northern region of the bed that historically has always had the highest biomass. However, other regions of the bed, specifically its southern extension, still were mostly lacking milfoil with eelgrass (*Vallisneria americana*) being the dominant species. The surface area of the Sutton Point Gully bed is still well below its long term maxima, and that contributes to an overall low standing crop of milfoil, but it is important to notice that all of these growth/biomass metrics in 2021 are considerable higher than they were in 2020 (**Tables 1 and 2**), indicating that the bed is slowly returning to its expansive milfoil dominated state.

The condition of the Cottonwood Gully bed is a bit more difficult to characterize. While it does appear that the milfoil density remains low (**Table 1**) the surface area covered by milfoil increased significantly between 2020 and 2021, and consequently so did the standing crop. It is possible that as with the Sutton Point bed, Cottonwood Gully is returning to a dense milfoil equilibrium, albeit more slowly. Nevertheless, in the last 3 years that this area has been studied (2021, 2020 and 2021) the surface area and standing crop of the milfoil bed has been very low compared to the long term averages. Therefore, it is possible that the Cottonwood Gully milfoil bed has settled into a more moderate state of growth. Why this would happen, and why two beds

in the same southwest region of the lake should show different trajectories defies simple explanation.

V. Conclusions

The results of our limited 2021 monitoring of four macrophyte beds in Conesus Lake shows that for the two reference sites this was a year of vigorous milfoil growth. Meanwhile, at the Cottonwood Gully and Sutton Point Gully sites that had little or no milfoil bed in 2020, the milfoil seems to be returning. This was particularly the case at Sutton Point Gully, where the Eurasian watermilfoil growth in northern reach of the bed was vigorous and achieved very high biomass. By contrast, the southern portion of the bed was still without significant milfoil, and eelgrass seems to have taken over the vacated habitat. We hypothesize that this will change in the next year or two, and that this bed will soon regain its dense and broad milfoil habitat. In the other bed in question at Cottonwood Gully the milfoil density remained low but there were signs that the area of habitat occupied by milfoil was increasing, and it is quite possible that this bed is also on the rebound, albeit more slowly than Sutton Point. Conversely, in the last three years that this area has been sampled the milfoil biomass was very low compared to what was seen from 2000-2010 and it may be that milfoil has settled into a less dominant phase.

VI. Acknowledgements

We thank SUNY Stony Brook undergraduate Jenna Inglese for her work on this project and for all of her help with the summer monitoring program.

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VIII. Tables

Table 1. Quadrat biomass of milfoil dominated areas in Conesus Lake macrophyte beds. The trends indicate that areas of Sutton Point Gully have been re-occupied by milfoil, which at a depth of 2m had regained biomass density that is comparable to that of the reference sites at Graywood Gully and North Gully. In contrast, the Cottonwood Gully bed continues to be small and very sparse, and in the last two years has not regained its size and milfoil biomass density.

Milfoil Bed Location	Aug 2020 Mean \pm S.D.	Aug 2021 Mean \pm S.D.
Graywood Gully		
1 m	No Milfoil	No Milfoil
2 m	437 \pm 257	494 \pm 268
3 m	260 \pm 192	665 \pm 564
North Gully		
1 m	No milfoil	No milfoil
2 m	374 \pm 105	556.4 \pm 219
3 m	236 \pm 80	529.5 \pm 201
Cottonwood Gully		
1 m	No Milfoil	No Milfoil
2 m	178 \pm 33	152 \pm 46
3 m	No plants	No plants
Sutton Pt. Gully		
1 m	No milfoil	No milfoil
2 m	210 \pm 121	445 \pm 141
3 m	No plants	342 \pm 135

Table 2. Long-term monitoring history of the Sutton Point macrophyte bed accompanied by the North Gully reference site sampled in 2021. The Sutton Point data shows significant biomass density but still reduced surface area compared to its historical record. Overall, the standing crop of milfoil was still moderate, especially compared to its history and to the trends in North Gully, but there are certainly signs that this bed is returning to its milfoil dominated state.

Location	Year	Average Biomass grams . m ²	Surface Area m ²	Standing Crop Kg Dry Wt
Sutton Point	2000	184 ± 43	---	---
	2001	467 ± 183	8,592	4,017
	2002	71 ± 40	3,688	262
	2003	138 ± 92	11,819	1631
	2004	227 ± 77	11,909	2,703
	2005	197 ± 90	11,995	2,349
	2006	364 ± 208	7,438	2,707
	2007	295 ± 94	10,973	3,232
	2008	190 ± 106	5,985	1,201
	2009	224 ± 112	13,802	3,099
	2010	135 ± 47	7,390	998
	2012	270 ± 57	6,610	1,785
	2020	210 ± 121	343	72
	2021	394 ± 142	2,856	1,125
North Gully	2000	262 ± 134	23,192	6,192
	2001	459 ± 202	25,783	11,834
	2002	151 ± 74	12,004	1,813
	2003	304 ± 176	19,760	6,007
	2004	186 ± 57	30,099	5,598
	2005	188 ± 105	21,798	4,098
	2006	230 ± 100	22,560	5,178
	2007	225 ± 70	27,850	6,266
	2008	266 ± 167	11,855	3,149
	2009	283 ± 108	24,267	6,874
	2010	265 ± 175	13,325	3,531
	2012	272 ± 153	14,133	3,844
	2020	313 ± 72	8,920	2,792
	2021	514 ± 160	17,660	9,077

Table 3. Long-term monitoring history of the Cottonwood Gully macrophyte bed accompanied by the Graywood Gully reference site sampled in 2021. The Cottonwood Gully milfoil bed biomass and surface area have increased since 2020 but are still well below the maxima recorded for the site. The Graywood Gully milfoil, by contrast, was very dense and its standing crop was at a record high. Nevertheless, it appears that the Cottonwood Gully milfoil bed is growing again, although its trajectory seems to be slower than that of the Sutton Point milfoil bed.

Location	Year	Average Biomass grams . m ²	Surface Area m ²	Standing Crop Kg Dry Wt
Cottonwood Gully	2000	193 ± 85	---	---
	2001	373 ± 168	9,387	3,501
	2002	316 ± 134	7,360	2,326
	2003	146 ± 43	3,750	548
	2004	234 ± 41	9,205	2,154
	2005	273 ± 81	6,880	1,878
	2006	283 ± 61	5,605	1,589
	2007	155 ± 140	8,100	1,253
	2008	-	-	-
	2009	135 ± 78	4,860	657
	2010	252 ± 90	7,077	1783
	2012	154 ± 107	2,283	352
	2020	178 ± 33	269	48
2021	152 ± 45	1,615	245	
Graywood Gully	2000	238	---	---
	2001	412 ± 162		
	2002	193 ± 123	6,703	1,294
	2003	131 ± 79	14,186	1,858
	2004	190 ± 54	26,864	5,104
	2005	230 ± 101	23,988	5,517
	2006	91 ± 37	21,843	1,982
	2007	168 ± 75	27,170	4,572
	2020	233 ± 130	9,780	2,279
	2021	592 ± 333	20,580	12,183