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Assessing Community Structure of Lower Trophic Levels In Onondaga Lake, New York in 2011

2011 Annual Report

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Prepared by

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Introduction

This report summarizes the information collected by Onondaga County and processed by Cornell Biological Field Station. The raw data is in the Onondaga County Bio Database.

The report consists of a method section and a series of tables and figures with our interpretations of the observed patterns.

Methods

Phytoplankton samples were collected approximately biweekly from end of March (3/30) to the middle of December (12/13) in 2011 and preserved in Lugol's Iodine solution. Total number of sampling occasions was 19. Samples were taken at the South Deep station except for 4 occasions when samples were collected at both the North Deep and South Deep stations (4/6, 6/21, 9/20, 11/8). The phytoplankton sample for each date and sampling site is an integrated sample of the upper mixed layer (UML) of the water column. The UML depth is the epilimnion depth when a thermocline is present or is a default of six meters when there is no thermocline. All integrated water samples for phytoplankton analysis were collected using a 2 cm inner diameter Tygon tube.

Phytoplankton samples were processed by PhycoTech, Inc. (Owner Dr. Ann St Amand, 620 Broad St., Ste. 100, St. Joseph, MI 49085). Raw water samples were run through filtration towers, and the filters from these towers were then made into slides. The method used in counting the phytoplankton depended on the relative importance of soft algae and diatoms in the samples as well as algal size. Phytoplankton were identified to species when possible and cells were measured to determine species-specific greatest axial length dimension (GALD) and individual biovolume. Species with GALD>50µm were classified as net-plankton and species with GALD<50µm were classified as nano-plankton. Total biovolume for each species was calculated by multiplying cell concentration by individual biovolume. PhycoTech reported total biovolume in $\mu m^3/mL$, which we converted to cm^3/m^3 (a unit more commonly used in the literature) by dividing by 1,000,000. We also converted total biovolume to algal biomass, assuming density of algal cells was equal to that of water ($1\ g/cm^3$). Converting among units of biovolume and biomass can be cumbersome and different literature sources uses different units. To convert among units use:

$1\ cm^3/m^3 = 1\ g/m^3$
$1\ cm^3/m^3 = 1\ mm^3/L = 1{,}000{,}000\ \mu m^3/mL$
$1\ g/m^3 = 1\ mg/L = 1\ \mu g/mL = 1000\ \mu g/L$

Calculations of zooplankton density, species composition, size structure, and biomass were based on vertical hauls using a 0.50 m diameter net with 80 micron nylon mesh. Vertical tows were taken from the upper mixed layer from a depth of six meters when the lake was thermally stratified and from 15 meters when no thermocline was present. Samples were also collected from 15 meters from July through October in addition to the

6 m upper mixed layer sample. Zooplankton samples were collected at the South Deep site throughout the year and at the North Deep site on 4 dates (4/6, 6/21, 9/20, 11/8). Samples were preserved in 95% ethyl alcohol, this preservative comprising at least 70% of each final sample volume. Flow meter readings were taken on the zooplankton net tows to determine the volume of water strained in each haul. In 2011, calculated efficiency of the net varied between 57 and 121%, with an average of 85% (SE 1.9%, N=37). As expected, efficiency is higher for the shorter upper mixed layer tows (from 6 m) than for the 15-m integrated tows (from 15 m, 6-m tows mean 91.3% efficiency, 15-m tows mean 80.4 % efficiency, t-test, $P<0.014$). However, because flow meter readings are not available for all years, the densities are calculated using the field measured tow depth and assuming 100% efficiency of the net. Also, only the historic samples that are comparable to the current sampling regime and only the South Deep station data are included in the time trends. These restrictions are necessary to allow for comparisons of the same type of data over all years.

A compound microscope (40X-200X magnification) was used to identify zooplankton to species when possible. For each sample, one to three 1-mL subsamples were withdrawn with a pipette from a known volume of sample, until at least 100 individual zooplankton were counted and measured. Zooplankton length was measured using a compound scope equipped with a drawing tube and a digitizing pad interfaced with a computer. Dry mass was estimated for each measured animal from standard species-specific length-weight regressions used in the Lake Ontario Biomonitoring program (Holeck et al. 2008).

Results and Discussion

Data are from 2011 and for the available time series from 1996 to 2011. Analysis is included in the table and figure headings when appropriate. A general discussion follows at the end.

Tables for 2011 data:
Table 1. Biomass (µg/L, dwt) of the major zooplankton groups.
Table 2. Comparison of zooplankton abundance in 15 and 6 m tows from July through October.
Table 3. Phytoplankton abundance and biovolume for the major divisions.
Table 4. Major genera of phytoplankton.

Figures for 2011 data:
Fig 1 Biovolume and proportional composition of phytoplankton of 7 algal division in 2011.
Fig 2 Biovolume of phytoplankton divided in net and nanoplankton in 2011.
Fig 3. Composition by genera of cyanophytes (bluegreens) in 2011
Fig 4. Biomass and density of crustacean zooplankton in 2011.
Fig 5. Zooplankton biomass in 2011 divided in copepods and cladocerans.
Fig 6 Proportional composition by biomass for the cladoceran and the copepod

Figures for time trends:

Onondaga Lake in 2011

Table 1. Biomass (µg/L, dwt) of the major zooplankton groups in Onondaga Lake in 2011. Groups are Calanoid Copepods (*Eurytemora affinis* and calanoid copepodites), Cyclopoid Copepods (mostly *Diacyclops thomasi*, a few *Acanthocyclops vernalis* and *Tropocyclops prasinus*; also includes cyclopoid copepodites), copepod nauplii, Bosminids (*Bosmina longirostris*, a few *Eubosmina coregoni*), Daphnids (*Daphnia retrocurva* and *Daphnia* sp.), Other Cladocerans (*Ceriodaphnia*, *Diaphanosoma* and *Moina*), Predatory Cladocerans (*Cercopagis pengoi*, *Leptodora kindtii*). Standard samples are the South Deep station samples. Int is integrated water column samples taken from 15 m depth, and UML is upper mixed layer taken from 6 m depth.

Total zooplankton density and biomass were highest in June and July. Bosminids peaked on 7/12 and remained moderately abundant during the rest of the year. Daphnids and calanoid copepods were rare. Cyclopoid copepods were abundant in May and June. The low abundance of both daphnids and calanoids indicates high alewife planktivory.

The lake started stratifying early in 2011 (May). Therefore, we used the upper mixed layers as standard samples from May through October.

The selected standard samples are indicated in the table (Std=Y).

Date	Station	Std	Calanoid copepods	Cyclopoid copepods	Nauplii	Bosmi-nids	Daph-nids	Other cladocera	Predatory cladocera
3/30/11	S-Int	Y	0.00	36.23	1.13	0.29	0.00	0.00	0.00
4/6/11	N-Int	N	0.00	2.79	1.83	0.83	0.00	0.00	0.00
4/6/11	S-Int	Y	0.00	7.62	1.86	0.16	0.00	0.00	0.00
4/19/11	S-Int	Y	0.00	11.53	6.07	0.00	0.00	0.00	0.00
5/3/11	S-Int	N	0.00	52.38	4.44	0.00	0.00	0.00	0.00
5/3/11	S-UML	Y	0.00	12.80	5.01	0.22	0.00	0.00	0.00
5/17/11	S-Int	N	0.00	27.46	2.68	0.07	0.00	0.00	0.00
5/17/11	S-UML	Y	0.00	26.79	6.11	0.00	0.00	0.00	0.00
6/1/11	S-Int	N	5.53	173.03	17.19	0.00	0.00	0.00	0.00
6/1/11	S-UML	Y	0.00	30.58	13.20	0.54	0.00	0.00	0.00
6/7/11	S-Int	N	0.40	91.07	5.41	1.33	0.00	0.00	0.00
6/7/11	S-UML	Y	0.00	53.55	10.26	1.05	0.00	0.00	0.00
6/21/11	N-Int	N	0.00	96.46	2.60	45.43	0.00	0.00	0.00
6/21/11	N-UML	N	0.66	134.98	6.57	131.75	0.00	0.00	0.00
6/21/11	S-Int	N	0.39	44.30	3.10	51.20	0.00	0.00	0.00
6/21/11	S-UML	Y	1.37	48.16	6.13	147.49	0.00	0.00	0.00
7/12/11	S-Int	N	0.00	28.17	2.03	90.49	1.14	0.00	6.09
7/12/11	S-UML	Y	0.00	0.00	2.33	215.56	2.54	0.00	7.55
7/26/11	S-Int	N	0.00	6.75	2.26	56.62	2.82	0.00	0.52
7/26/11	S-UML	Y	0.00	9.32	3.70	128.20	8.21	0.00	0.42
8/9/11	S-Int	N	0.00	3.73	1.88	14.08	1.73	1.19	1.08
8/9/11	S-UML	Y	0.00	9.52	2.49	20.37	0.00	2.19	0.57
8/24/11	S-Int	N	0.00	4.95	1.87	26.55	0.00	0.55	0.04
8/24/11	S-UML	Y	0.00	3.82	1.73	28.35	0.00	0.56	0.14
9/13/11	S-Int	N	0.00	1.62	1.59	22.02	0.00	0.05	0.03
9/13/11	S-UML	Y	0.00	3.59	1.32	31.21	0.00	1.23	0.05
9/20/11	N-Int	N	0.00	1.35	0.72	13.27	0.00	0.00	0.03
9/20/11	N-UML	N	0.00	1.65	1.63	16.65	0.00	0.00	0.00
9/20/11	S-Int	N	0.00	0.46	0.83	4.99	0.05	0.00	0.01
9/20/11	S-UML	Y	0.00	0.81	1.82	12.66	0.00	0.00	0.01
10/4/11	S-Int	N	0.00	4.60	0.78	12.00	0.00	0.00	0.00
10/4/11	S-UML	Y	0.00	3.64	1.45	12.90	0.00	0.00	0.01
10/24/11	S-Int	N	0.00	4.82	0.92	7.68	0.00	0.00	0.00
10/24/11	S-UML	Y	2.78	2.96	1.72	17.83	0.00	0.40	0.00
11/8/11	N-Int	N	0.00	1.59	0.78	6.26	0.00	0.00	0.00
11/8/11	N-UML	N	0.99	0.51	0.71	9.52	0.00	0.00	0.00
11/8/11	S-Int	Y	0.00	0.91	0.37	8.25	0.00	0.00	0.00
11/8/11	S-UML	N	0.00	0.31	0.86	14.59	0.00	0.00	0.00
11/21/11	S-Int	Y	0.00	2.47	0.91	4.64	0.00	0.00	0.00
12/13/11	S-Int	Y	1.13	2.93	0.97	5.18	0.00	0.00	0.00

Table 2. Comparison of biomass (volumetric in mg/m^3 (=µg/L) and areal in mg/m^2, both in dry wt) obtained with integrated (15 m) and upper mixed layer (6 m) tows. When the volumetric biomass is similar in the two tows, biomass is similar throughout the water column. The ratio of biomass per unit area in the two tows reflect the proportion of the zooplankton biomass below 6-m (epilimnion). The majority of zooplankton are in the epilimnion from June through September, which reflects the stratified season when oxygen levels below the thermocline is low). On two occasions (5/3 and 6/1), there was a concentration of biomass below 6 m.

Date	StationID	Volumetric Total Biomass mg/m^3	Volumetric Ratio Int/UML	Areal Total Biomass mg/m^2	Areal Ratio Int/UML
5/3/2011	S-Int	56.8		852.3	
5/3/2011	S-UML	18.0	3.15	108.2	7.88
5/17/2011	S-Int	30.2		453.1	
5/17/2011	S-UML	32.9	0.92	197.4	2.3
6/1/2011	S-Int	195.8		2936.3	
6/1/2011	S-UML	44.3	4.42	265.9	11.04
6/7/2011	S-Int	98.2		1473.0	
6/7/2011	S-UML	64.9	1.51	389.1	3.79
6/21/2011	N-Int	144.5		2167.4	
6/21/2011	N-UML	274.0	0.53	1643.7	1.32
6/21/2011	S-Int	99.0		1484.8	
6/21/2011	S-UML	203.2	0.49	1218.9	1.22
7/12/2011	S-Int	127.9		1918.9	
7/12/2011	S-UML	228.0	0.56	1367.9	1.4
7/26/2011	S-Int	69.0		1034.7	
7/26/2011	S-UML	149.9	0.46	899.1	1.15
8/9/2011	S-Int	23.7		355.4	
8/9/2011	S-UML	35.1	0.67	210.8	1.69
8/24/2011	S-Int	34.0		509.4	
8/24/2011	S-UML	34.6	0.98	207.6	2.45
9/13/2011	S-Int	25.3		379.8	
9/13/2011	S-UML	37.4	0.68	224.4	1.69
9/20/2011	N-Int	15.4		230.5	
9/20/2011	N-UML	19.9	0.77	119.6	1.93
9/20/2011	S-Int	6.3		95.1	
9/20/2011	S-UML	15.3	0.41	91.8	1.04
10/4/2011	S-Int	17.4		260.7	
10/4/2011	S-UML	18.0	0.97	108.0	2.42
10/24/2011	S-Int	13.4		201.3	
10/24/2011	S-UML	25.7	0.52	154.1	1.31
11/8/2011	N-Int	8.6		129.4	
11/8/2011	N-UML	11.7	0.74	70.4	1.84
11/8/2011	S-Int	9.5		143.0	
11/8/2011	S-UML	15.8	0.6	94.6	1.51

Table 3. Biomass (µg/L) of phytoplankton in Onondaga Lake in 2011. The phytoplankton community of Onondaga Lake typically consists of Bacillariophyta, Chlorophyta, Chrysophyta, Cryptophyta, Cyanophyta, Pyrrhophyta, Euglenophyta, and "miscellaneous microflagellates," but Euglenophyta and miscellaneous microflagellates were not recorded in 2011. Data are presented for each sampling date at both north and south stations, when taken. Samples taken were integrated upper mixed layer samples.

Date	Station	Bacillario	Chloro	Chryso	Crypto	Cyano	Eugleno	Misc. Micro	Pyrrho
3/30	South	71.88	36.23	0.06	101.61	1.12	0.00	0.24	20.68
4/6	North	175.06	36.92	0.65	97.35	0.54	0.00	0.00	4.42
4/6	South	237.24	6.41	0.50	92.66	0.32	0.00	0.00	111.21
4/19	South	354.69	2.74	0.00	205.53	0.48	0.00	0.00	0.00
5/3	South	79.69	42.07	4.23	377.47	0.87	0.00	0.00	6.42
5/17	South	1816.24	82.21	33.39	963.80	2.41	0.00	0.00	33.19
6/1	South	1603.41	22.00	295.17	449.34	10.24	0.00	0.00	0.00
6/7	South	1729.13	19.56	402.08	79.61	92.34	0.00	0.00	27.98
6/21	North	10.71	183.43	380.14	81.08	60.22	0.00	0.00	0.00
6/21	South	18.30	153.45	419.96	100.16	60.22	0.00	0.00	12.86
7/12	South	10.28	172.34	9.72	115.06	4.21	0.00	0.00	0.00
7/26	South	33.36	348.22	358.67	8.68	6.99	0.00	0.00	24.82
8/9	South	41.54	105.85	267.56	27.41	13.96	0.00	0.00	2.23
8/24	South	641.74	288.65	232.05	55.24	25.40	0.00	0.00	287.78
9/13	South	290.18	85.45	82.45	280.25	18.22	0.00	0.00	976.40
9/20	North	198.80	28.35	107.19	165.86	22.43	0.00	0.00	0.00
9/20	South	259.54	132.41	127.76	370.12	59.32	0.00	0.00	80.89
10/4	South	707.99	80.84	31.33	51.47	32.66	0.00	0.00	383.64
10/24	South	2057.78	62.03	19.79	121.17	29.73	0.00	0.00	70.32
11/8	North	33.46	9.54	10.82	47.12	9.99	0.00	0.00	1.14
11/8	South	66.30	21.95	4.42	17.24	10.96	0.00	0.00	0.49
11/21	South	81.33	27.04	13.74	59.19	6.56	0.00	0.00	0.00
12/13	South	13.17	25.54	1.55	60.54	4.25	0.00	0.00	0.00

Table 4. The major algal genera in Onondaga Lake in 2011 at the South Station contributing more the 1% of the total average biovolume (15 genus in 2011). Total number of species identified were 27 diatoms, 34 chlorophytes, 10 chrysophytes, 4 cryptophytes, 9 cyanophytes, and 6 dinoflagellates. Of the 10 most abundant genera in 2011, all but one was among the 16 most abundant genera in 2009 and 2010. The most abundant genera in 2011 was *Cyclotella*, a common diatom that have increased in abundance whereas *Fragilaria*, the most abundant genera in 2010, was less abundant in 2009 and 2011. The number of abundant dinoflagellates (Pyrrhophyta) increased in 2011. It is notable that for the fourth year in a row, no cyanobacteria genus made up more than 1 % of the biomass (2008-2011). Also notable is that the most abundant diatom identified in 2009, *Actinocyclus normani*, was rare in 2010 and not found in 2011. This species is considered an exotic in Great Lakes (Mills et al. 1993) and present in 1938 in Lake Ontario (Stoermer et al. 1985). In 2011, the dominant algal genus changed through the season with *Cryptomonas* and *Stephanodiscus* in April-May, *Diatoma* and *Synedra* in June, *Erkenia* and *Oocystis* in July and August, *Cyclotella,* and *Peridinum* in end of August through November. The genus of the Chlorococcales was not determined.

Genus	Division	Mean biomass (ug/L)	Relative biomass (% of total)	2010 Biomass/ Rank	2009 Biomass/ Rank
Cyclotella	Bacillariophyta	204.0	19.3	19.3/13	6.2/16
Diatoma	Bacillariophyta	142.4	13.5	125.8/3	84.4/7
Cryptomonas	Cryptophyta	109.5	10.4	123.5/5	87.2/5
Synedra	Bacillariophyta	104.4	9.9	131.6/2	30.1/10
Erkenia	Chrysophyta	92.3	8.7	76.3/7	81.2/8
Peridinium	Pyrrhophyta	81.5	7.7	53.9/10	1.1/30
Rhodomonas	Cryptophyta	76.7	7.2	59.0/9	52.3/9
Asterionella	Bacillariophyta	41.7	3.9	124.3/4	171.5/3
Stephanodiscus	Bacillariophyta	30.3	2.9	68.9/8	135.6/4
Chlamydomonas	Chlorophyta	28.8	2.7	17.2/14	12.6/13
Chlorococcales	Chlorophyta	25.4	2.4	82.6/6	10.8/14
Uroglena	Chrysophyta	21.6	2.0	2.0/26	0
Glenodinium	Pyrrhophyta	15.1	1.4	3.2/22	0

Figure 1. Temporal trends in biovolume (panel A) and proportional biovolume (panel B) of phytoplankton divisions in Onondaga Lake in 2011. When both north and south station samples were available we present the mean values. Phytoplankton biomass peaked in May and again in October during the diatom-dominated spring and fall blooms (Bacillariophyta). Biomass was low from the end of June through the beginning of August. The late summer phytoplankton consisted of several groups including diatoms and dinoflagellates (Pyrrhophyta). Bluegreens (Cyanophyta) were only present at low abundance. The first sample was collected on 3/30 and the last on 12/13. Sample dates are in Table 3.

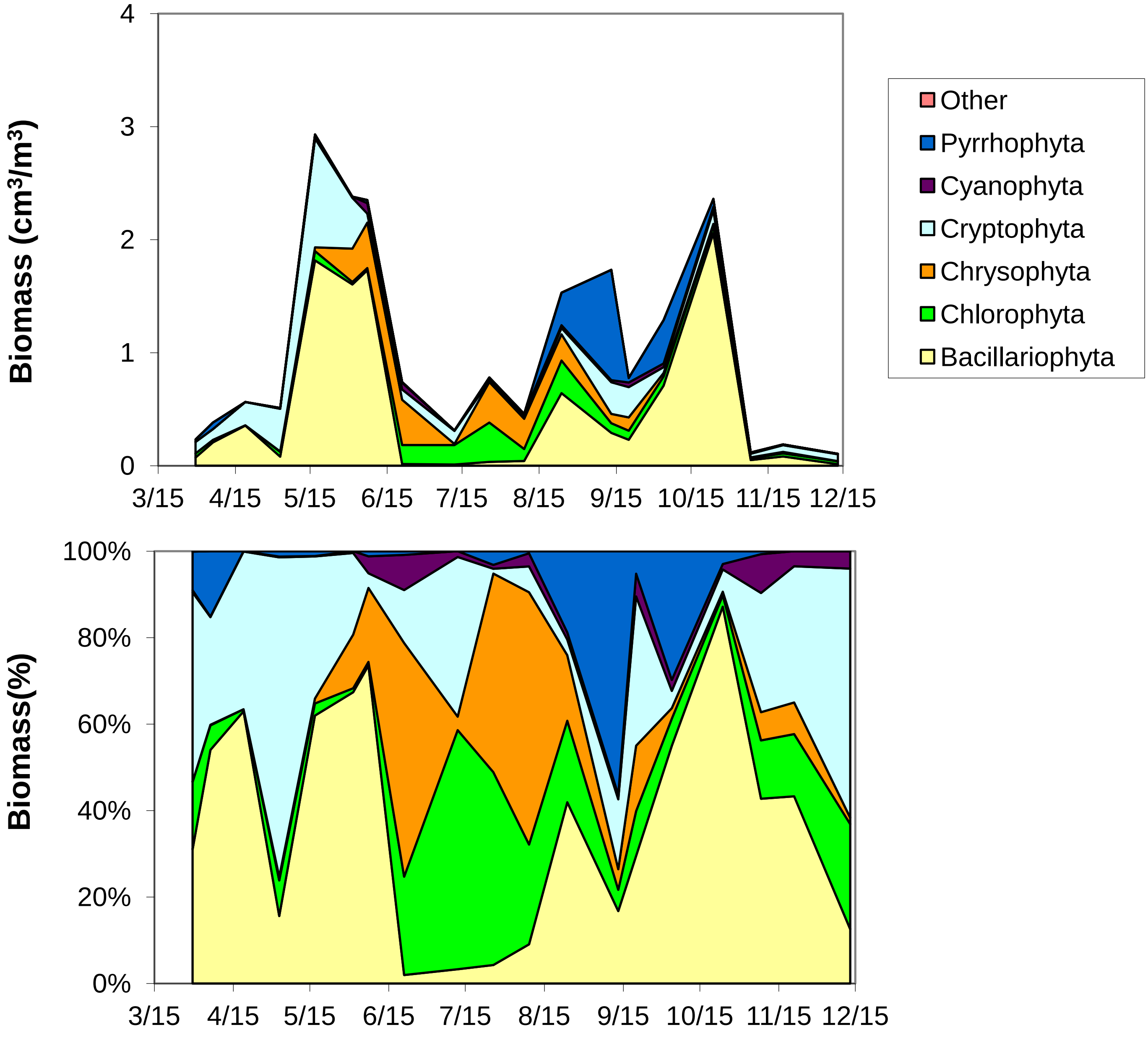


Figure 2. Temporal trends in phytoplankton in Onondaga Lake in 2011 divided in netplankton (GALD>50 µm) and nanoplankton (GALD<50 µm). Small phytoplankton dominate most of the year except during the spring diatom bloom.

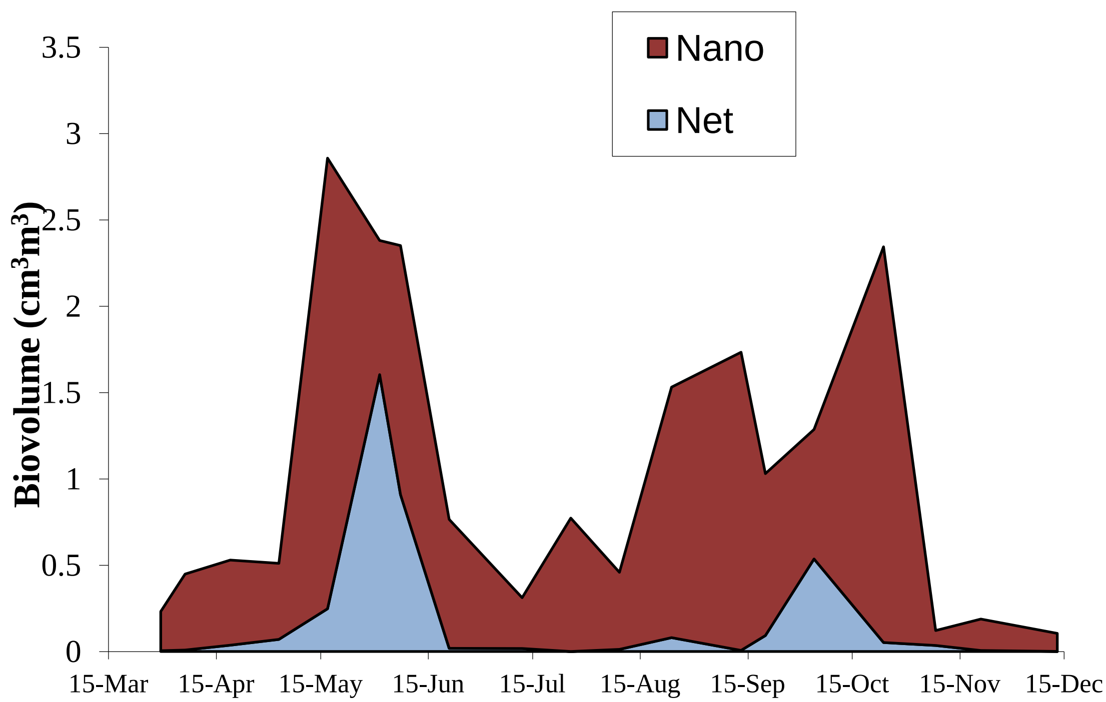


Figure 3. Temporal trend of biovolume of cyanobacteria genera in Onondaga Lake (South station) in 2011. Cyanobacteria biovolume was very low throughout the year. Synechocystis is a unicellular bluegreen. Of the large nitrogen fixing bluegreens, only *Oscillatoria* was present in low numbers. The other group includes the genera *Aphanocaspa, Chroococcus, Merismopedia, Pseudoanabena* and *Synechococcus*.

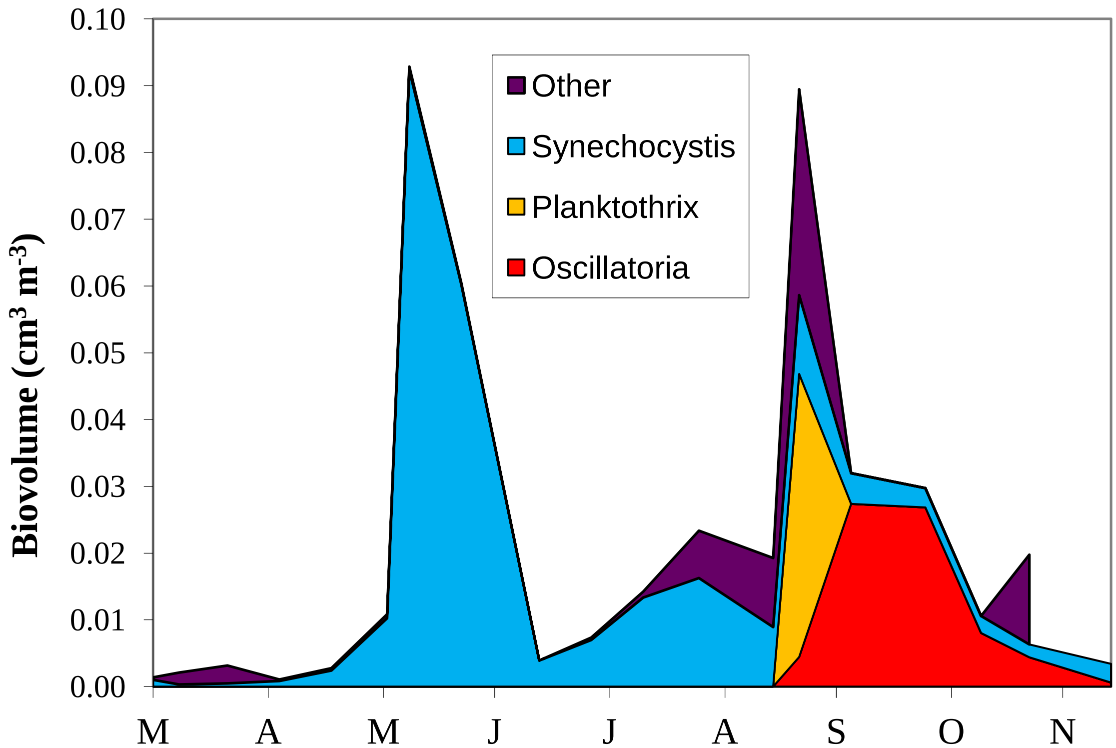


Figure 4. Total density (#/L) and biomass (µg/L) of crustacean zooplankton in Onondaga Lake in 2011 from standard samples (South Deep). Density and biomass was highest in June through July and consisted mostly of *Bosmina*. Data from the North Deep station are similar to the results from the South Deep station when both were available.

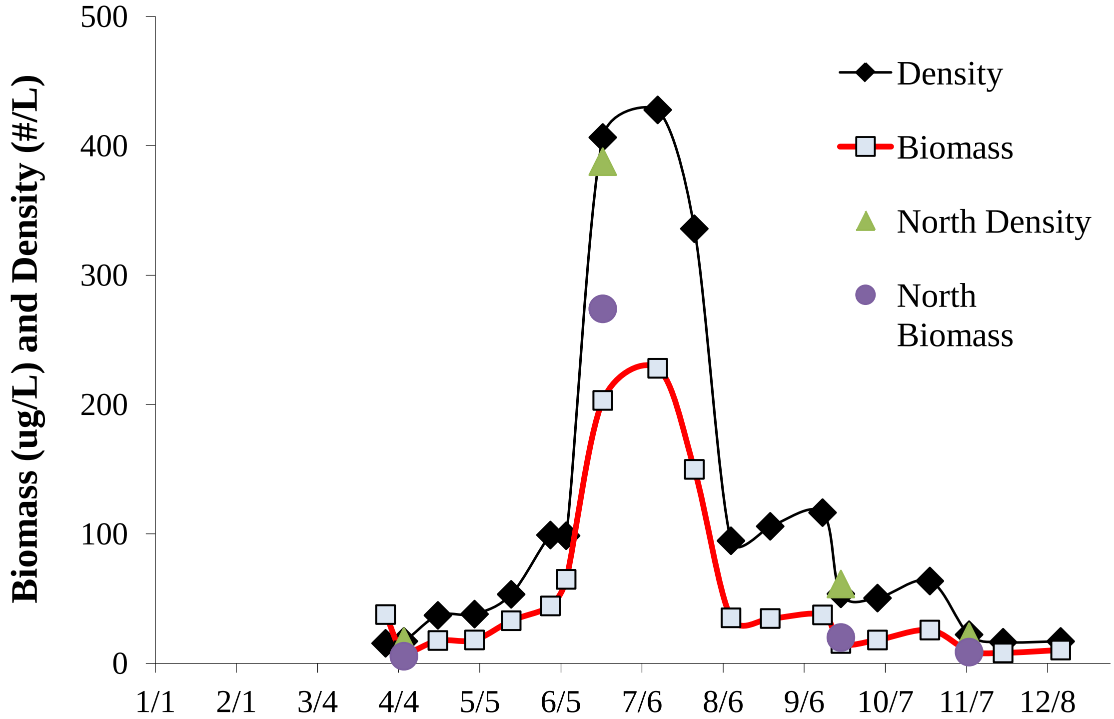


Figure 5. Composition of copepods and cladocerans as total biomass (A) and as proportion of biomass (B) in Onondaga Lake in 2011.

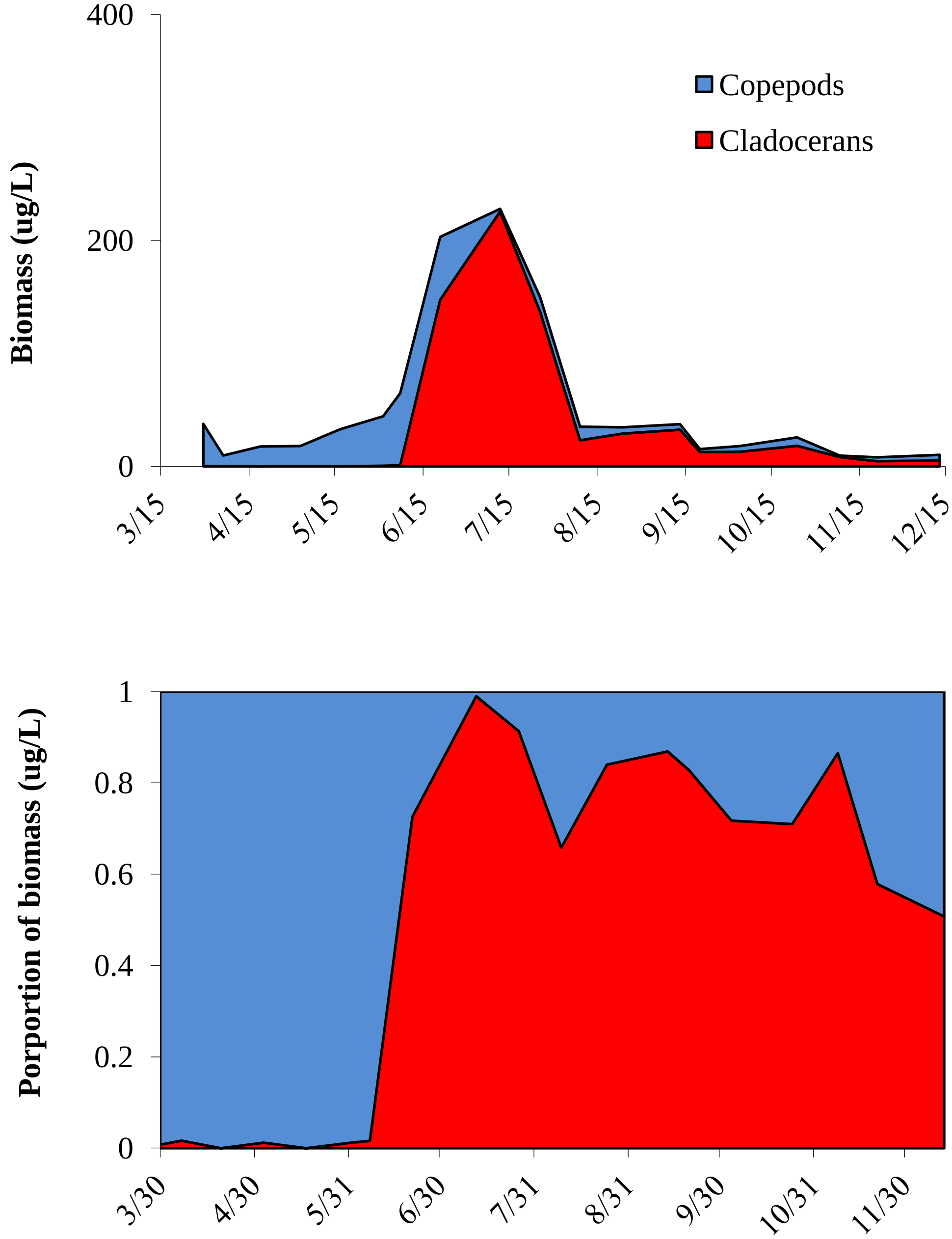


Figure 6. Composition of the cladoceran (upper panel) and copepod (lower panel) community in Onondaga Lake in 2011. A total of 10 species, as well as nauplii and copepodites, were identified in Onondaga Lake in 2010. *Bosmina longirostris* dominated the cladoceran group with other species rare. *Diacyclops thomasi* was the most common zooplankton species in the spring and early summer with higher diversity in the summer and fall. Nauplii are not identified to species.

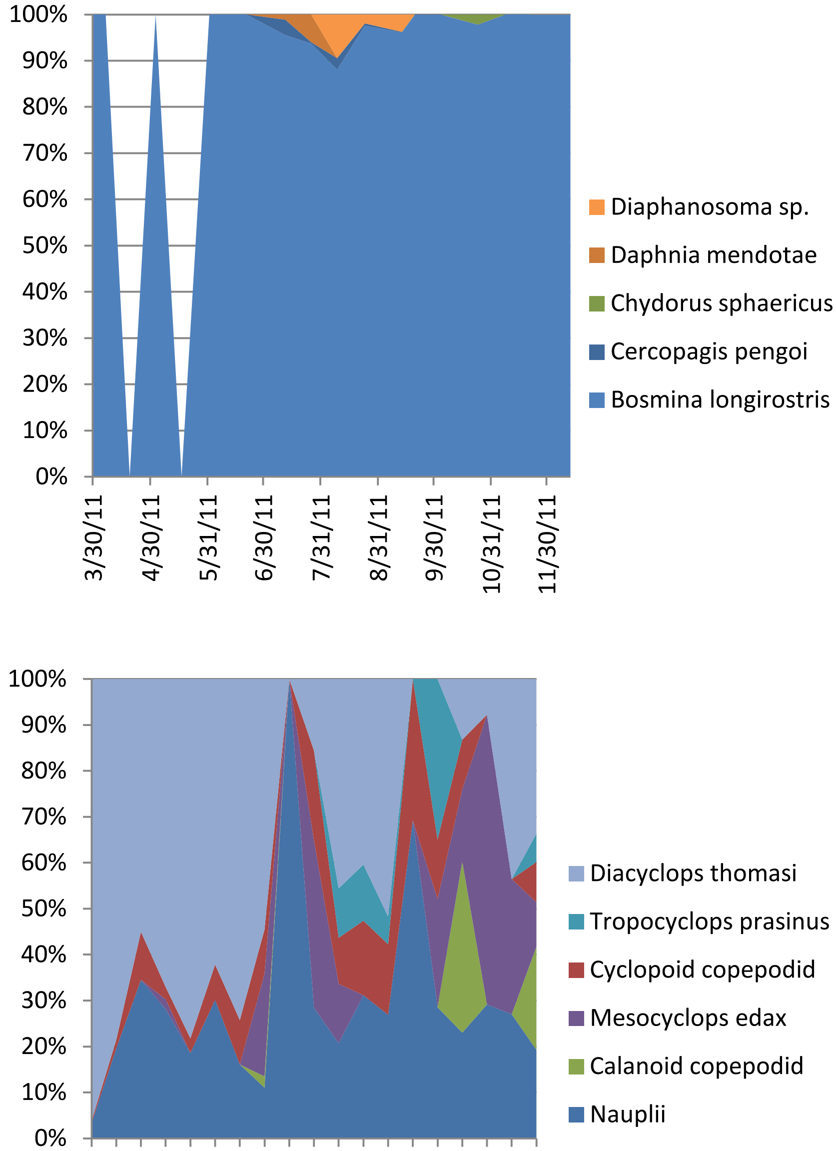


Figure 7. Biomass of predatory zooplankton in Onondaga Lake in 2011. Predatory cyclopoid copepod (primarily *Mesocyclops*) were similar in abundance to the exotic predatory cladoceran *Cercopagis pengoi*. *C pengoi* was observed in 2011 as it has been in 2000, 2002- 2008 and 2010. It was found in collections from 7 dates (7/12 to 10/4) in relatively low numbers Although *Cercopagis* can have an impact on smaller zooplankton such as *Bosmina* and nauplii (Benoit et al. 2002, Warner et al. 2006), this is unlikely in 2011.

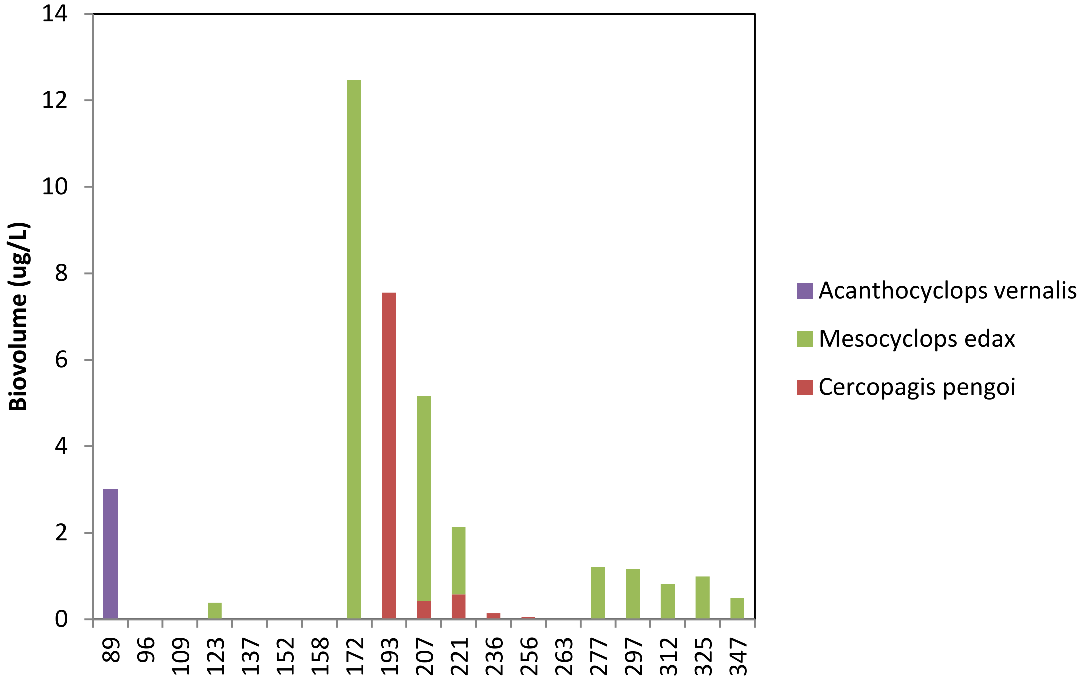


Figure 8. Average crustacean zooplankton length (mm) in Onondaga Lake in 2011. The largest mean size of zooplankton (0.46 mm) was observed in a March spring sample. The decline in length in the spring is due to high proportion of nauplii in the samples starting in March. Length remained small throughout the rest of the season when the zooplankton community became dominated by *Bosmina* and cyclopoids. The seasonal pattern in 2010 was similar to 2011. In 2009, zooplankton were large until September (light color, 2 point moving average line). This decline in large zooplankton correspond to the increase in biomass of the 2009 alewife year class. Average length is based on standard samples from the South Deep with Cercopagis excluded.

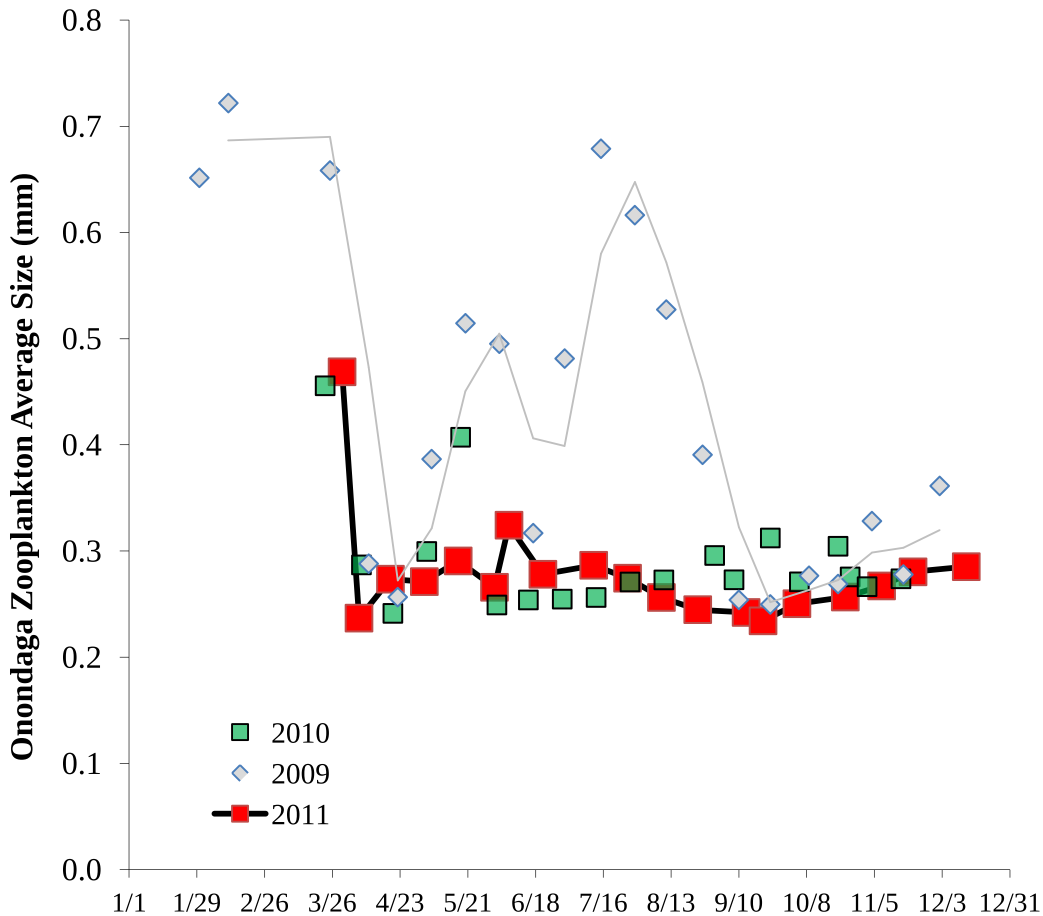
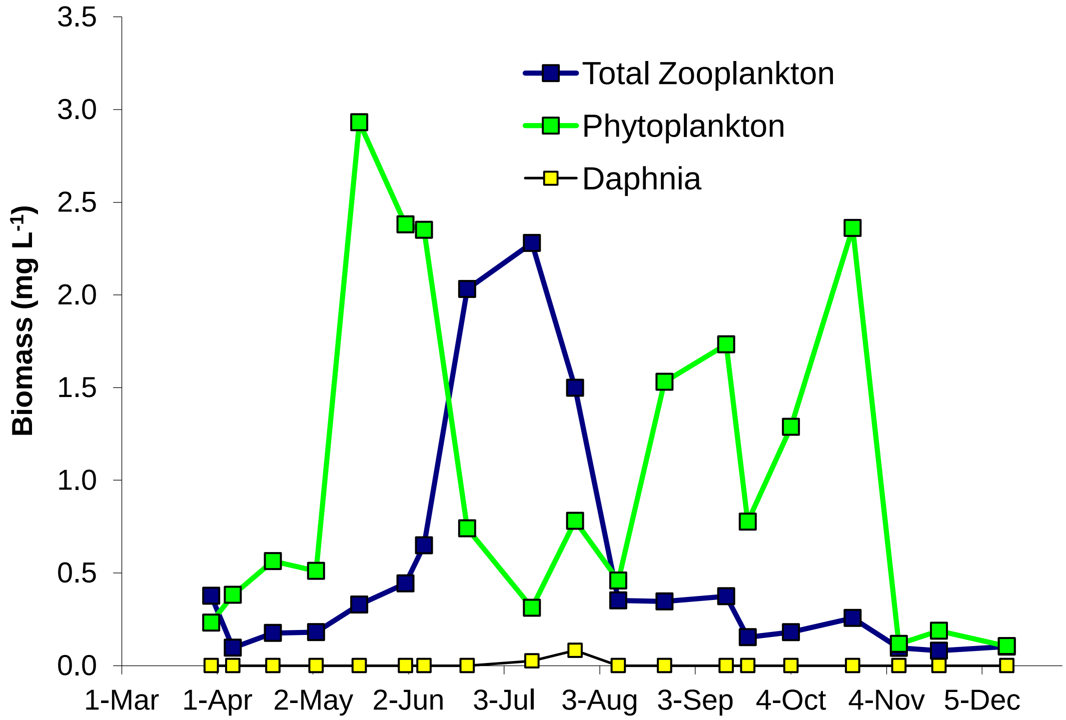


Figure 9. Temporal trend of zooplankton and phytoplankton biomass in Onondaga Lake in 2011. Zooplankton biomass was dominated by bosminids through most of the year. The decline in phytoplankton biomass in the middle of June is associated with declines in diatoms. Zooplankton biomass increased at that time but the decline in phytoplankton is more likely the result of silica depletion as the decline was mainly in large diatoms.



Time series 1996 – 2011 for Onondaga Lake

Figure 10. Temporal trend of average annual phytoplankton biovolume (April – October) in Onondaga Lake from 1998-2011. Annual biovolume decreased significantly during this period (linear regression, R^2= 0.76, p<0.001). However, there is no further decline in biovolume since the low values recorded in 2008. The heavy line is a 3 point moving average.

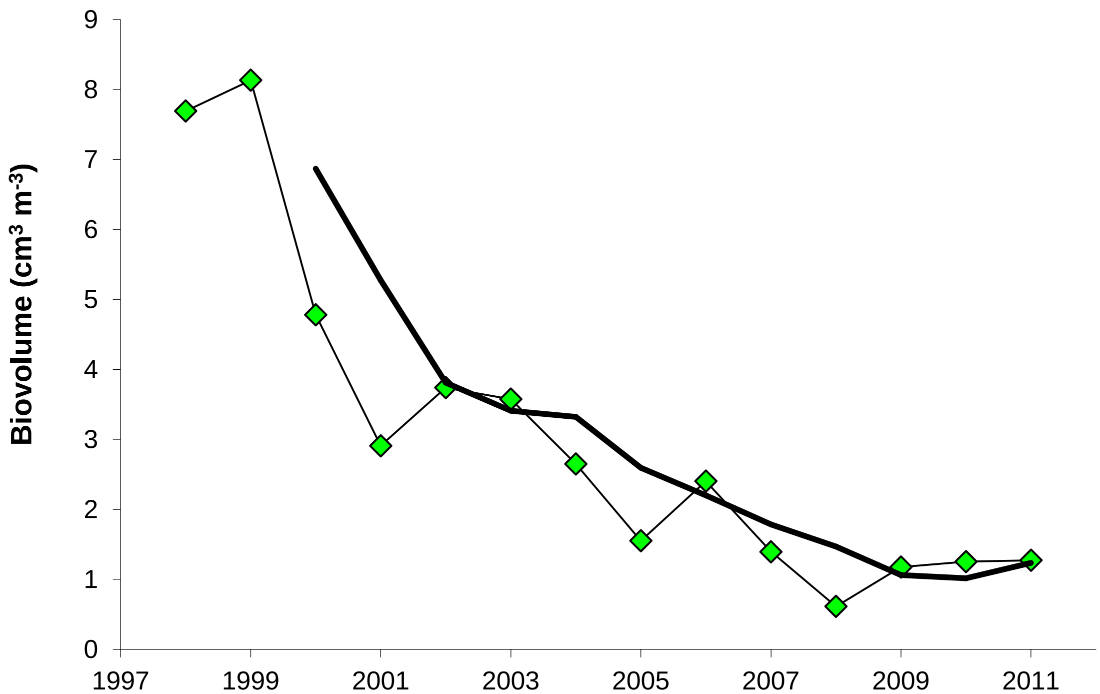


Figure 11. Temporal trend of average annual biovolume (April-October) of phytoplankton divisions in Onondaga Lake from 1998-2011. The phytoplankton community of Onondaga Lake consists of Bacillariophyta, Chlorophyta, Chrysophyta, Cryptophyta, Cyanophyta, Pyrrhophyta, and Euglenophyta. Euglenophyta and Xanthophyta were present briefly in June 2002, but Xanthophyta has not been seen since then, and Euglenophyta are only present in some years in low numbers. Cyanobacteria (Cyanophyta) and dinoflagellates (Pyrrhophyta) decreased significantly during this period (linear regressions, both $p<0.002$). Crysophytes are a small component of the biomass and have increased significantly ($p<0.003$). Other groups show no significant time trends. Figure 11B has the time trend for cyanobacteria by major genera.

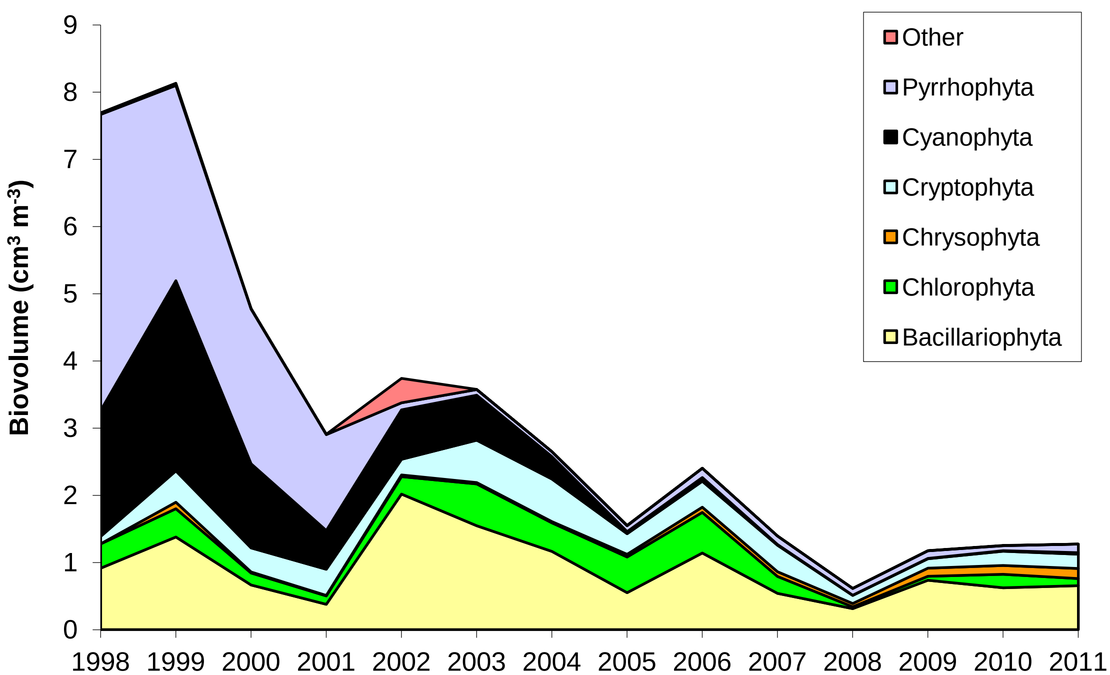


Figure 11B. Time trend of mean annual biovolume of cyanobacteria genera in Onondaga Lake from 1998 to 2011. Cyanobacteria biovolume in 2011 was very low.

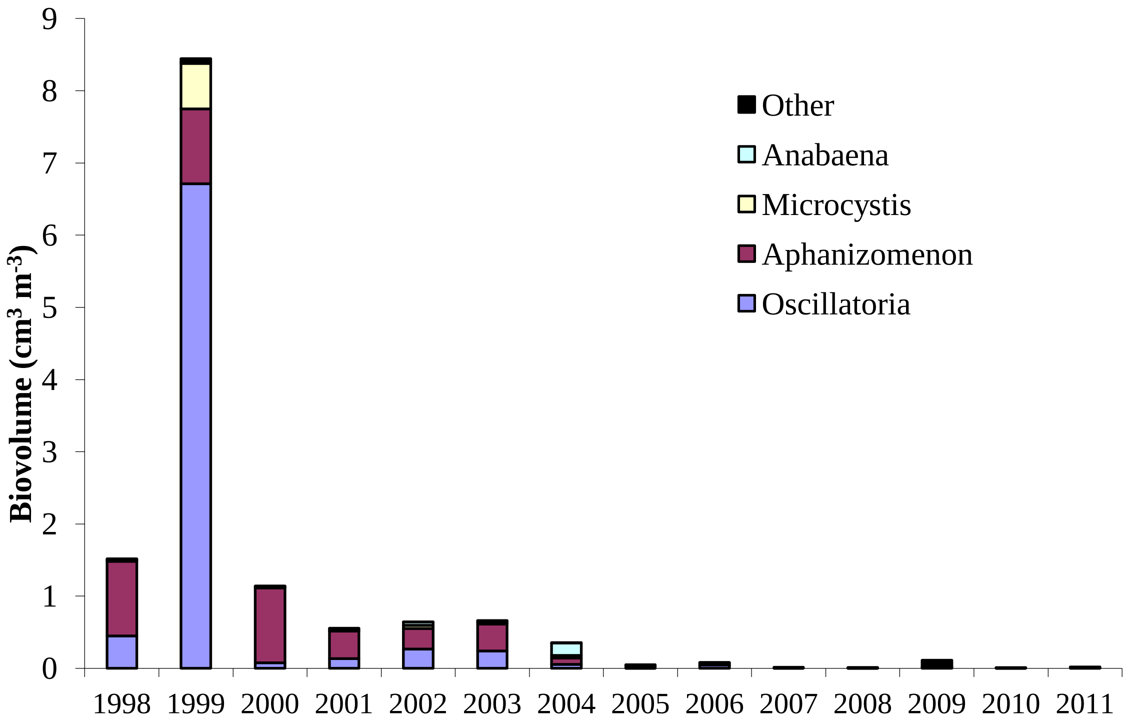


Figure 12. Temporal trend of average annual proportional biovolume of phytoplankton divisions in Onondaga Lake from 1998-2011. Chrysophytes, cryptophytes and diatoms increased in proportional biovolume over this period, while cyanobacteria (Cyanophyta) and dinoflagellates (Pyrrhophyta) decreased (linear regressions, all $p<0.02$).

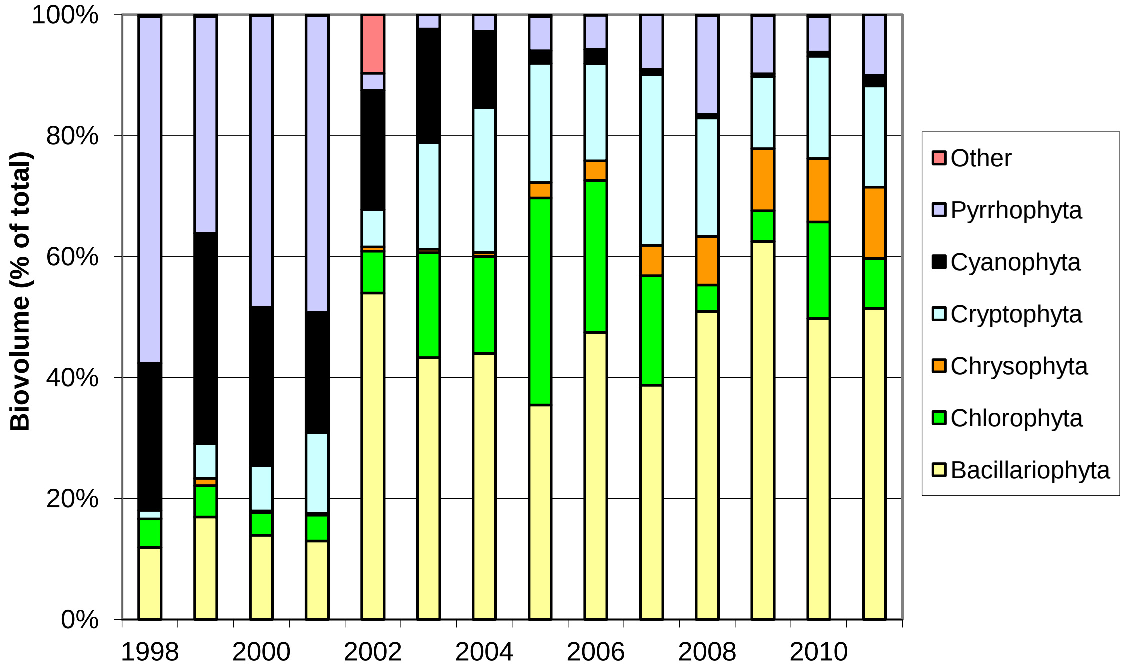
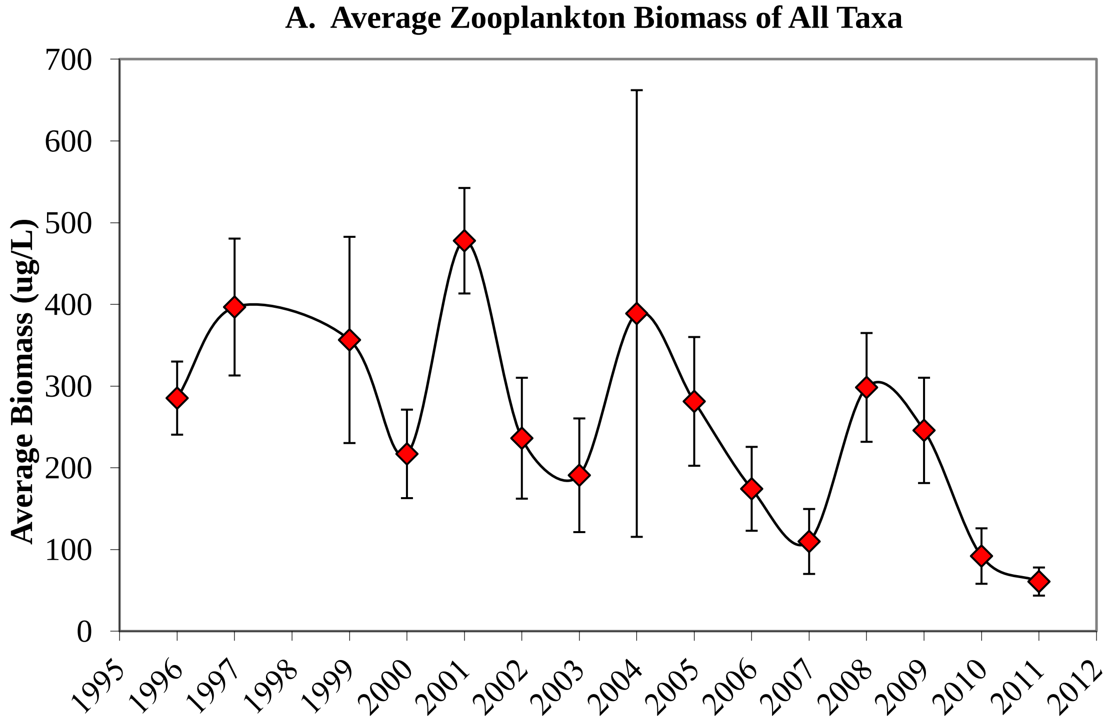


Figure 13. Average biomass of zooplankton (all taxa combined) and the proportion of major taxa in Onondaga Lake from April through October in 1996-1997 and 1999-2011. For consistency across time, all densities are based on the 2008 sampling schedule (integrated samples during the mixed period, and upper mixed layer during the stratified period, and South Deep only, with volume strained calculated using field tow depth). Biomass is calculated based on the length-weight relationships in Watkins et al. (2011). Error bars in Figure A are one standard error and represent variability across seasons. The community composition changed dramatically in the late summer of 2002 as alewife increased in abundance, in the summer of 2008 following alewife declines and again in the summer of 2009 and continuing through 2011 when alewife abundance increased again. The high alewife abundance and strong 2009 year class suggested by the changes in late summer of 2009 was confirmed by the changes in 2010 and continued in 2011. Data from 1998 is only available for proportions due to an error in recording sample volume that year.



B. Proportion of major groups across time

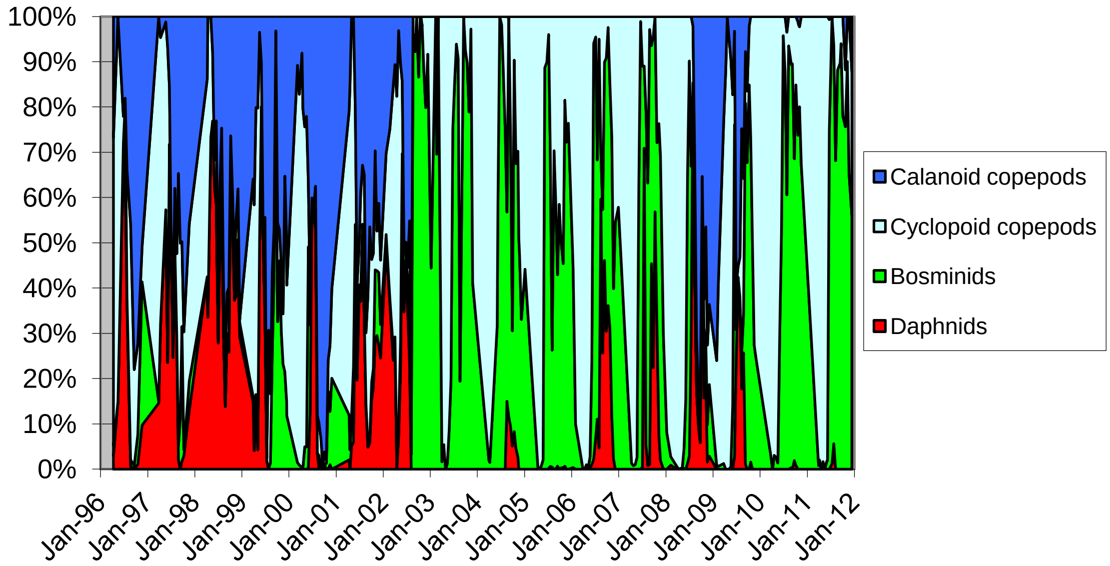
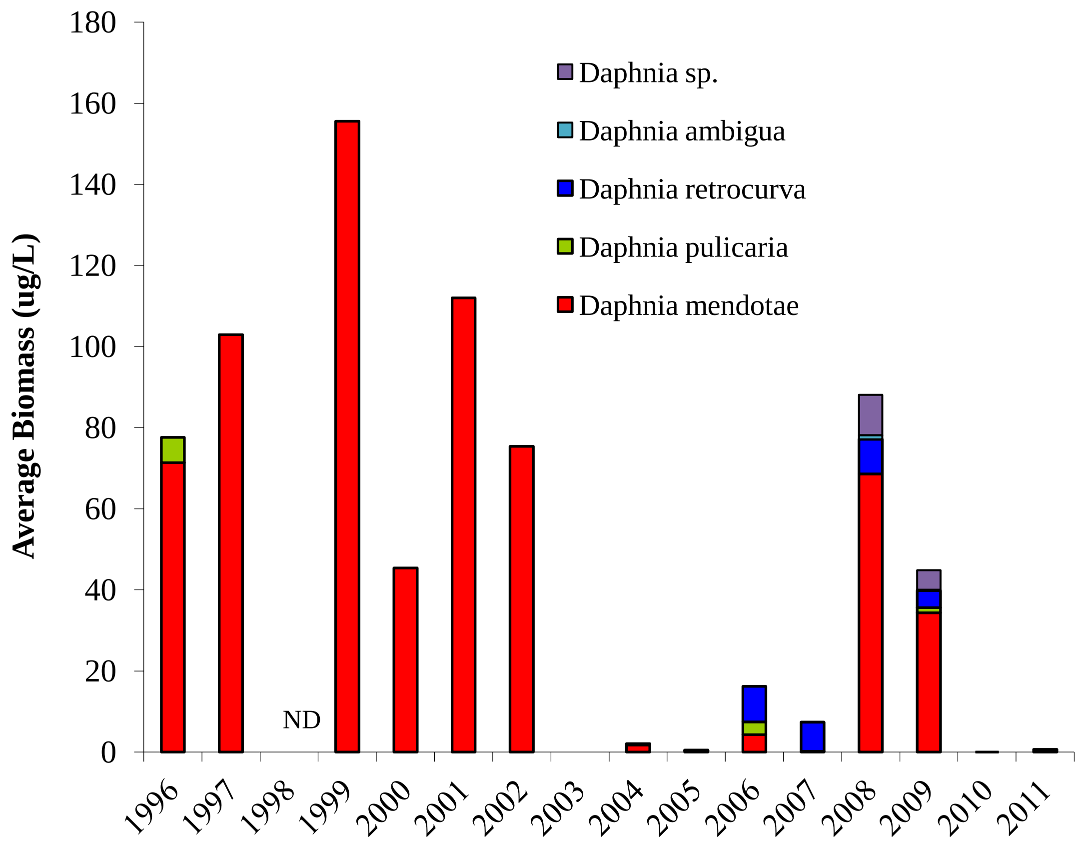
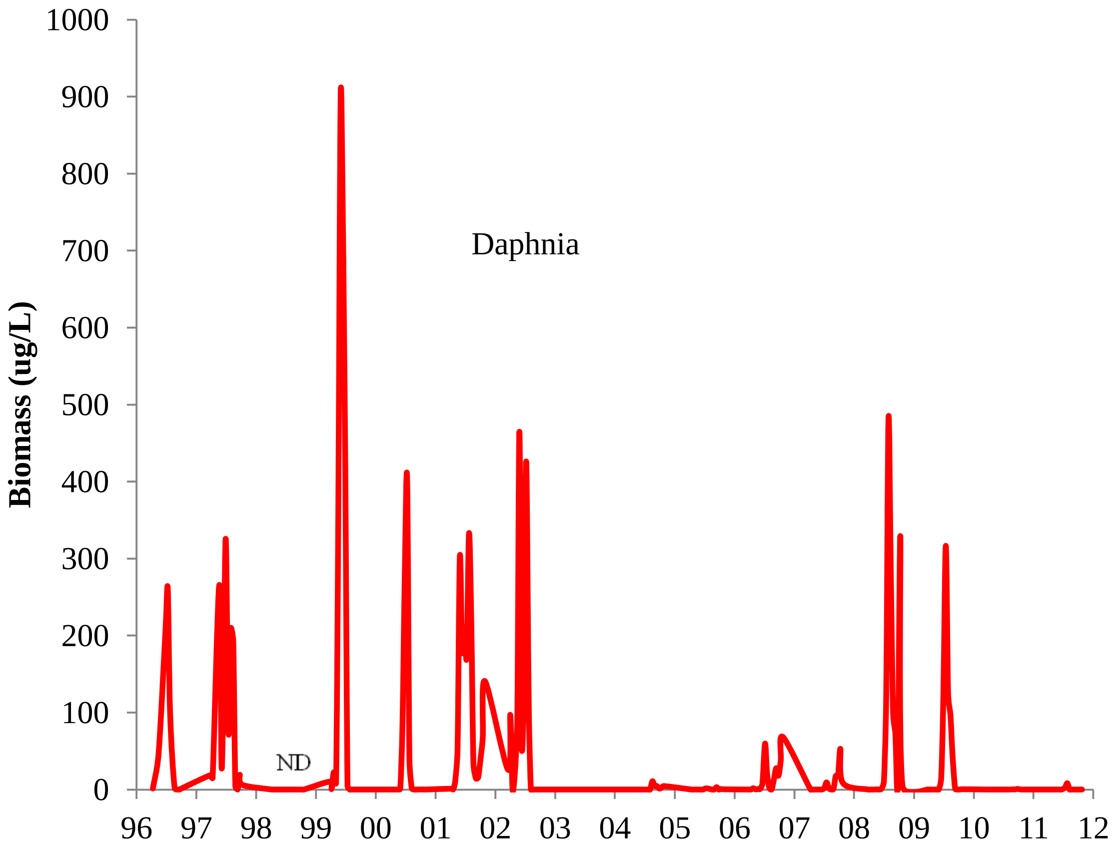


Fig 14. Biomass of different *Daphnia* species in Onondaga Lake. There is no data available on biomass for 1998, but the *Daphnia* population that year was dominated by *D. mendotae*. *Daphnia* species composition is a sensitive indicator of fish zooplanktivory rate. Data are average of standard South Deep samples collected from April to October. Most samples are from the upper mixed layer. In 2008 and 2009, April and October samples are from integrated water column samples. The low biomass of *Daphnia* in the years between 2003 and 2007 and then again in 2010-11 is attributed to the presence of abundant alewife during these time periods. *Daphnia* was abundant in 2008 and 2009, and mostly consisted of *D. mendotae* and limited biomass of *D. retrocurva*. *D. mendotae* was present from mid-July to early December in 2008, and from mid-June through August in 2009. This indicates a strong year class of alewife in 2009. These fish would be large enough by August to affect daphnids. *D. retrocurva* was a significant contributor to cladoceran biomass from mid-July to late October in 2006 and 2007 and to a lesser extent from mid-July to late July in 2008. This species is more abundant at higher planktivory rates. All *Daphnia* species have been virtually absent in the lake since fall of 2009. Also shown is a more detailed time series for all *Daphnia* combined. (Note: ND = No data for 1998).





1000
900
800
700
600
500
400
300
200
100
0
Biomass (ug/L)
Daphnia
ND
96
97
98
99
00
01
02
03
04
05
06
07
08
09
10
11
12

Figure 15. Time trends in average size of all crustaceans from 1996 to 2011 in Onondaga Lake. Note the return of 2008 and 2009 to almost pre-2002 average lengths followed by the decline in 2010 and continued small sizes in 2011 These lengths include nauplii. Based on the average of weekly average zooplankton lengths in the South Deep station from samples collected April – October using the sampling regime established in 2008-2011. Error bars are one SE and represent variability across seasons. *Cercopagis pengoi* is not included.

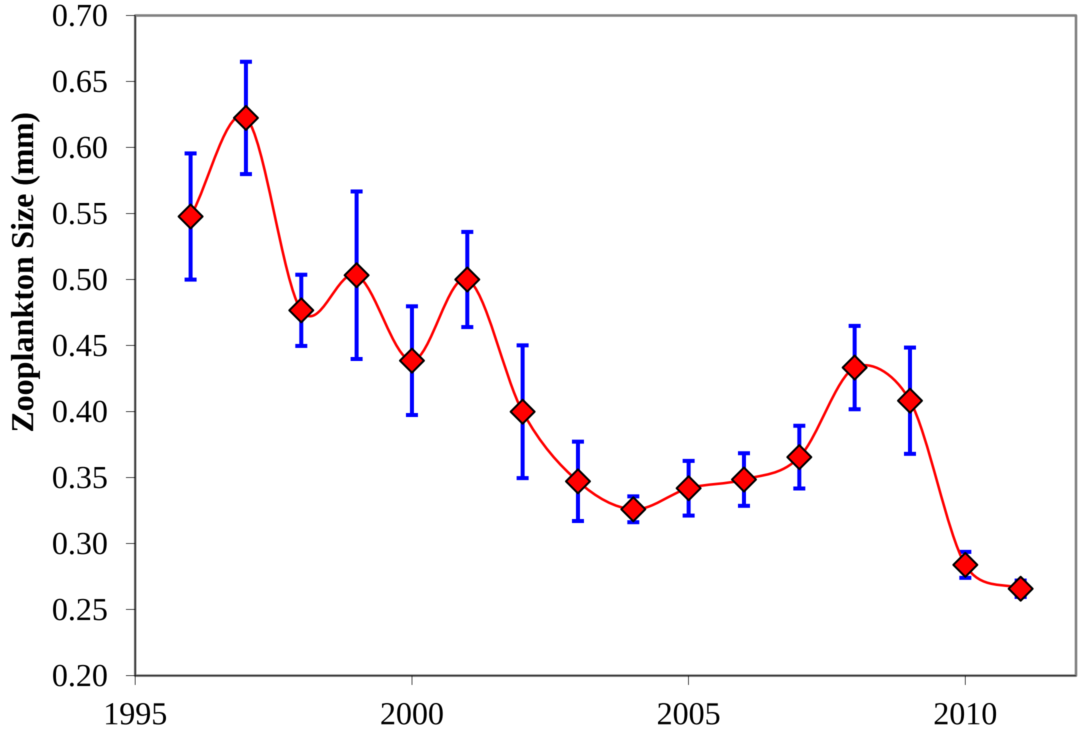
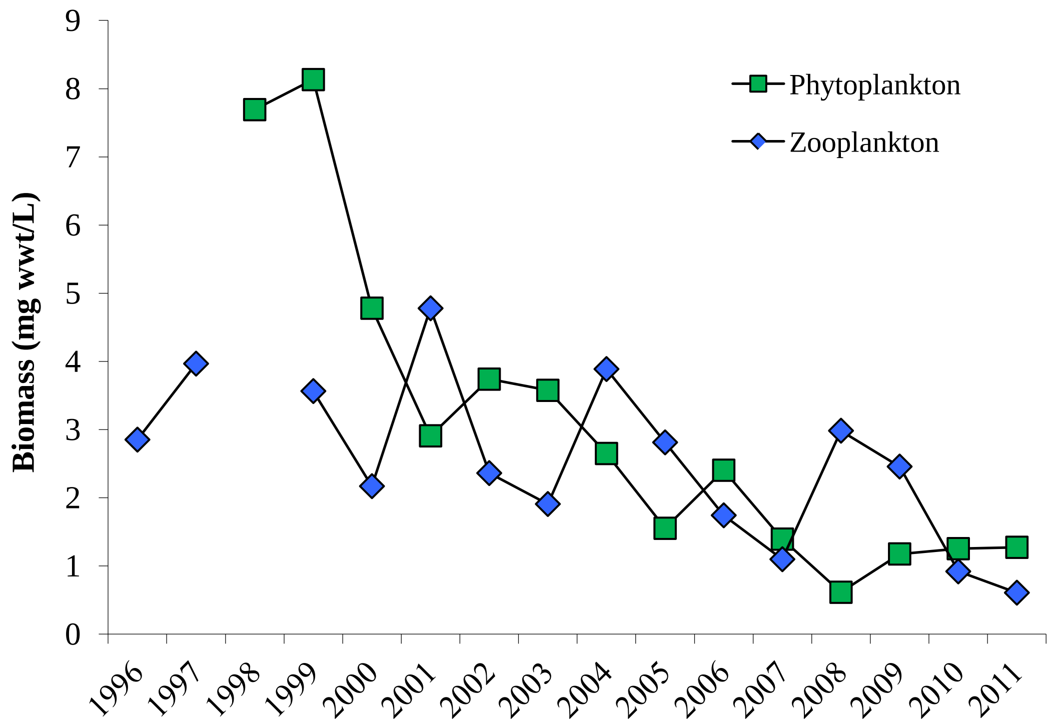


Figure 16. Time trend of zooplankton and phytoplankton biomass in Onondaga Lake 1996 to 2011 (April-October). Zooplankton biomass was converted to wet weight assuming a dry to weight ratio of 10%. For zooplankton biomass in dry weight, see Figure 13.



Significant Findings

The algal biomass in Onondaga Lake since 2007 have been below 1.5 mg/L, values lower than expected from meso-eutrophic systems (3-5 mg/L, Wetzel 2001). Peak algal biomass did not exceed 3 mg/L for the second year in a row. Average biomass in 2011 was slightly higher than in 2010 and about twice the values in 2008 (Fig. 16). The longer term time trend shows a significant decline in algal biomass since 1998 but algal biomass appears not to have declined further since 2007. We attribute the low algal biomass to lower phosphorus loading. In 2008 and 2009, algal biovolume was also affected by grazing from large zooplankton and likely mussels. Large zooplankton were rare in 2011 and algal biomass increased marginally compared to 2009.

Large bluegreens (cyanobacteria) have almost disappeared from the lake (Fig 11B). The main species in the past was *Aphanizomenon flos-aquae*. This species historically occurred July through October but blooms decreased in duration to July – August in 1997-2000. Most bluegreens present in recent years are small unicellular species. Peak cyanobacteria abundance was only 0.09 mg/L in 2011, slightly higher than in 2010 but still very low.

Diatoms had the highest biovolume of all algae groups and showed two peaks, an spring peak in May-early June and a fall peak in October. *Diatoma* and *Synedra* were common genera in June and *Cyclotella* in the fall.

Average total zooplankton biomass (dry wt) was 60 μg/L in Onondaga Lake which is the lowest recorded in the data series for the April-October time period. Zooplankton biomass declined in recent years and the second lowest value was in 2010. This long term decline is likely due to decreased algal production. Variability among years, such as the increase in 2008 and 2009 is due to the low abundance of planktivorous alewife in those two years. The change over time indicated that the decline in nutrient concentrations can cause a 3-5 fold decline in zooplankton and an increase in planktivory can cause a 2-3 fold decline. Peak biomass in 2011 was 227 μg/L on 7/7 and dominated by bosminids. The average size of the total zooplankton community in Onondaga Lake throughout the year in 2011 (0.27mm) was smaller than any previous year including the high alewife years of 2003-2007 (0.33 mm). The species and size composition is similar to 2003-2007 and quite different from what was observed in 2008 and 2009. The decrease in large daphnids and calanoids in later summer of 2009 was similar to the shift in the late summer of 2002 when the alewife became abundant in Onondaga Lake. Zooplankton species and size composition indicate high planktivory continuing in 2011, similar to 2010 (Figure 13B).

The temporal changes in the zooplankton community are linked to changes in predation by the dominant fish planktivore in the lake, the alewife (*Alosa pseudoharengus*) (Wang et al. 2010). Alewife density in spring of 2008 and 2009 were below 100 fish/ha, but density rebounded in the spring of 2010 and increased further to the spring of 2012 (see alewife report). In addition, alewife grew fast in 2008-09, especially in 2008. 70% of the alewife caught in 2010 were from the 2009 year class confirming a strong 2009 year class. The data from Onondaga Lake support the strong structuring effect fish planktivory, especially alewife, on the species composition and size structure of zooplankton (Brooks and Dodson 1965, Post et al. 2008, Wang et al. 2010). *Cercopagis pengoi* was observed in 2011 but only at low to moderate abundance.

Populations of *Daphnia* can exert strong influence on the phytoplankton community (Sommer et al. 1986, Mills and Forney 1988). This was likely the case with the reduced spring clear water phase after *Daphnia* declined following the 2002 alewife year class (Wang et al. 2010). High water clarity and low phytoplankton biovolume was observed in 2008 and 2009 associated with the combination of high grazing from large zooplankton, decreased phosphorus loading, and possible increased grazing by dreissenids. Interestingly, algal biovolume remained low in 2010 and 2011 even though the zooplankton biomass declined and was dominated by small grazers (bosminids). Phosphorus loading was similar in 2009 to 2011. Algal biovolume is about twice the values observed in 2008 a year with both low TP loading and high Daphnia populations. The possible effects of mussel grazing should be explored further.

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