Assessing Community Structure of Lower Trophic Levels In Onondaga Lake, New York in 2010

2010 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 have been sent to the Onondaga County through Ecologic and have been incorporated 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 March (3/23) through November (11/16) in 2010 and preserved in Lugol's Iodine solution. Total number of sampling occasions was 19. Samples were taken at just the South Deep station except for 4 occasions when samples were collected at both the North and South Deep stations (4/7, 6/15, 9/23, 11/16). 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 netplankton and species with GALD<50µm were classified as nannoplankton. 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:

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

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 several dates (4/7, 6/15, 9/23, 11/16). 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 2010, calculated efficiency of the net varied between 52 and 105%, with an average of 86% (SE 2.3%). 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 2010 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 from 2010 and for the available time series. 1996 and 1997 has been added in addition to 2010 in the time series data. Analysis is included in the table and figure headings when appropriate. A general discussion follows at the end.

Tables for 2010 data:

Figures for 2010 data:

<u>Figures for time trends:</u>

Onondaga Lake in 2010

Table 1. Biomass (µg/L, dwt) of the major zooplankton groups in Onondaga Lake in 2010. 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 through early September. Bosminids peaked on 6/29 and remained abundant into early September. Daphnids and calanoid copepods were rare. Cyclopoid copepods were abundant in May through August. The low abundance of both daphnids and calanoids suggest a return of high alewife planktivory.

Date	StationID	Calanoid Copepods	Cyclopoid Copepods	Nauplii	Bosminids	Daphnids	Other cladocerans	Predatory cladocerans
3/23/10	S-Int	0.00	5.11	0.07	0.28	0.00	0.00	0.00
4/7/10	N-Int	0.00	5.79	0.65	0.00	0.00	0.00	0.00
4/7/10	S-Int	0.00	7.14	0.38	0.00	0.00	0.00	0.00
4/20/10	S-Int	0.00	5.01	1.12	0.25	0.00	0.00	0.00
5/4/10	S-Int	0.00	10.90	1.14	0.51	0.00	0.00	0.00
5/18/10	S-Int	0.00	12.04	0.48	0.33	0.00	0.00	0.00
6/2/10	S-UML	0.00	6.25	1.84	6.09	0.00	0.00	0.00
6/15/10	N-UML	0.00	12.27	1.63	110.69	0.00	0.00	0.00
6/15/10	S-UML	0.00	17.37	1.58	41.35	0.00	0.00	0.00
6/29/10	S-UML	0.00	17.67	0.71	865.57	0.00	0.00	0.00
7/13/10	S-UML	0.00	8.57	0.72	134.48	0.00	0.00	0.00
7/27/10	S-Int	0.00	6.52	0.50	41.58	0.00	0.72	0.22
7/27/10	S-UML	2.97	30.52	1.27	111.55	0.00	3.08	0.91
8/10/10	S-Int	0.53	4.14	0.13	102.18	0.00	0.32	0.05
8/10/10	S-UML	0.00	14.82	0.46	433.77	0.00	10.99	0.11
8/31/10	S-Int	0.00	6.57	0.46	32.27	0.00	10.22	0.64
8/31/10	S-UML	0.00	6.91	0.28	114.04	0.32	20.80	1.83
9/8/10	S-Int	0.00	3.44	0.17	55.20	0.66	6.39	2.36
9/8/10	S-UML	0.00	9.48	0.29	169.16	0.00	19.82	8.76
9/23/10	N-Int	0.30	2.71	0.22	19.06	0.00	11.09	0.11
9/23/10	N-UML	0.00	3.99	0.07	33.36	0.37	13.35	0.31
9/23/10	S-Int	0.00	4.21	0.10	14.76	0.13	9.46	0.01
9/23/10	S-UML	0.00	9.93	0.32	42.09	0.91	28.72	0.09
10/5/10	S-Int	0.00	6.79	0.55	74.51	0.00	3.03	0.32
10/5/10	S-UML	0.00	5.20	0.76	60.58	0.44	5.45	0.42
10/21/10	S-Int	0.00	5.98	0.17	15.31	0.00	0.34	0.02
10/21/10	S-UML	0.15	3.14	0.06	19.08	0.00	0.65	0.00
10/26/10	S-Int	0.25	2.84	0.18	14.25	0.00	0.00	0.00
10/26/10	S-UML	0.12	1.48	0.13	11.20	0.00	0.54	0.00
11/2/10	S-Int	0.30	2.30	0.54	21.47	0.00	0.14	0.00
11/16/10	N-Int	0.00	3.24	0.60	2.48	0.00	0.00	0.00
11/16/10	S-Int	0.00	3.57	0.45	14.42	0.00	0.00	0.00

Table 2. Areal comparison of integrated (15m) and upper mixed layer (6m) tows. When the Areal Ratio Int:UML is less than 1, the majority of zooplankton are located in the epilimnion, whereas when the values are greater than 1 the lake is mixed. In 2010 the lake started to mix towards the end of September and then throughout the month of October the areal comparison shows mixing occurred.

Date	**StationID**	**Standard sample**	**Total Density (#/m^3)**	**Total Density (#/m^2)**	**Areal Ratio Int:UML**
7/27/10	S-Int	N	87772	1316581	
7/27/10	S-UML	Y	232052	1392313	0.95
8/10/10	S-Int	N	158402	2376023	
8/10/10	S-UML	Y	675517	4053103	0.59
8/31/10	S-Int	N	66106	991597	
8/31/10	S-UML	Y	200059	1200356	0.83
9/8/10	S-Int	N	106612	1599177	
9/8/10	S-UML	Y	303087	1818519	0.88
9/23/10	N-Int	N	43772	656579	
9/23/10	N-UML	N	68527	411160	1.60
9/23/10	S-Int	N	35242	528624	
9/23/10	S-UML	Y	105157	630941	0.84
10/5/10	S-Int	N	138256	2073847	
10/5/10	S-UML	Y	114423	686538	3.02
10/21/10	S-Int	N	28556	428333	
10/21/10	S-UML	Y	33165	198992	2.15
10/26/10	S-Int	N	23881	358218	
10/26/10	S-UML	Y	23886	143316	2.50

Table 3. Density (#/mL) and biomass (µg/L) of phytoplankton in Onondaga Lake in 2010. The phytoplankton community of Onondaga Lake typically consists of Bacillariophyta, Chlorophyta, Chrysophyta, Cryptophyta, Cyanophyta, Pyrrhophyta, Euglenophyta, and "miscellaneous microflagellates," but Euglenophyta were only present on 6/29 and miscellaneous microflagellates only on 6/2 in 2010. Data are presented for each sampling date at both north and south stations, when taken. Samples taken were integrated upper mixed layer samples.

Date	Depth	Station	Variable	Bacillario	Chloro	Chryso	Crypto
3/23	UML	South	Abundance	4358.96	170.39	0.00	238.55
3/23	UML	South	Biomass	2736.99	16.64	0.00	39.85
4/7	UML	North	Abundance	391.91	306.71	178.82	903.09
4/7	UML	North	Biomass	470.39	93.06	13.28	176.12
4/7	UML	South	Abundance	650.24	283.99	176.07	471.42
4/7	UML	South	Biomass	313.35	83.01	2.58	138.93
4/20	UML	South	Abundance	593.15	184.59	241.39	3400.79
4/20	UML	South	Biomass	736.39	8.05	4.87	153.74
5/4	UML	South	Abundance	1451.09	255.59	269.79	3975.87
5/4	UML	South	Biomass	2653.23	21.71	175.20	145.60
5/18	UML	South	Abundance	3192.05	116.34	675.90	488.46
5/18	UML	South	Biomass	2457.03	9.17	207.56	100.26
6/2	UML	South	Abundance	1476.75	511.18	26780.30	1533.55
6/2	UML	South	Biomass	1161.52	115.35	821.41	298.11
6/15	UML	North	Abundance	70.51	397.59	7024.03	908.77
6/15	UML	North	Biomass	22.38	21.46	215.17	404.39
6/15	UML	South	Abundance	151.46	302.92	6967.23	1476.75
6/15	UML	South	Biomass	27.72	11.30	233.27	234.33
6/29	UML	South	Abundance	27.26	358.81	708.84	1617.61
6/29	UML	South	Biomass	2.31	11.22	11.78	175.33
7/13	UML	South	Abundance	80.86	49500.06	2453.68	1003.42
7/13	UML	South	Biomass	110.50	1391.84	135.44	54.31
7/27	UML	South	Abundance	95.27	1553.69	4525.67	4543.85
7/27	UML	South	Biomass	12.77	255.15	105.95	751.07
8/10	UML	South	Abundance	90.88	1385.72	4270.60	513.30
8/10	UML	South	Biomass	6.41	284.30	143.87	154.24
8/31	UML	South	Abundance	77.09	3225.20	2144.70	3235.22
8/31	UML	South	Biomass	6.52	211.58	64.57	248.41
9/8	UML	South	Abundance	81.79	924.29	2269.65	1390.42
9/8	UML	South	Biomass	76.17	183.81	67.76	172.50
9/23	UML	North	Abundance	1212.22	1130.09	2675.19	4024.05
9/23	UML	North	Biomass	1896.44	644.35	78.90	370.42
9/23	UML	South	Abundance	1442.67	979.67	1340.44	1306.36
9/23	UML	South	Biomass	2173.69	205.81	40.36	166.98
10/5	UML	South	Abundance	181.75	363.51	327.16	872.42
10/5	UML	South	Biomass	148.96	80.61	5.94	178.00
10/21	UML	South	Abundance	413.34	575.55	2574.85	817.89
10/21	UML	South	Biomass	122.77	62.62	37.62	89.71
10/26	UML	South	Abundance	195.23	303.97	2017.47	1026.91
10/26	UML	South	Biomass	21.65	44.02	28.81	125.60
11/2	UML	South	Abundance	181.60	722.32	386.23	1156.41
11/2	UML	South	Biomass	34.89	55.20	5.83	100.52
11/16	UML	North	Abundance	918.61	803.40	7.10	2129.93
11/16	UML	North	Biomass	168.88	67.96	0.21	236.21
11/16	UML	South	Abundance	531.32	365.70	122.68	1085.98
11/16	UML	South	Biomass	95.34	27.88	1.95	144.06

Date	Depth	Station	Variable	Cyano	Eugleno	Misc. Micro	Pyrrho
3/23	UML	South	Abundance	0.00	0.00	0.00	25.46
3/23	UML	South	Biomass	0.00	0.00	0.00	23.66
4/7	UML	North	Abundance	1499.47	0.00	0.00	30.56
4/7	UML	North	Biomass	2.31	0.00	0.00	97.42
4/7	UML	South	Abundance	1295.00	0.00	0.00	22.72
4/7	UML	South	Biomass	2.12	0.00	0.00	34.26
4/20	UML	South	Abundance	3123.90	0.00	0.00	14.20
4/20	UML	South	Biomass	5.30	0.00	0.00	8.56
5/4	UML	South	Abundance	3038.70	0.00	0.00	0.00
5/4	UML	South	Biomass	6.99	0.00	0.00	0.00
5/18	UML	South	Abundance	1249.56	0.00	0.00	0.00
5/18	UML	South	Biomass	2.13	0.00	0.00	0.00
6/2	UML	South	Abundance	1703.94	0.00	227.19	2.74
6/2	UML	South	Biomass	2.77	0.00	57.90	8.04
6/15	UML	North	Abundance	2158.33	0.00	0.00	5.49
6/15	UML	North	Biomass	3.32	0.00	0.00	36.03
6/15	UML	South	Abundance	2215.13	0.00	0.00	18.93
6/15	UML	South	Biomass	3.59	0.00	0.00	3.17
6/29	UML	South	Abundance	1090.52	9.09	0.00	0.00
6/29	UML	South	Biomass	1.57	7.13	0.00	0.00
7/13	UML	South	Abundance	327.16	0.00	0.00	4.39
7/13	UML	South	Biomass	0.42	0.00	0.00	13.79
7/27	UML	South	Abundance	1090.52	0.00	0.00	36.35
7/27	UML	South	Biomass	1.93	0.00	0.00	149.47
8/10	UML	South	Abundance	1563.08	0.00	0.00	18.18
8/10	UML	South	Biomass	2.61	0.00	0.00	98.67
8/31	UML	South	Abundance	2380.98	0.00	0.00	95.27
8/31	UML	South	Biomass	5.07	0.00	0.00	608.62
9/8	UML	South	Abundance	2265.03	0.00	0.00	27.26
9/8	UML	South	Biomass	11.49	0.00	0.00	95.93
9/23	UML	North	Abundance	982.22	0.00	0.00	53.86
9/23	UML	North	Biomass	27.87	0.00	0.00	115.34
9/23	UML	South	Abundance	582.08	0.00	0.00	11.36
9/23	UML	South	Biomass	23.52	0.00	0.00	2.28
10/5	UML	South	Abundance	63.61	0.00	0.00	4.54
10/5	UML	South	Biomass	52.63	0.00	0.00	42.82
10/21	UML	South	Abundance	1973.39	0.00	0.00	15.15
10/21	UML	South	Biomass	8.69	0.00	0.00	9.14
10/26	UML	South	Abundance	817.89	0.00	0.00	0.00
10/26	UML	South	Biomass	1.45	0.00	0.00	0.00
11/2	UML	South	Abundance	545.26	0.00	0.00	13.63
11/2	UML	South	Biomass	0.96	0.00	0.00	60.49
11/16	UML	North	Abundance	411.79	0.00	0.00	7.10
11/16	UML	North	Biomass	27.42	0.00	0.00	9.52
11/16	UML	South	Abundance	627.05	0.00	0.00	4.54
11/16	UML	South	Biomass	1.09	0.00	0.00	0.76

Table 4. The major algal genera in Onondaga Lake in 2010. Number of species identified were 35 diatoms, 41 chlorophytes, 8 chrysophytes, 5 cryptophytes, 10 cyanophytes, 7 dinoflagellates, 1 euglenophyte, and miscellaneous flagellates. The top genera were mostly the same as in 2009 with 10 of the 12 most abundant genera in 2009 also being the most abundant in 2010. Of the top 13 genera in 2010, 6 were diatoms, two (*Oocystis* and *Chlamydomonas*) are chlorophytes, two (*Cryptomonas* and *Rhodomonas*) are cryptophytes, two (*Erkenia* and *Dinobryon*) are chrysophytes and one *Peridinium* is a large dinoflagellate. It is notable that no cyanobacteria genus made up more than 1 % of the biomass in 2008-2010. Also notable is that the most abundant diatom identified in 2009, *Actinocyclus normani*, was a small contributor in 2010. The species is considered an exotic in Great Lakes (Mills et al. 1993) and considered to be present in 1938 in Lake Ontario (Stoermer et al. 1985). In 2010 the large colonial *Asterionella* dominated the first sampling date in March, *Synedra*, *Diatoma* and *Fragilaria* dominated in May, and the large colonial *Fragilaria* dominated in September.

Genus	**Division**	**Mean biomass (ug/L)**	**Relative biomass (% of total)**	**2009 Biomass/Rank**
Fragilaria	Bacillariophyta	198.6	16.47	177.5/2
Synedra	Bacillariophyta	131.6	10.92	30.1/10
Diatoma	Bacillariophyta	125.8	10.43	84.4/7
Asterionella	Bacillariophyta	124.3	10.31	171.5/3
Cryptomonas	Cryptophyta	123.5	10.25	87.2/5
Erkenia	Chrysophyta	76.3	6.33	81.2/8
Stephanodiscus	Bacillariophyta	68.9	5.72	135.6/4
Rhodomonas	Cryptophyta	59.0	4.89	52.3/9
Peridinium	Pyrrhophyta	53.9	4.47	1.1/not ranked
Oocystis	Chlorophyta	21.8	1.81	13.3/12
Dinobryon	Chrysophyta	20.6	1.71	14.8/11
Cyclotella	Bacillariophyta	19.3	1.60	6.2/not ranked
Chlamydomonas	Chlorophyta	17.2	1.43	12.6/not ranked

Figure 1. Temporal trends in biovolume (panel A) and proportional biovolume (panel B) of phytoplankton divisions in Onondaga Lake in 2010. When both north and south station samples were available we present the mean values. Phytoplankton biomass peaked in May during the diatom-dominated spring bloom (Bacillariophyta), and was low in June, coinciding with increasing zooplankton biomass (Fig. 9). A summer chlorophyte bloom with some diatoms and chrysophytes occurred in July. September was more diatoms with some chlorophytes and cryptophytes. Note that bluegreens (Cyanophyta) are almost absent. The first sample was collected on 3/23 and the last on 11/16. Sample dates are in Table 2.

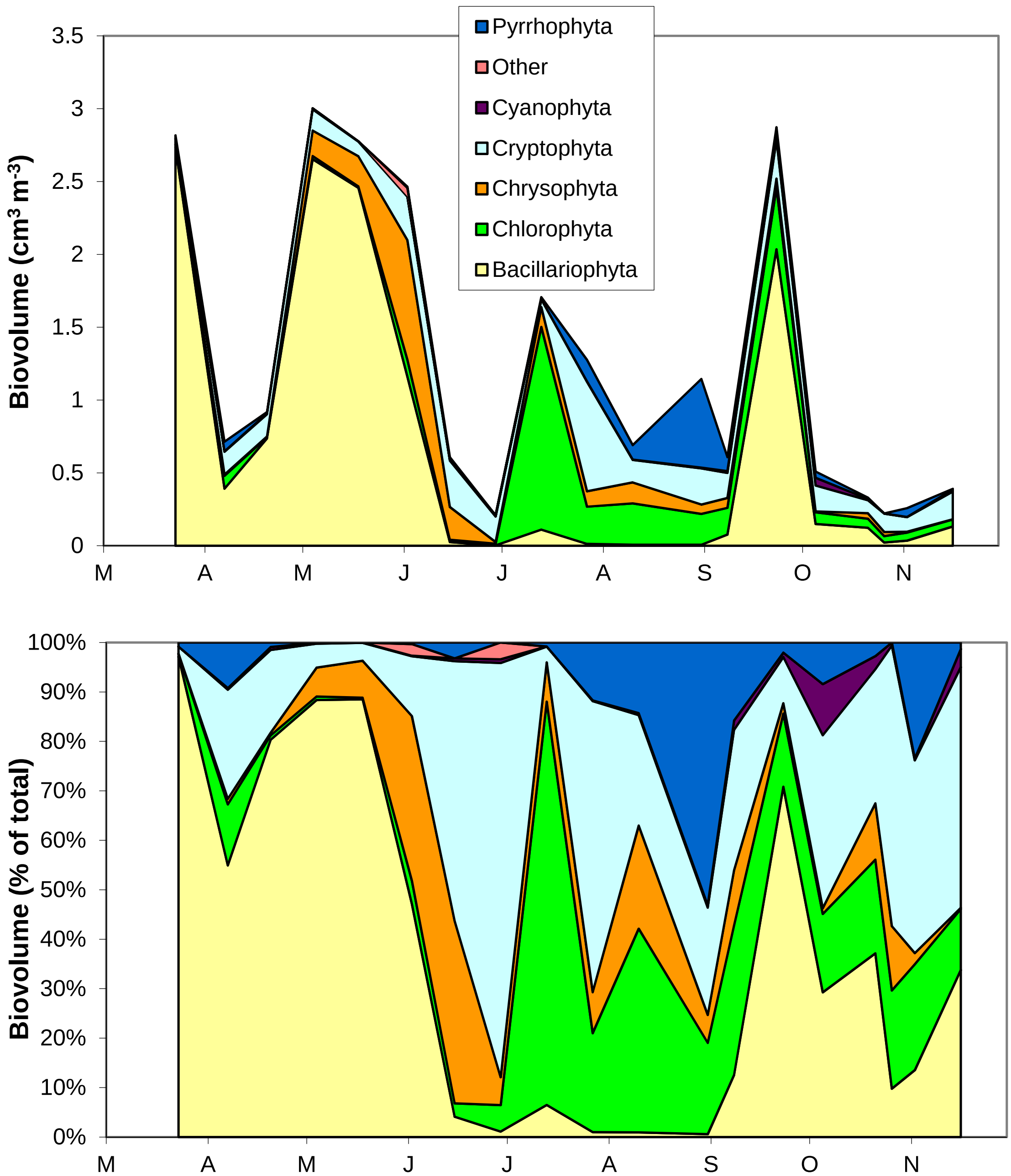


Figure 2. Temporal trends in phytoplankton in Onondaga Lake in 2010 divided in netplankton (GALD>50 µm) and nanoplankton (GALD<50 µm). Small phytoplankton dominate most of the year, but the March and May diatom bloom consisted of larger taxa (*Asterionella* and *Synedra*). The fall diatom bloom was mainly *Fragilaria* which was smaller than 50 µm.

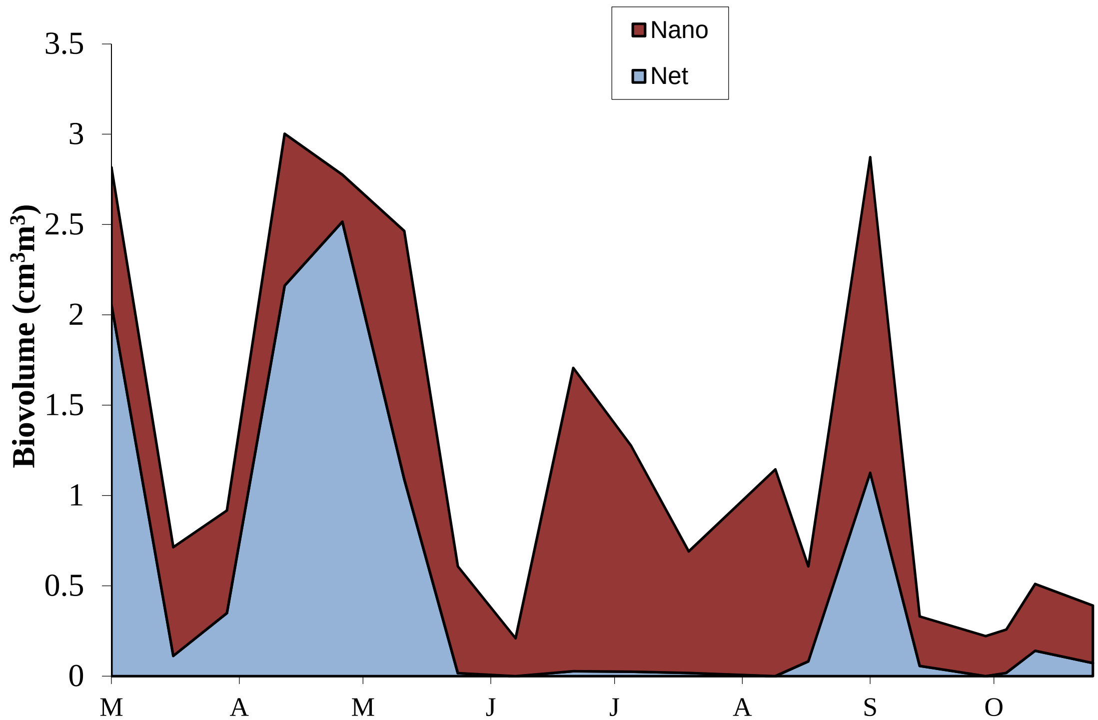


Figure 3. Temporal trend of biovolume of cyanobacteria genera in Onondaga Lake in 2010. Cyanobacteria biovolume was very low throughout the year. The largest peak occurred in beginning of October and was dominated by *Planktothrix* and *Aphanizomenon.* The large nitrogen fixing and often toxic colonial bluegreens (*Microcystis*, *Anabaena*, and *Oscillatoria*) are almost absent. The other group includes the genera *Planktothrix*, *Chroococcus* and *Synechococcus*.

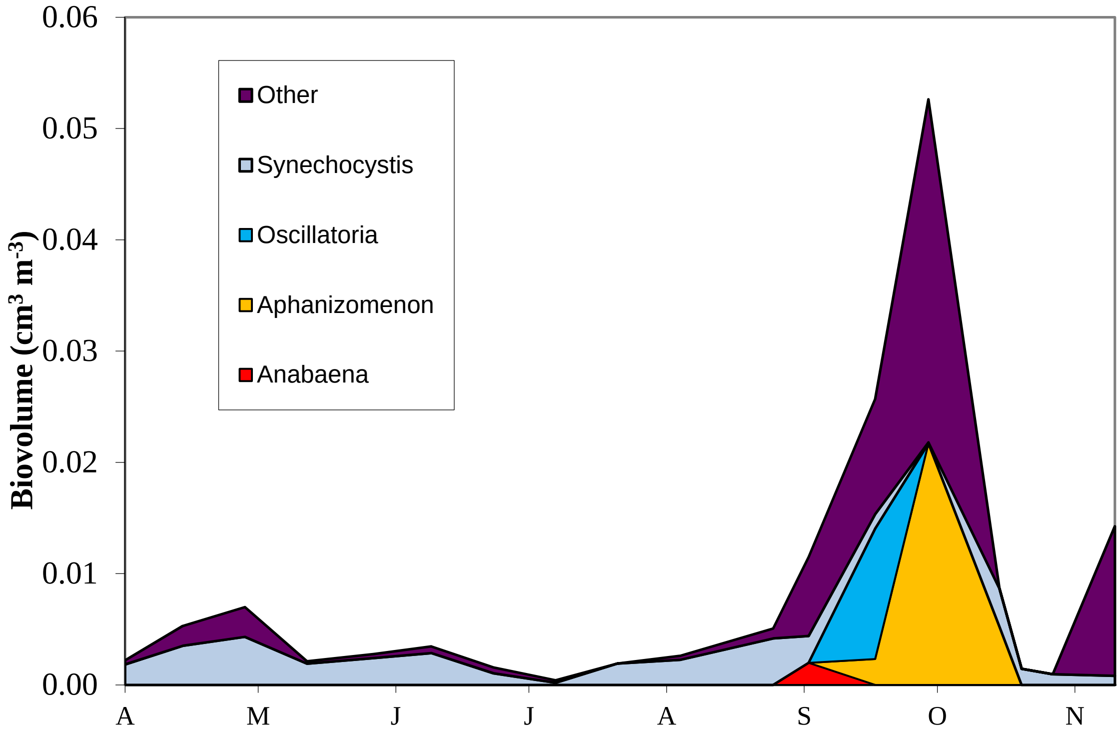


Figure 4. Total density (#/L) and biomass (ug/L) of crustacean zooplankton in Onondaga Lake in 2010 from standard samples (south deep). Density and biomass increased at the end of June although declined thereafter with another peak in the middle of August and a smaller peak in early September. Values declined considerably by late September through the rest of the year. All three biomass peaks (6/29, 8/10 and 9/8) consist mostly of *Bosmina*. Data from the North Deep station are similar to the results from the South Deep station when both were available.

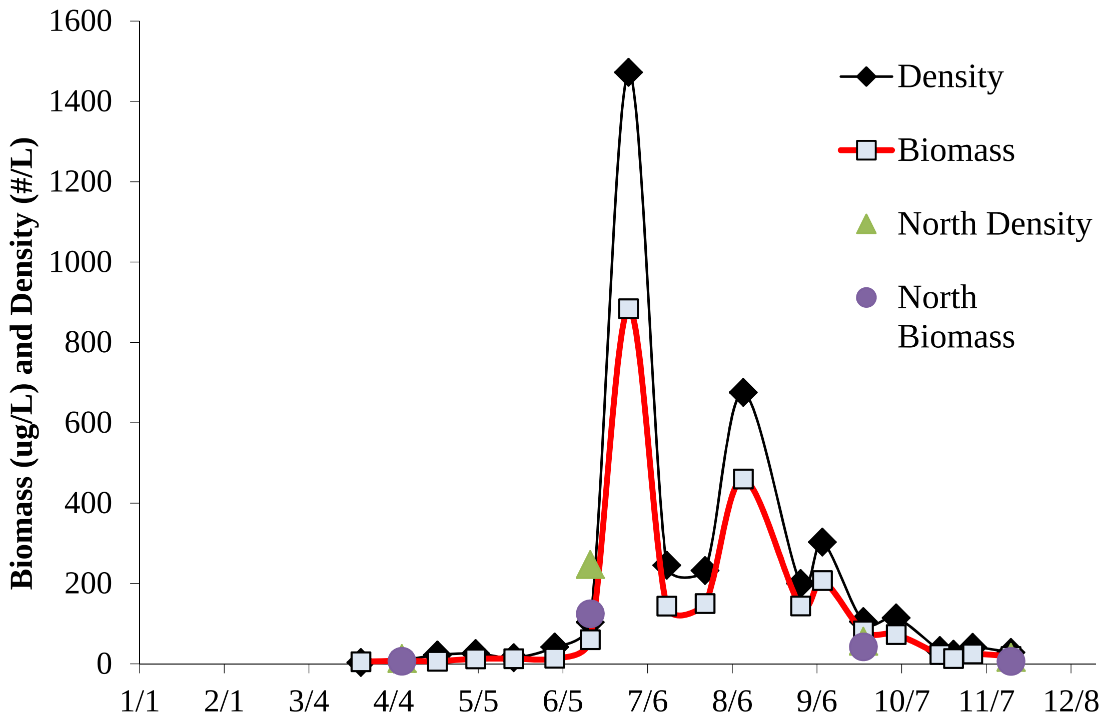


Figure 5. Composition of copepod and cladocerans as total biomass (A) and as proportion of biomass (B) in Onondaga Lake in 2010.

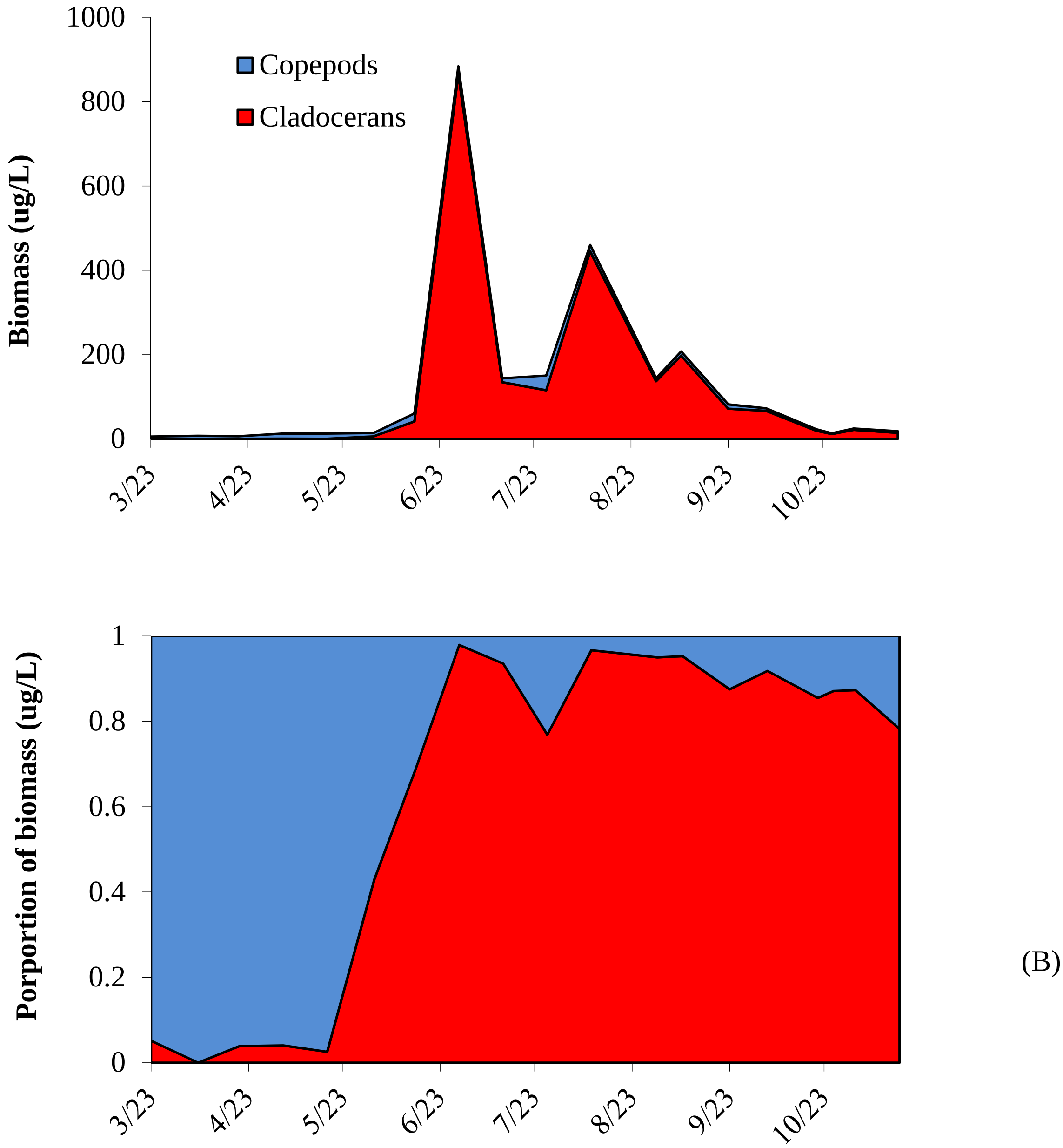
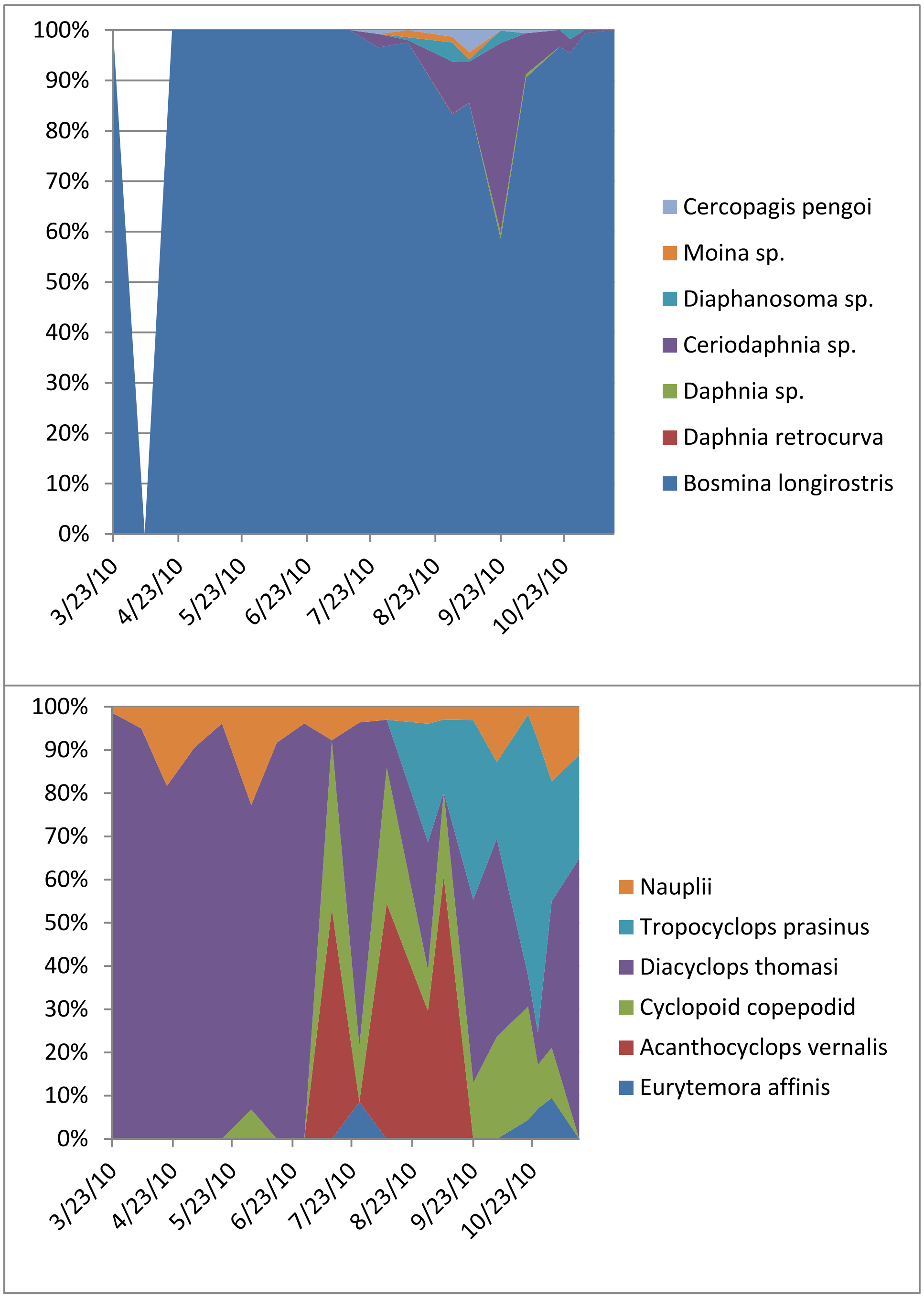


Figure 6. Composition of the cladoceran (A) and copepod (B) community in Onondaga Lake in 2010. A total of 10 species, as well as nauplii and copepodites, were identified in Onondaga Lake in 2010. The dominant cladocerans were *Bosmina longirostris* and *Ceriodaphnia sp*. Other cladocerans present included *Diaphanosoma birgei*, *Daphnia retrocurva*, *Moina sp*. and *Cercopagis pengoi*. The predatory cladoceran *Leptodora kindtii* was not observed in 2010. The dominant copepods during the year were the cyclopoids *Diacyclops thomasi*, *Acanthocyclops vernalis* and *Tropocylops prasinus*.



(B)

Figure 7. Biomass of predatory zooplankton in Onondaga Lake in 2010. Predatory cyclopoid copepod (*Acanthocyclops* and *Mesocyclops*) were more abundant than predatory cladocerans in 2010. The exotic zooplanktor *Cercopagis pengoi* was observed in 2010 as it has been in 2000 and 2002- 2008. It was found in samples collected on 7 dates (7/27, 8/10, 8/31, 9/8, 9/23, 10/5, 10/21), in mid-summer to mid-fall. The biomass of the species was relatively small throughout most of the season (maximum value of 8.8 µg/L), only reaching a proportion of 4.2% of the total biomass in early September of 2010. 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 2010.

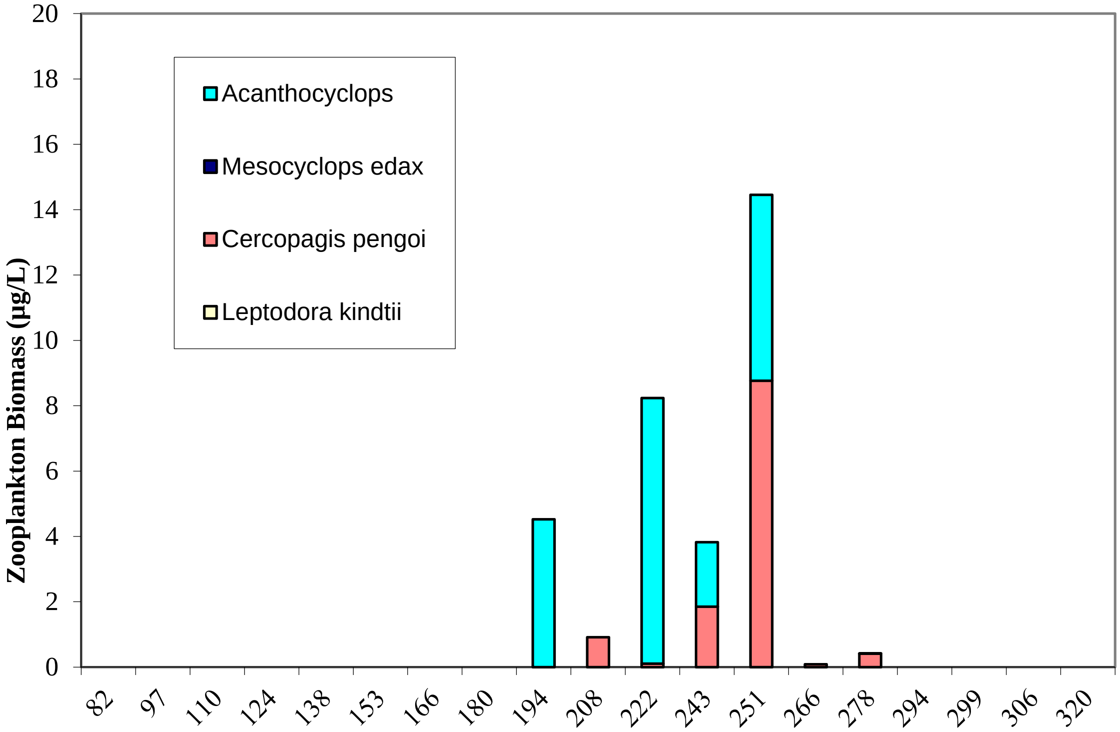


Figure 8. Average crustacean zooplankton length (mm) in Onondaga Lake in 2010. The largest mean size of zooplankton (0.46 mm) was observed in a March spring sample. The decline in length in the spring is due to high proportion of nauplii in the samples. Length remained small throughout the rest of the season when the zooplankton community became dominated by *Bosmina* and cyclopoids. The corresponding line from 2009 is in light colors. The lines are 2-point moving averages. The decline in length in the fall of 2009 indicates a strong alewife year class in 2009, which is supported by the small lengths throughout the 2010 season. Average length is based on both north and south stations when available.

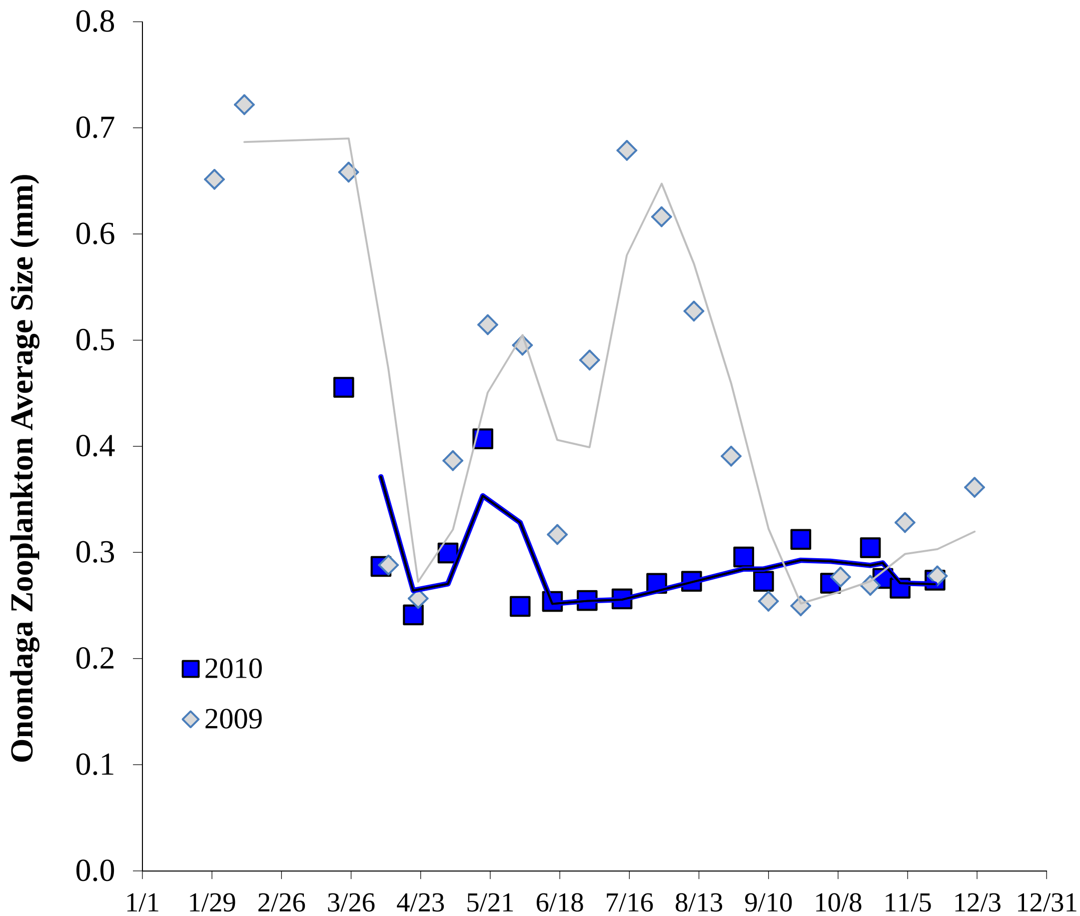
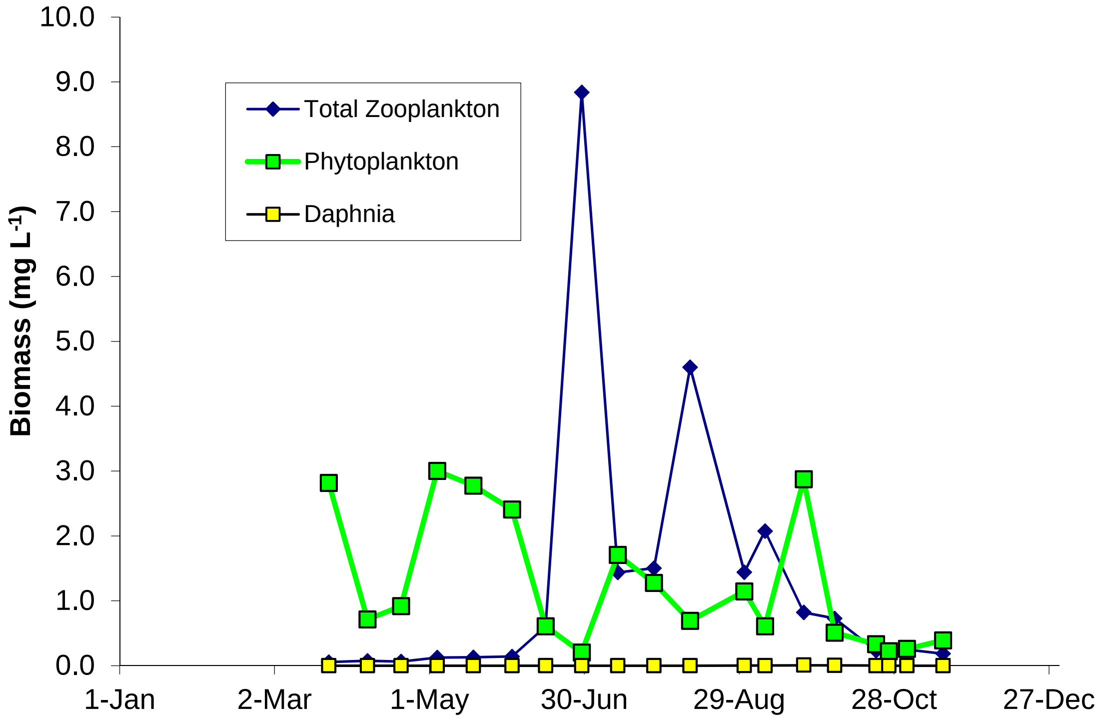


Figure 9. Temporal trend of zooplankton and phytoplankton biomass in Onondaga Lake in 2010. Zooplankton biomass was dominated by bosminids through most of the year. The decline in phytoplankton biomass in the middle of June is associated with declines in diatoms. Zooplankton biomass increased at that time but the decline could be due to silica depletion as the decline was mainly in diatoms, or to increased grazing by zebra/quagga mussels as temperatures increase in June.



Time series 1996 – 2010 for Onondaga Lake

Figure 10. Temporal trend of average annual phytoplankton biovolume (April – October) in Onondaga Lake from 1998-2010. Annual biovolume decreased significantly during this period (linear regression, $p<0.001$).

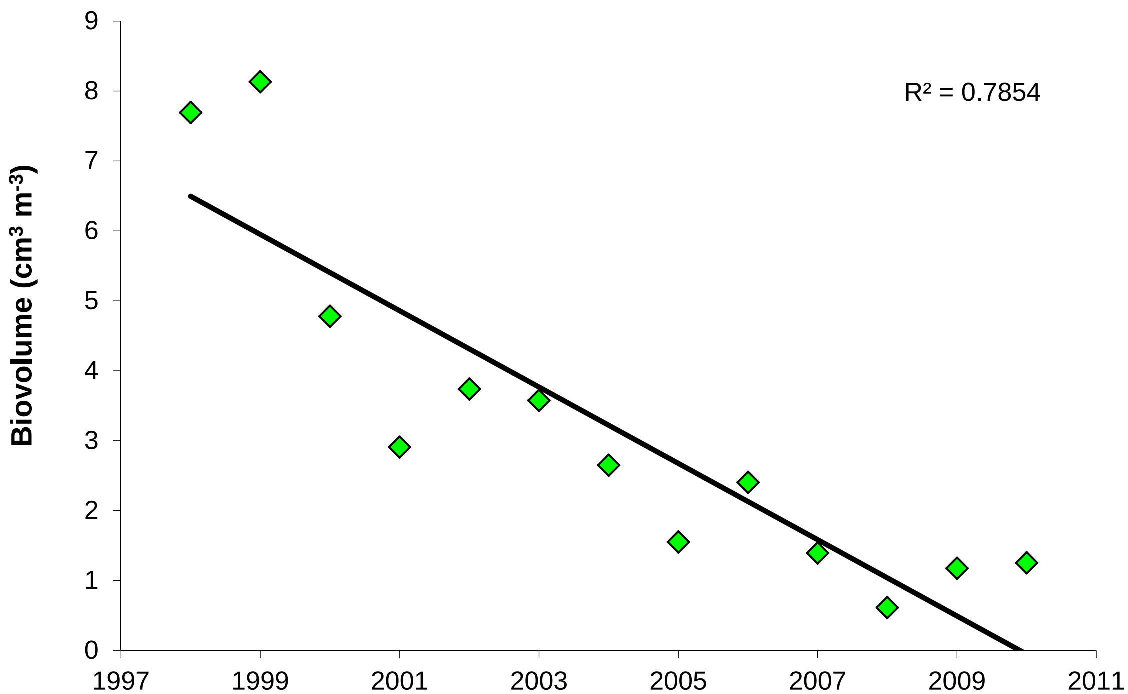


Figure 11. Temporal trend of average annual biovolume (April-October) of phytoplankton divisions in Onondaga Lake from 1998-2010. The phytoplankton community of Onondaga Lake consists of Bacillariophyta, Chlorophyta, Chrysophyta, Cryptophyta, Cyanophyta, Pyrrhophyta, and Euglenophyta. Euglenophyta and Xanthophyta were present briefly in June 2002 but Xanthophyta has not been seen since 2002, and Euglenophyta was absent in 2003 and 2004 but present briefly in 2005, 2006, 2007, 2009 and 2010. Cyanobacteria (Cyanophyta) and dinoflagellates (Pyrrhophyta) decreased significantly during this period (linear regressions, both $p<0.003$). Crysophytes are a small component of the biomass and have increased significantly ($p<0.03$). Figure 11B has the time trend for cyanobacteria by major genera.

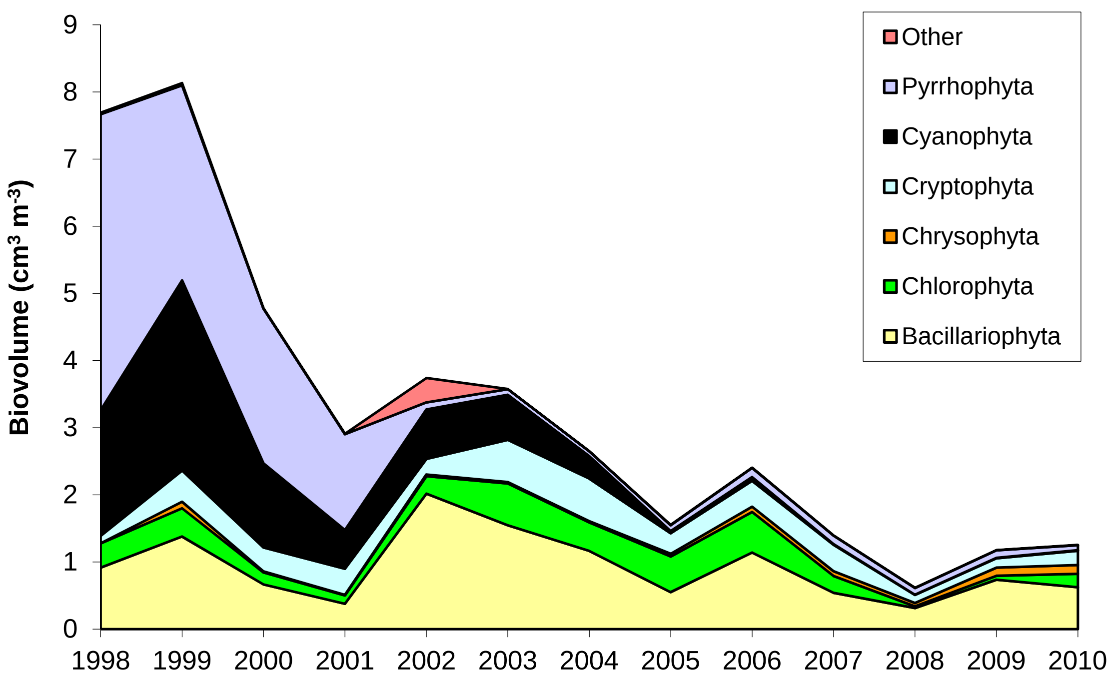


Figure 11B. Time trend of mean annual biovolume of cyanobacteria genera in Onondaga Lake from 1998 to 2010. Cyanobacteria biovolume in 2010 was very low.

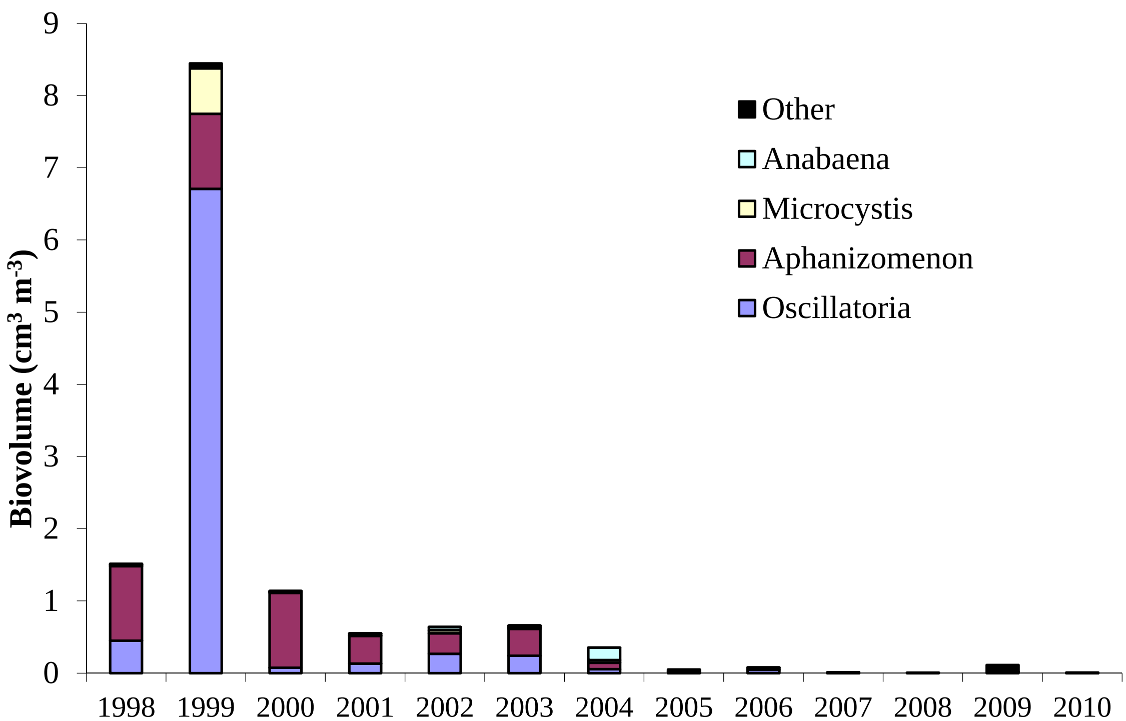


Figure 12. Temporal trend of average annual proportional biovolume of phytoplankton divisions in Onondaga Lake from 1998-2010. Chrysophytes, cryptophytes and diatoms increased in proportional biovolume over this period, while cyanobacteria (Cyanophyta) and dinoflagellates (Pyrrhophyta) decreased (linear regressions, all $p<0.05$).

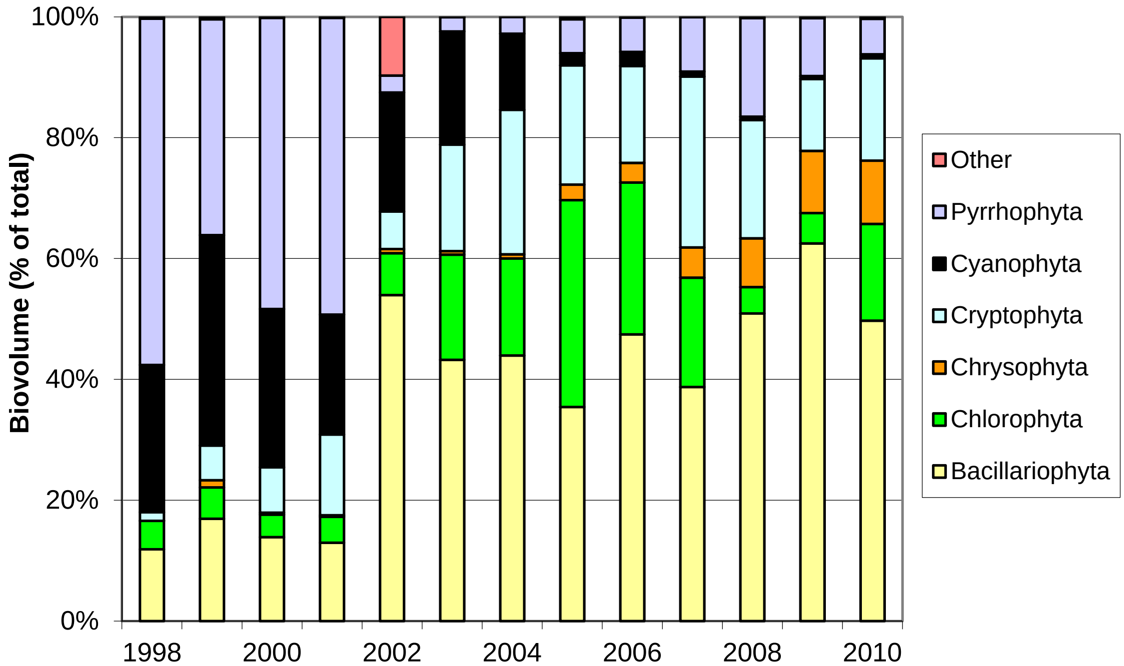
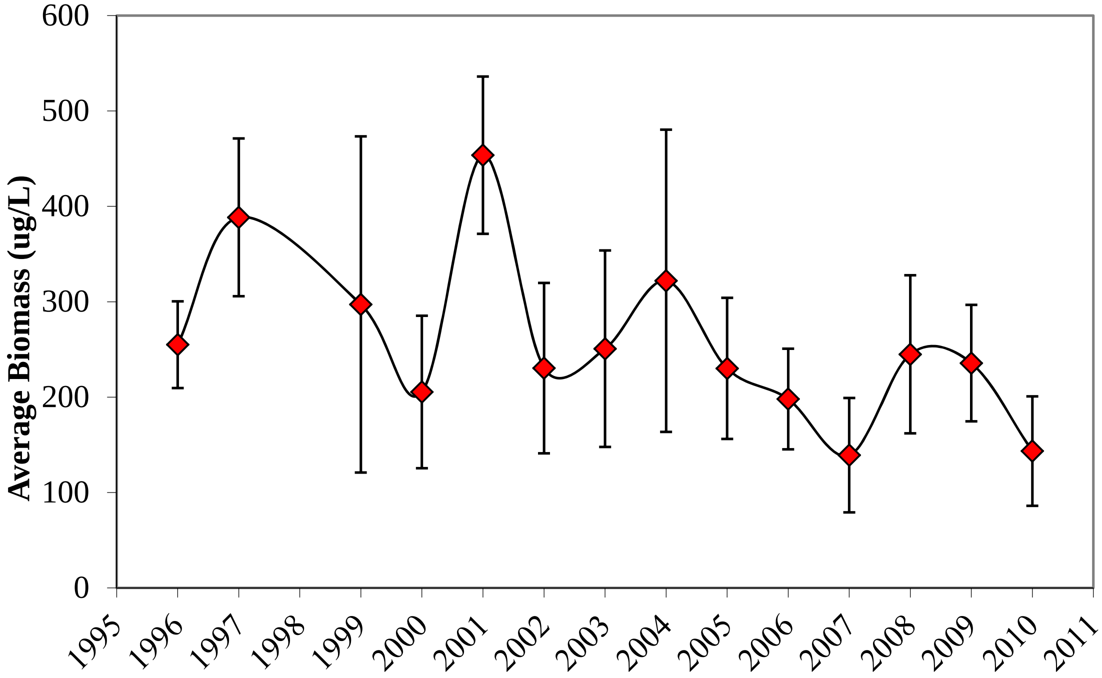


Figure 13. Average biomass of zooplankton (all taxa combined) and the proportion of major taxa in Onondaga Lake from April through October in 1996-1997 and 1999-2010. For consistency across time, all densities are based on the 2008 sampling schedule (integrated samples during the mixed period, and upper 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 Holeck et al. (2008). 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, and in the summer of 2008 following alewife declines. 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. Data from 1998 is only available for proportions due to an error in recording sample volume that year.

A. Average Zooplankton Biomass of All Taxa



B. Proportion of major groups across time

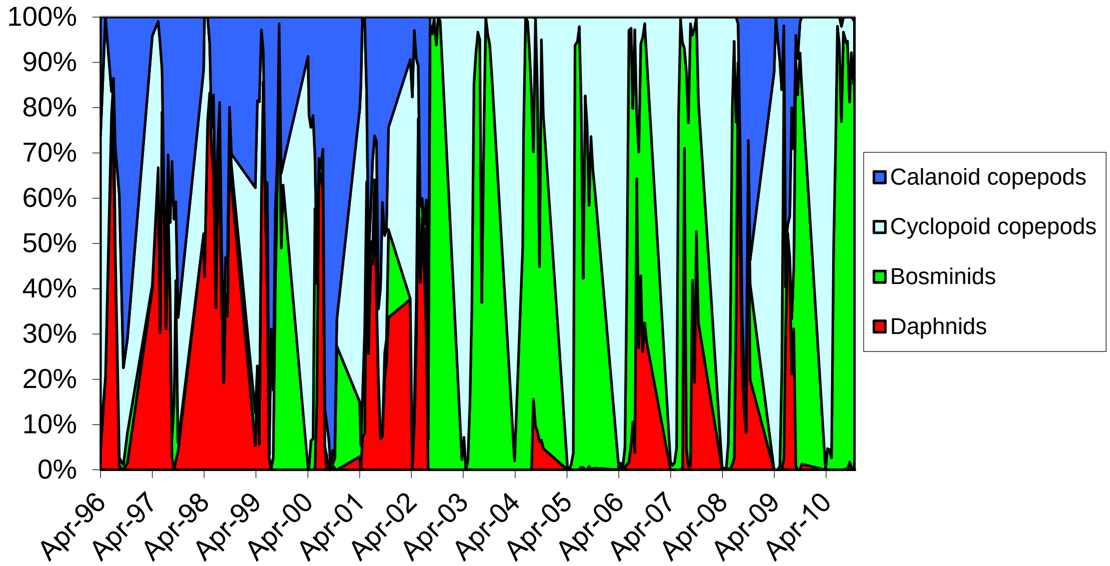
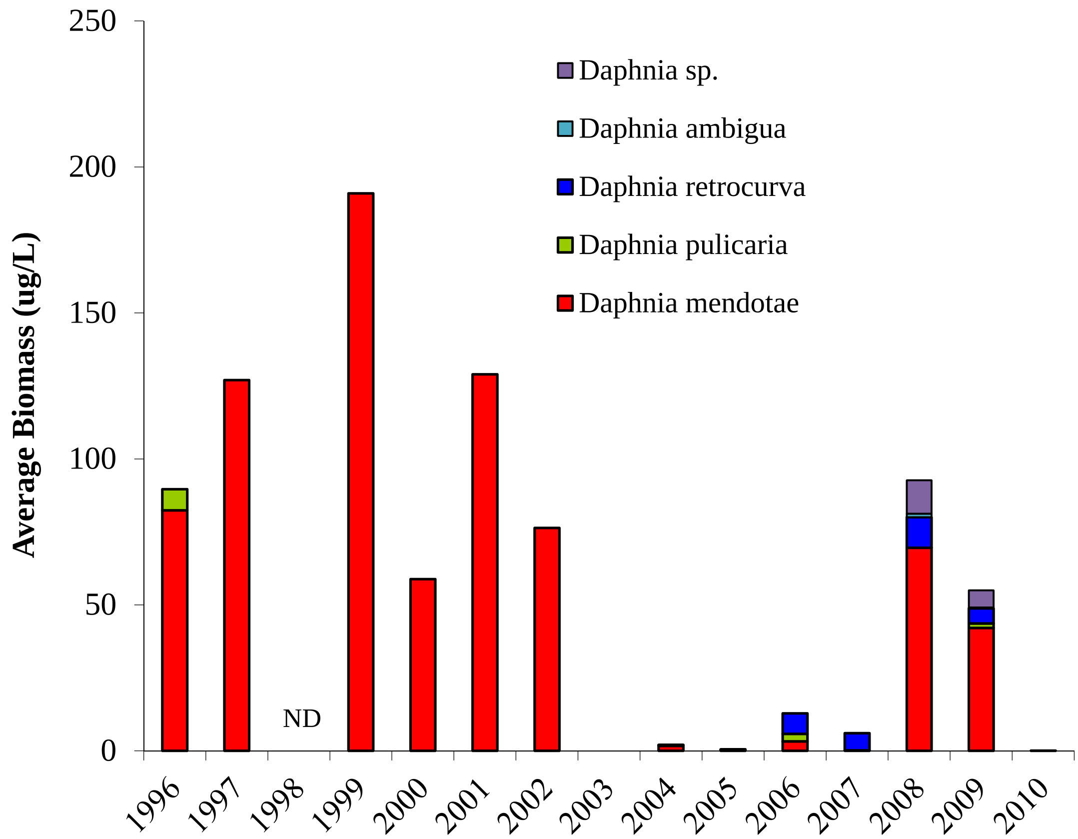


Figure 14. Biomass of different *Daphnia* species in Onondaga Lake. There is no data available on biomass for 1998, but the *Daphnia* population that year was dominated by *D. mendotae*. *Daphnia* species composition is a sensitive indicator of fish zooplanktivory rate. Data are average of samples collected during each year extracted from the Onondaga Bio Database using the samples from the South Deep station only 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 is attributed to the presence of abundant alewife during these time periods. *Daphni*a 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 that would have a high enough biomass and large enough individual fish size 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 data are based on standard sites only (see Fig 13). Also shown is a more detailed time series for all *Daphnia* combined. (Note: ND = No Data)



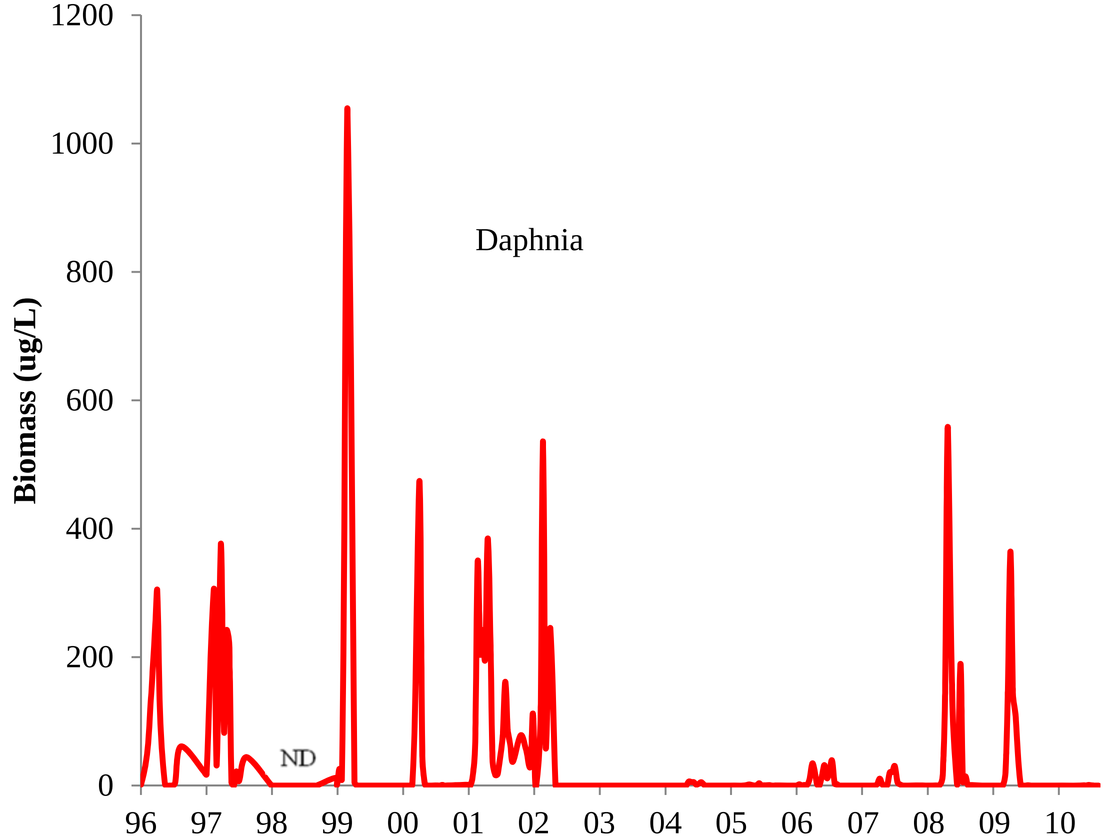

1200
1000
800
600
400
200
0
Biomass (ug/L)
Daphnia
ND
96
97
98
99
00
01
02
03
04
05
06
07
08
09
10

Figure 15. Time trends in average size of all crustaceans from 1996 to 2010 in Onondaga Lake. Data is extracted from the Onondaga Lake Bio Database. Error bars are one SE and represent variability across seasons. Note the return of 2008 and 2009 to almost pre-2002 average lengths followed by the decline in 2010. 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 2008-2010. *Cercopagis pengoi* is not included.

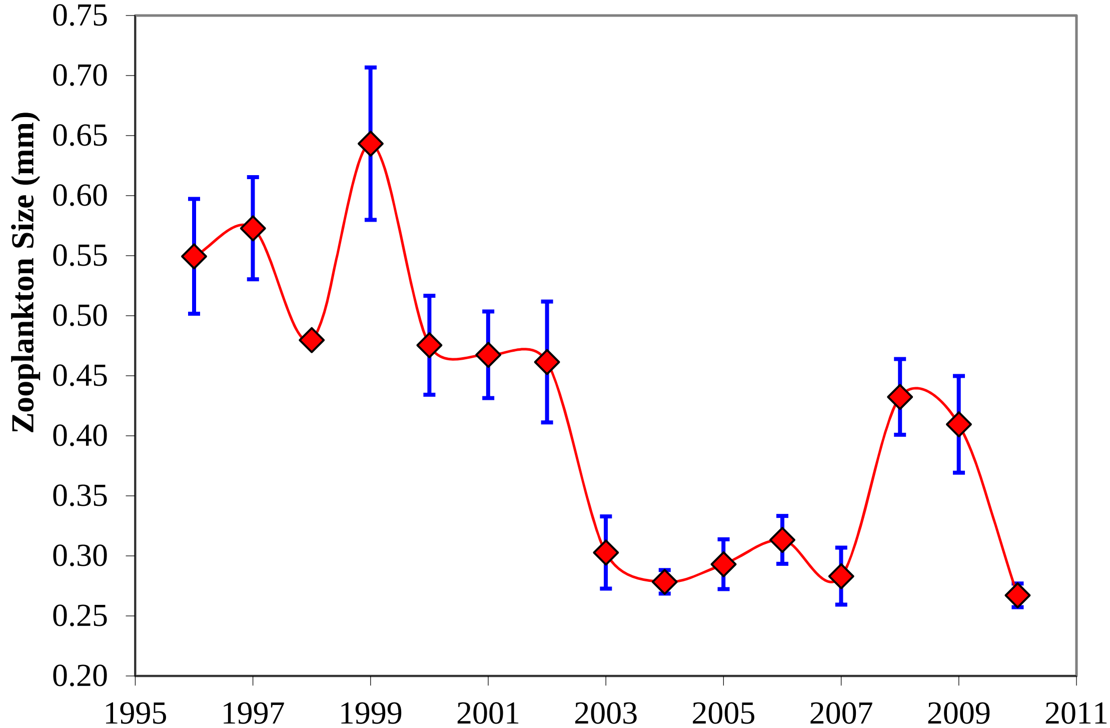


Figure 16. Time trend of zooplankton and phytoplankton biomass in Onondaga Lake 1996 to 2010 (April-October). Zooplankton biomass was converted to wet weight assuming a dry to weight ratio of 10%. For zooplankton biomass in dry weight, see Figure 13.

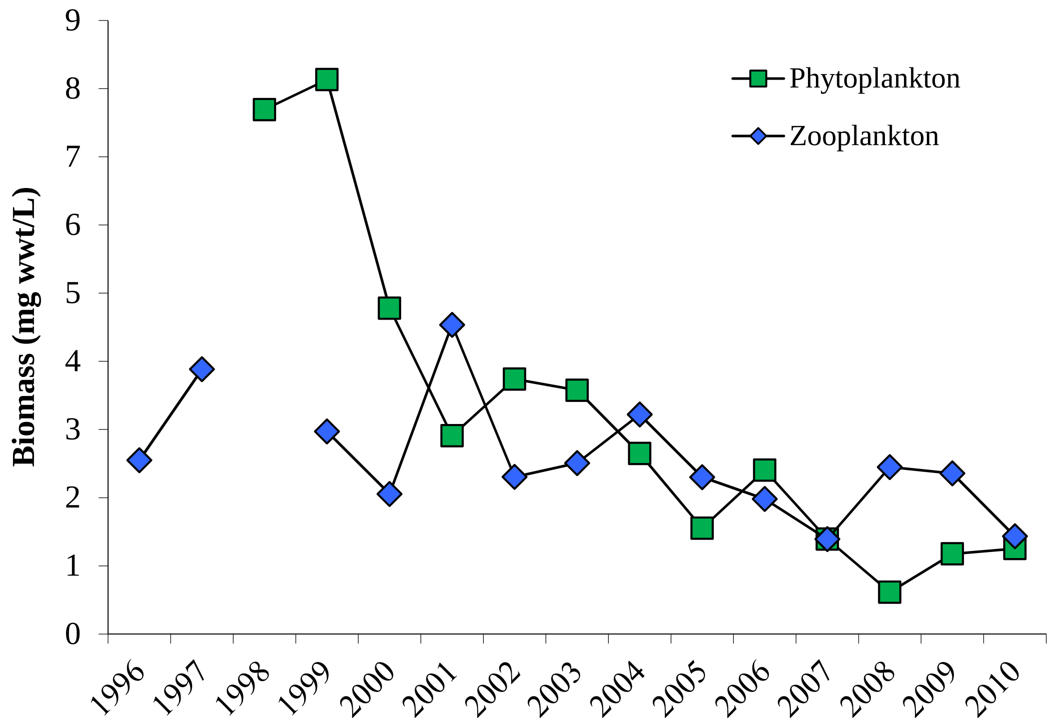
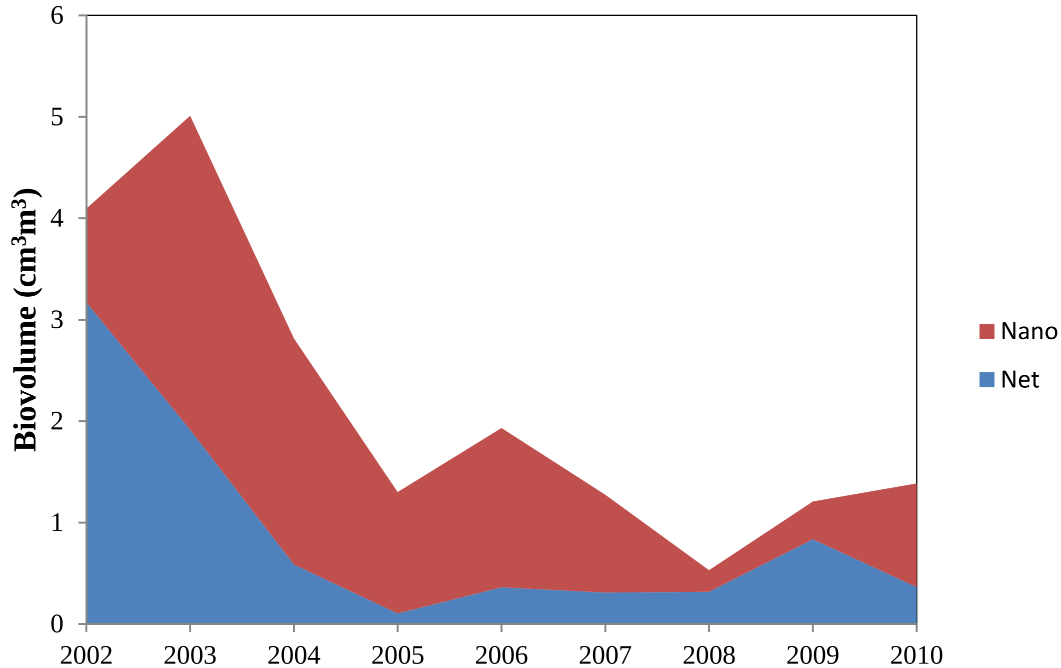


Figure 17. Temporal trend in phytoplankton in Onondaga Lake in 2002-2010 divided in netplankton (GALD>50 µm) and nanoplankton (GALD<50 µm). Values are based on the average weekly standard sample June-September. Proportion of nano plankton was higher in 2010 than in 2008 and 2009 which can contribute to lower water clarity in 2010 compared to 2008 and 2009.



Significant Findings

The algal biomass in Onondaga Lake is declining. Average algal biomass in 2010 was only slightly higher than in 2009, and the average algal biovolume in 2010 (1.3 mg/L) is still at lower than expected from meso-eutrophic systems (3-5 mg/L, Wetzel 2001). Peak algal biomass did not exceed 3 mg/L. Average biomass in 2010 was the third lowest on record (the lowest being 2008 and 2009, Fig 16). The time trend shows a continuous decline in algal biomass since 1998 that is highly significant. We attribute the low algal biomass to lower phosphorus loading. In 2008 and 2009, algal biovolume was also affected by grazing from mussels and large zooplankton. Large zooplankton were rare in 2010 and algal biomass increased marginally compared to 2009. Interestingly, quagga and zebra mussels also declined in 2010 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. In 2010, *Aphanizomenon* (*A. gracile* and *A. flos-aquae*) was not found in significant numbers. Peak cyanobacteria abundance was only 0.05 mg/L in 2010, only slightly higher than in 2009.

Diatoms had the highest biovolume of all algae groups and showed three peaks, an early spring peak, a mid-spring peak, and a fall peak. In 2009 a diatom species not previously identified from Onondaga Lake (*Actinocyclus normani*) was the most abundant phytoplankton species in the lake (average over the season). It dominated the 2009 fall diatom bloom. This species is an exotic that has been in Lake Ontario since 1938 (Stoermer et al. 1985, Mills et al. 1993). In 2010 *Actinocyclus normani* was rare and the most abundant phytoplankton species was *Fragilaria crotonensis* which dominated the fall bloom. The other common genera in 2009 were also common in 2010 (Table 4).

Average total zooplankton biomass (dry wt) was 143 μg/L in Onondaga Lake for the April-October time period, which is similar to 2007 and lower than in 2008 and 2009. In 2008-2010, as had been the case from 1997-2003, average zooplankton biomass (μg/L) was greater in Onondaga Lake than in nearby Oneida Lake. During 1996, and 2004-2007 small zooplankton dominated Onondaga Lake while larger species, especially *Daphnia pulicaria* and *Daphnia mendotae*, led to high average total zooplankton biomass in Oneida Lake. Peak biomass in 2010 was 884 μg/L on 6/29 and dominated by bosminids. The average size of the total zooplankton community in Onondaga Lake throughout the year in 2010 (0.27 mm, calculated as the average of weekly samples) is smaller than values observed in 2003-2007 (0.28 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 speices and size composition indicate high planktivory throughout 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 rebouned to approximately 1000 fish/ha in the spring of 2010 (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* and *Leptodora kindtii* were observed in 2010 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 even though the zooplankton biomass declined and was dominated by small ineffective grazers (bosminids). Phosphorus loading was similar to 2009 and TP concentration in the water column increased slightly compared to 2009. Mussels are known to maintain phytoplankton biomass at a lower level than expected from the decreased nutrient loading alone (Idrisi et al. 2001, Zhu et al. 2006), but their density did not increase in standard sampling and the proportion of quagga mussels declined. We would have predicted a higher phytoplankton biovolume than observed given these changes in grazers and the slight increase in phosphorus loading.

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