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Assessing Community Structure of Lower Trophic Levels In Onondaga Lake, New York in 2009

2009 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 January (1/29) through December (12/1) in 2009 and preserved in Lugol's Iodine solution. Total number of sampling occasions was 21. The first two samples of the year (1/29 and 2/10) were from the north station. During the remainder of the year, samples were taken at just the south station except for 4 occasions when samples were collected at both the north and south deep stations (4/9, 6/16, 9/22, 11/17). 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 same depth as 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 nanoplankton. 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 three or six meters when the lake was thermally stratified and from 15 meters when no thermocline was present. Zooplankton samples were collected at the South Deep site throughout the year and at the North Deep site on several dates. 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 2009, calculated efficiency of the net varied between 33 and 198%, with an average of 101% (SE 8.1%). 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 2009 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

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Onondaga Lake in 2009

Table 1. Biomass (µg/L, dwt) of the major zooplankton groups in Onondaga Lake in 2009. Groups are Calanoid copepods (*Diaptomus minutus*, *D. oregonensis*, *D. siciloides*, and calanoid copepodites), Cyclopoid copepods (mostly *Diacyclops thomasi* and *Mesocyclops edax*, a few *Acanthocyclops vernalis*, *Eucyclops sp*. and *Tropocyclops prasinus*; also includes cyclopoid copepodites), copepod nauplii, Bosminids (*Bosmina longirostris*, a few *Eubosmina coregoni*), Daphniids (*Daphnia mendotae*, *D. retrocurva*, *D. pulicaria*, *D. ambigua* and *Daphnia* sp.), Other cladocerans (*Alona*, *Camptocercus*, *Ceriodaphnia*, *Chydorus*, *Diaphanosoma*), Predatory cladocerans (*Cercopagis pengoi*, *Leptodora kindtii*). Predatory cladocerans were not detected in 2009. The only other group caught was some harpacticoid copepods in December (not shown). Standard samples are the south station samples and the two north station winter samples. "Int" is integrated water column samples; "UML" is upper mixed layer, mostly from 6 m depth, a few tows from 3 m depth.

Seasonally, total zooplankton density and biomass were highest in June through August. Bosminids peaked on 6/16 and declined thereafter before returning in abundance in September and October. Daphnids, primarily *D. mendotae*, and calanoid copepods were most abundant from the end of June through August. Cyclopoid copepods were abundant in May through August. The decline in August of both daphnids and calanoids suggest a return of high alewife planktivory.

Date	Station ID	Calanoid Copepods	Cyclopoid Copepods	Nauplii	Bosminids	Daphniids	Other cladocerans	Predatory cladocerans
1/29/09	N-Int	7.28	2.15	0.12	0.13	0.00	0.00	0.00
2/10/09	N-Int	4.79	3.10	0.03	0.08	0.00	0.00	0.00
3/24/09	S-Int	3.76	12.03	0.07	0.33	0.00	0.00	0.00
4/9/09	N-Int	4.39	9.74	0.77	0.00	0.00	0.00	0.00
4/9/09	S-Int	1.89	13.70	0.86	0.00	0.00	0.00	0.00
4/21/09	S-Int	0.00	4.76	1.20	0.00	0.00	0.00	0.00
5/5/09	S-Int	2.32	44.10	2.16	0.00	0.00	0.00	0.00
5/19/09	S-Int	9.60	88.44	1.04	0.86	0.00	0.00	0.00
6/2/09	S-Int	36.11	139.23	0.93	49.38	0.23	0.00	0.00
6/16/09	N-UML	58.13	62.61	2.11	130.58	7.37	0.00	0.00
6/16/09	S-UML	13.95	88.64	8.34	609.19	17.45	5.52	0.00
6/29/09	S-UML	231.25	39.07	12.40	44.12	138.72	0.00	0.00
7/14/09	S-UML	322.05	13.45	3.82	2.21	364.44	0.00	0.00
7/28/09	S-UML	141.92	29.20	2.19	7.66	143.75	0.00	0.00
8/11/09	S-UML	106.09	247.06	2.20	64.64	112.29	0.00	0.00
8/25/09	S-UML	43.95	39.43	6.23	20.59	47.03	0.00	0.00
9/9/09	S-UML	2.78	3.94	0.34	61.80	0.61	0.00	0.00
9/22/09	N-UML	3.98	3.30	0.51	79.61	0.46	0.00	0.00
9/22/09	S-UML	3.67	3.21	0.46	33.16	0.00	0.00	0.00
10/8/09	S-Int	0.72	4.19	0.54	57.17	0.00	0.19	0.00
10/20/09	S-Int	0.00	5.34	0.20	30.49	0.47	0.00	0.00
11/3/09	S-Int	0.00	5.36	0.26	9.41	0.00	0.00	0.00
11/16/09	N-Int	0.00	6.52	0.89	5.74	0.00	0.00	0.00
11/16/09	S-Int	0.00	9.11	1.69	6.37	0.00	0.00	0.00
12/1/09	S-Int	0.00	11.62	0.52	7.18	0.00	0.00	0.00

Table 2. Abundance (#/mL) and biomass (µg/L) of phytoplankton in Onondaga Lake in 2009. 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 7/28 in 2009. 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
1/29	UML	North	Abundance	80.22	1641.84	12.12	105.92
			Biomass	70.78	140.24	0.37	42.36
2/10	UML	North	Abundance	322.46	1122.33	31.81	81.79
			Biomass	131.68	214.63	3.22	11.06
3/24	UML	South	Abundance	533.90	619.10	28.34	789.49
			Biomass	405.78	128.94	2.29	248.28
4/9	UML	South	Abundance	450.60	102.24	7.57	560.41
			Biomass	585.06	8.93	2.65	128.57
4/9	UML	North	Abundance	475.59	96.94	0.00	551.32
			Biomass	835.49	4.66	0.00	116.29
4/21	UML	South	Abundance	1029.03	131.77	13.63	1272.28
			Biomass	1200.19	14.03	0.57	157.34
5/5	UML	South	Abundance	2314.52	71.00	854.71	3152.29
			Biomass	1858.42	6.20	49.09	121.93
5/19	UML	South	Abundance	2068.61	99.40	3933.27	2499.12
			Biomass	1762.23	9.19	118.86	133.29
6/2	UML	South	Abundance	1176.70	58.92	3298.83	1990.21
			Biomass	923.26	5.89	194.24	74.39
6/16	UML	North	Abundance	27.26	72.70	2898.98	1399.51
			Biomass	7.02	4.16	110.37	69.78
6/16	UML	South	Abundance	18.18	9.09	1010.93	3289.75
			Biomass	4.20	0.13	53.49	217.85
6/29	UML	South	Abundance	83.30	60.59	295.35	1340.44
			Biomass	3.42	2.49	8.93	97.64
7/14	UML	South	Abundance	1029.36	358.48	255.95	681.58
			Biomass	2411.58	136.66	47.44	36.56
7/28	UML	South	Abundance	329.35	622.51	567.98	1295.00
			Biomass	1545.54	103.50	59.30	85.37
8/11	UML	South	Abundance	0.00	199.93	3166.91	654.31
			Biomass	0.00	24.73	102.54	168.71
8/25	UML	South	Abundance	0.00	247.56	2399.15	1190.49
			Biomass	0.00	153.19	72.56	300.34
9/9	UML	South	Abundance	58.92	367.59	24704.74	190.84
			Biomass	47.98	85.15	752.07	46.75
9/22	UML	South	Abundance	14.20	209.77	10212.20	1135.96
			Biomass	3.18	46.99	378.82	56.43
9/22	UML	North	Abundance	109.05	422.11	5275.41	1690.31
			Biomass	7.95	74.52	244.37	60.78
10/8	UML	South	Abundance	202.15	430.89	490.74	2535.47
			Biomass	240.90	139.24	14.49	335.52
10/20	UML	South	Abundance	113.60	127.31	184.59	1434.15
			Biomass	308.74	136.84	10.41	215.97
11/3	UML	South	Abundance	171.76	87.24	10.91	327.16
			Biomass	607.52	27.77	0.35	62.54
11/17	UML	North	Abundance	759.50	216.44	893.62	1416.17
			Biomass	2312.69	84.30	24.34	62.52
11/17	UML	South	Abundance	789.49	118.74	482.78	1698.26
			Biomass	2003.00	54.78	6.92	94.80
12/1	UML	South	Abundance	741.12	113.60	283.99	1760.74
			Biomass	3193.22	33.15	4.01	69.47

Date	Depth	Station	Variable	Eugleno	Cyano	Misc. Micro	Pyrrho
1/29	UML	North	Abundance	0	1381.33	581.61	0.00
			Biomass	0	2.44	8.11	0.00
2/10	UML	North	Abundance	0	1090.52	545.26	13.63
			Biomass	0	1.92	11.13	2.51
3/24	UML	South	Abundance	0	170.39	408.95	22.72
			Biomass	0	0.30	5.70	19.59
4/9	UML	South	Abundance	0	624.78	45.44	11.36
			Biomass	0	1.09	0.33	4.85
4/9	UML	North	Abundance	0	227.19	136.32	15.15
			Biomass	0	0.40	1.90	7.47
4/21	UML	South	Abundance	0	218.11	231.74	9.09
			Biomass	0	0.38	9.49	5.63
5/5	UML	South	Abundance	0	511.18	468.58	14.20
			Biomass	0	0.90	11.50	7.49
5/19	UML	South	Abundance	0	2257.72	28.40	14.20
			Biomass	0	3.99	10.31	2.75
6/2	UML	South	Abundance	0	17516.53	163.58	0.00
			Biomass	0	29.51	2.75	0.00
6/16	UML	North	Abundance	0	2844.45	54.53	4.39
			Biomass	0	1.51	0.76	174.58
6/16	UML	South	Abundance	0	327.16	0.00	0.00
			Biomass	0	0.31	0.00	0.00
6/29	UML	South	Abundance	0	2203.77	136.32	0.00
			Biomass	0	1.59	1.90	0.00
7/14	UML	South	Abundance	0	975.03	47.33	18.93
			Biomass	0	1.72	0.66	866.75
7/28	UML	South	Abundance	4.54	59.07	136.32	9.09
			Biomass	0.99	8.67	1.90	382.24
8/11	UML	South	Abundance	0	129.42	0.00	0.00
			Biomass	0	1.94	0.00	0.00
8/25	UML	South	Abundance	0	299.89	0.00	9.09
			Biomass	0	0.53	0.00	234.97
9/9	UML	South	Abundance	0	1063.26	0.00	0.00
			Biomass	0	0.81	0.00	0.00
9/22	UML	South	Abundance	0	2669.51	0.00	16.94
			Biomass	0	2.34	0.00	156.19
9/22	UML	North	Abundance	0	9678.40	0.00	27.26
			Biomass	0	16.01	0.00	5.48
10/8	UML	South	Abundance	0	14449.44	54.53	27.26
			Biomass	0	18.29	0.76	14.39
10/20	UML	South	Abundance	0	6049.00	0.00	0.00
			Biomass	0	4.95	0.00	0.00
11/3	UML	South	Abundance	0	2787.95	0.00	0.00
			Biomass	0	9.97	0.18	0.00
11/17	UML	North	Abundance	0	840.61	15.15	15.15
			Biomass	0	0.86	0.46	4.76
11/17	UML	South	Abundance	0	511.18	0.00	0.00
			Biomass	0	0.59	0.00	0.00
12/1	UML	South	Abundance	0	1022.37	0.00	5.68
			Biomass	0	0.43	0	0.46

Table 3. The major algal genera in Onondaga Lake in 2009. Numbers of species identified were 40 diatoms, 35 chlorophytes, 9 chrysophytes, 7 cryptophytes, 7 cyanophytes, 5 dinoflagellates, 1 euglenophyte, and miscellaneous flagellates. The top genera were mostly the same as in 2008 with 10 of the 11 most abundant genera in 2008 also being the most abundant in 2009. Of the tope 12 genera in 2009, 6 were diatoms, two (*Cryptomonas* and *Rhodomonas*) are cryptophytes, two (*Erkenia* and *Dinobryon*) are chrysophytes and one *Ceratium* is a large dinoflagellates. It is notable that no cyanobacteria genus made up more than 1 % of the biomass in 2008 or 2009. Also notable is that the most abundant diatom identified is *Actinocyclus normani*. This species were not identified in past years in Onondaga Lake. 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). The species was present in the summer diatom bloom in Onondaga Lake but the large colonial *Fragilaria* and *Asterionella* dominated in the summer. *Actinocyclus* dominated in the fall bloom.

Genus	Division	Mean biomass (ug/L)	Relative biomass (% of total)	2008 Biomass/rank
Actinocyclus	Bacillariophyta	283.8	21.9	Not present
Fragilaria	Bacillariophyta	177.5	13.7	11.3/5
Asterionella	Bacillariophyta	171.5	13.3	4.8/6
Stephanodiscus	Bacillariophyta	135.6	10.5	11.7/3
Cryptomonas	Cryptophyta	87.2	6.7	14.8/1
Ceratium	Pyrrhophyta	85.6	6.6	11.3/4
Diatoma	Bacillariophyta	84.4	6.5	4.0/8
Erkenia	Chrysophyta	81.2	6.3	3.0/11
Rhodomonas	Cryptophyta	52.3	4.0	4.2/7
Synedra	Bacillariophyta	30.1	2.3	14.8/2
Dinobryon	Chrysophyta	14.8	1.1	3.2/10
Oocystis	Chlorophyta	13.3	1.0	3.0/not ranked

Figure 1. (A) Temporal trends in biovolume (panel A) and proportional biovolume (panel B) of phytoplankton divisions in Onondaga Lake in 2009. 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 diatom bloom with some dinoflagellates (Pyrrhophyta) occurred in July. September was more chrysophytes and cryptophytes until a late diatom bloom in November. Note that bluegreens (Cyanophyta) are almost absent. The month symbol refers to the 29th of each month because the first sample was taken on 1/29. Sample dates are in Table 2.

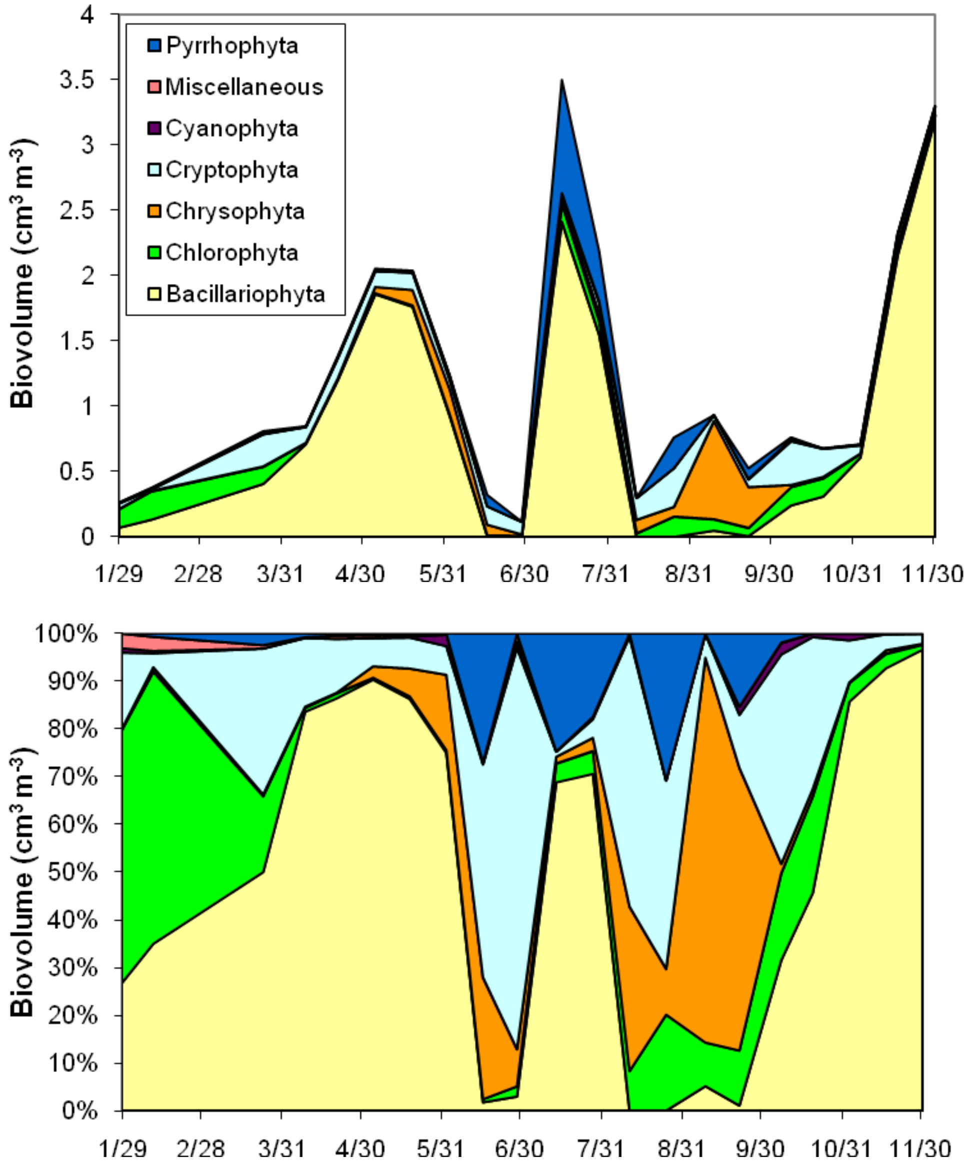


Figure 2. Temporal trends in phytoplankton in Onondaga Lake in 2009 divided in netplankton (GALD>50 µm) and nanoplankton (GALD<50 µm). Small phytoplankton dominate most of the year, but the May and July diatom bloom consisted of larger taxa (*Asterionella* and *Fragilaria*). The fall diatom bloom was mainly *Actinocystis* which is smaller than 50 µm.

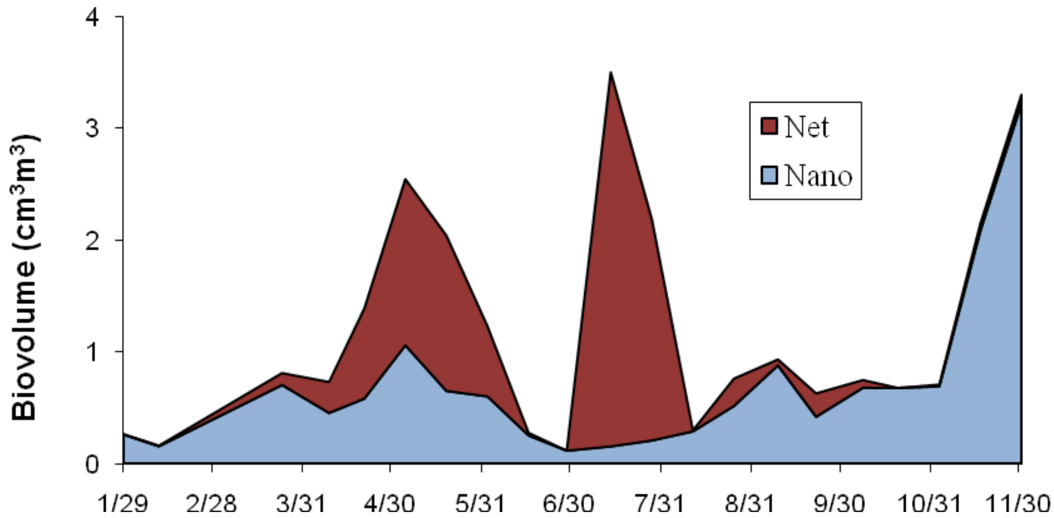


Figure 3. Temporal trend of biovolume of cyanobacteria genera in Onondaga Lake in 2009. Cyanobacteria biovolume was very low throughout the year. The largest peak occurred in beginning of June and was dominated by *Aphanocapsa.* The large nitrogen fixing and often toxic colonial bluegreens (*Microcystis, Aphanizomenon, Anabaena*, and *Oscillatoria*) are almost absent. The other group includes the genera *Cyanoephron*, *Pseudoanabaena,* and *Synechococcus*.

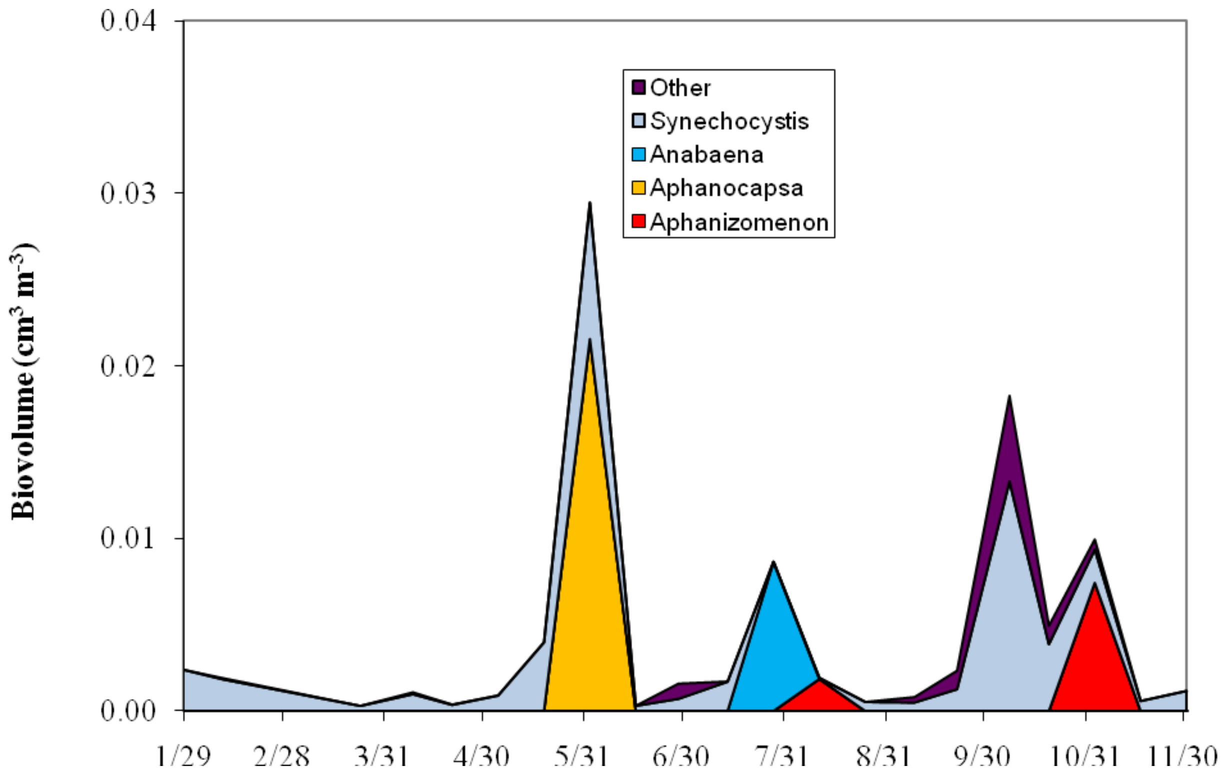


Figure 4. Total density (#/L) and biomass (ug/L) of crustacean zooplankton in Onondaga Lake in 2009 from standard samples (south deep, with the exception of winter samples from north deep). Density and biomass increased in the middle of June and remained relatively high through the middle of August with a considerable decline in late August through the rest of the year. The first biomass peak (6/16/) consist mostly of *Bosmina*, the second (7/14) is due to *Daphnia mendotae* and calanoid copepods, and the third (8/11) is due to all four major groups (calanoids, cyclopoids, bosminids and daphnids).

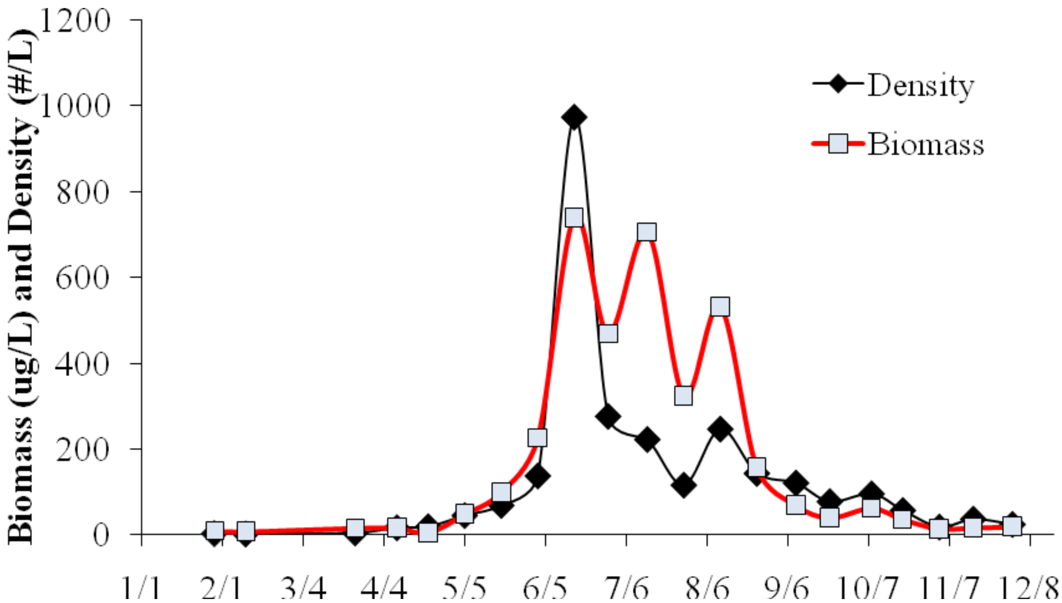
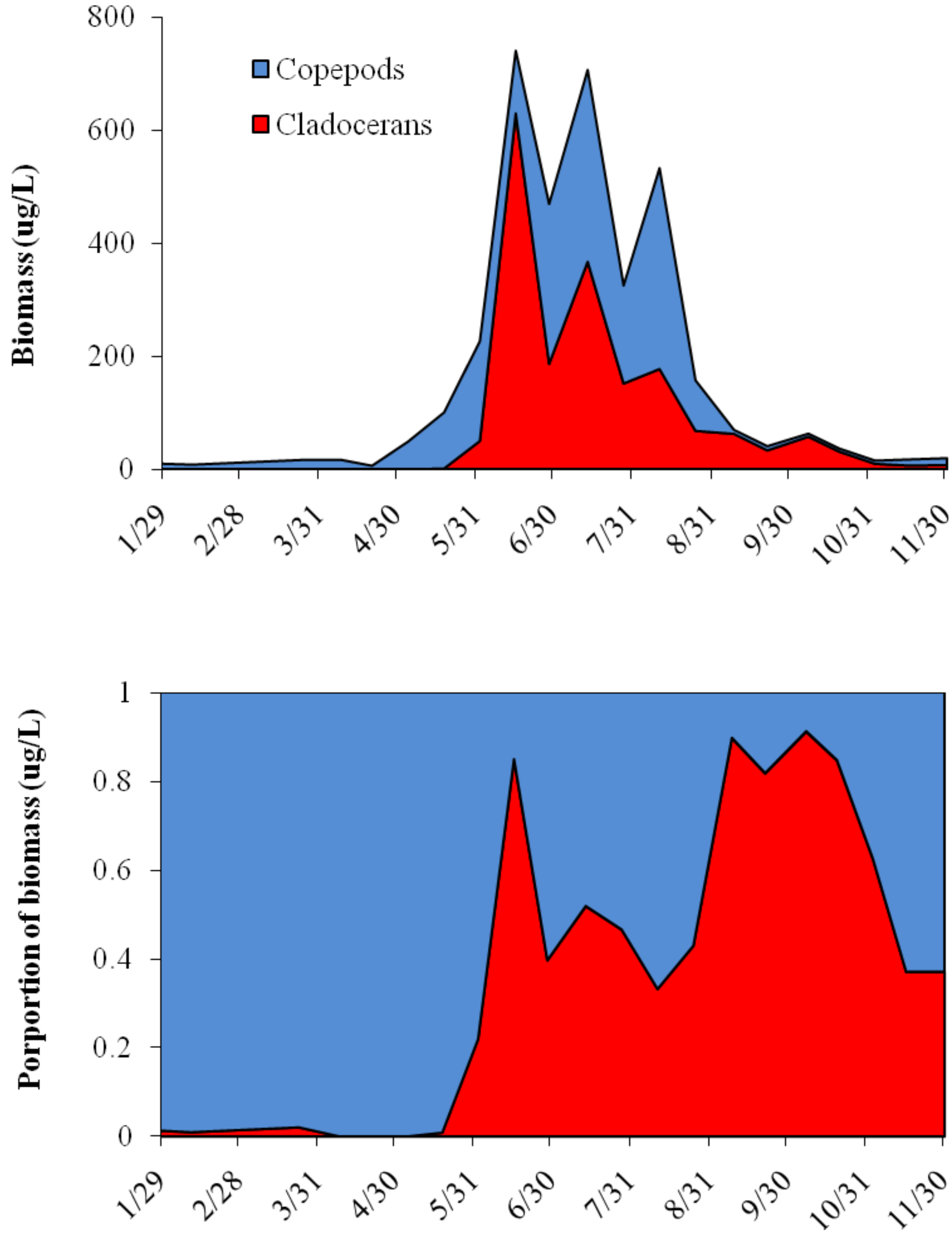
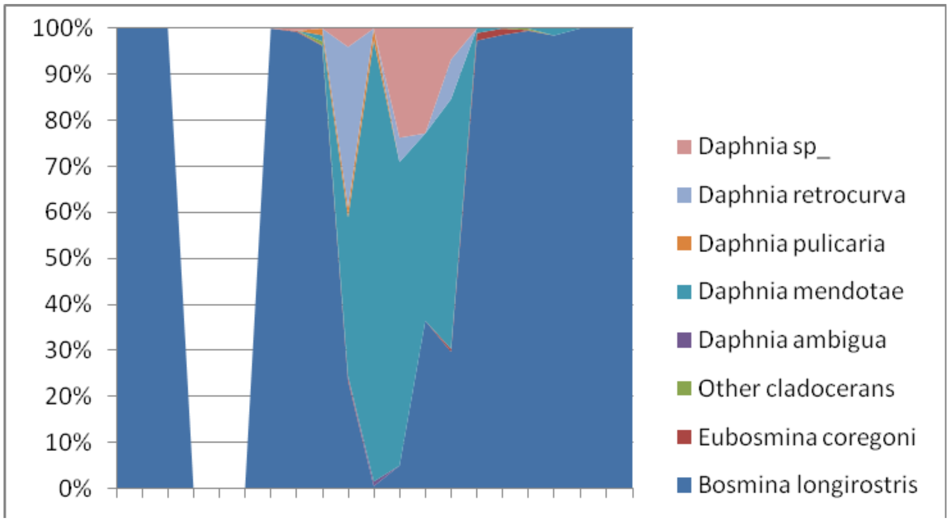


Figure 5. Composition of copepod and cladocerans as total biomass (A) and as proportion of biomass (B) in Onondaga Lake in 2009.



(B)

Figure 6. Composition of the cladoceran (A) and copepod (B) community in Onondaga Lake in 2009. A total of 15 species, as well as nauplii and copepodites, were identified in Onondaga Lake in 2009. The dominant cladocerans were *Bosmina longirostris* and *Daphnia mendotae*. Other cladocerans present included *Diaphanosoma birgei*, *Eubosmina coregoni*, *Chydorus sphaericus*, *Alona sp.*, *Camptocercus sp.*, *Daphnia retrocurva*, *Daphnia ambigua*, *Daphnia pulicaria*. The predatory cladocerans *Leptodora kindtii*, and *Cercopagis pengoi* were not observed in 2009. The dominant copepods during the year were the cyclopoids *Diacyclops thomasi and Mesocyclpos edax* and the calanoid copepods *Diaptomus minutus, D. oregonensis and D. siciloides.*



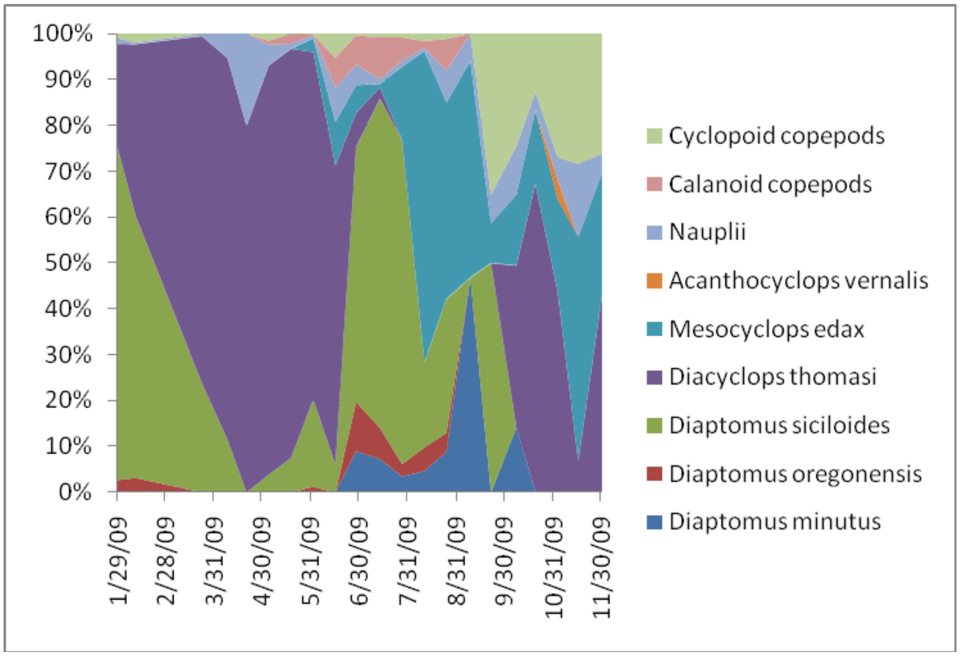


Figure 8. Average crustacean zooplankton length (mm) in Onondaga Lake in 2009. The largest mean size of zooplankton (0.72 mm) was observed in February winter sample. The decline in length in the spring is due to high proportion of nauplii in the sample. Length increased through the summer until the end of August, when *Daphnia* and calanoid copepods declined and the zooplankton community became dominated by *Bosmina* and cyclopoids. The corresponding line from 2008 is in light colors. The lines are 2-point moving averages. Note the lack of a decline in average length in the fall of 2008 and the similar pattern in winter to summer development of average length in the two years. The decline in length in the fall of 2009 indicates a strong alewife year class in 2009. Average length is based on both north and south stations when available.

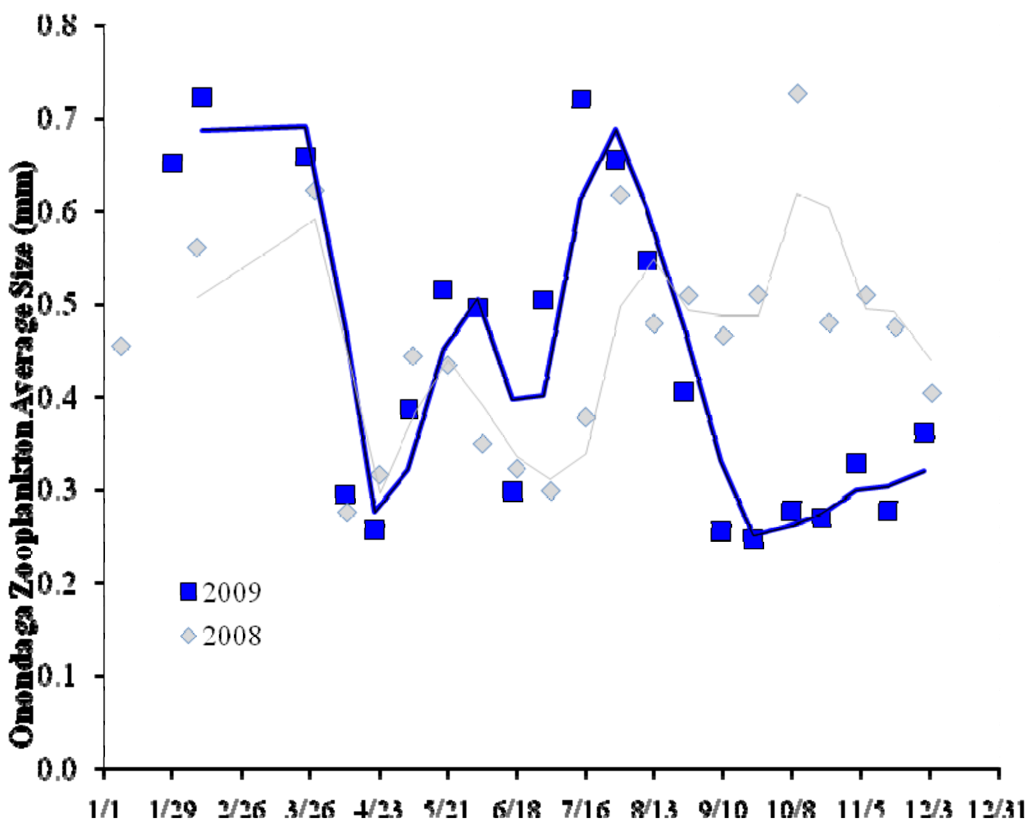
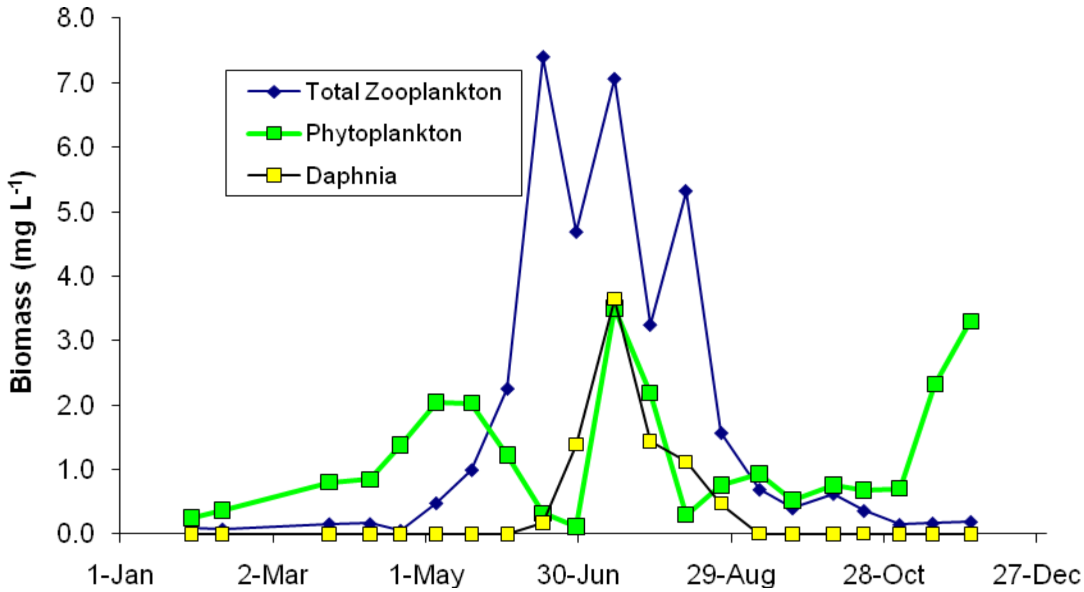


Figure 9. Temporal trend of zooplankton and phytoplankton biomass in Onondaga Lake in 2009. The decline in phytoplankton biomass in the middle of June is associated with declines in diatoms. Zooplankton biomass increased at that time but the decline could be due to silica depletion as the decline was mainly in diatoms, or to increased grazing by zebra/quagga mussels as temperatures increase in June.



Time series 1998 – 2009 for Onondaga Lake

Figure 10. Temporal trend of average annual phytoplankton biovolume (April – October) in Onondaga Lake from 1998-2009. Annual biovolume decreased significantly during this period (linear regression, p<0.001).

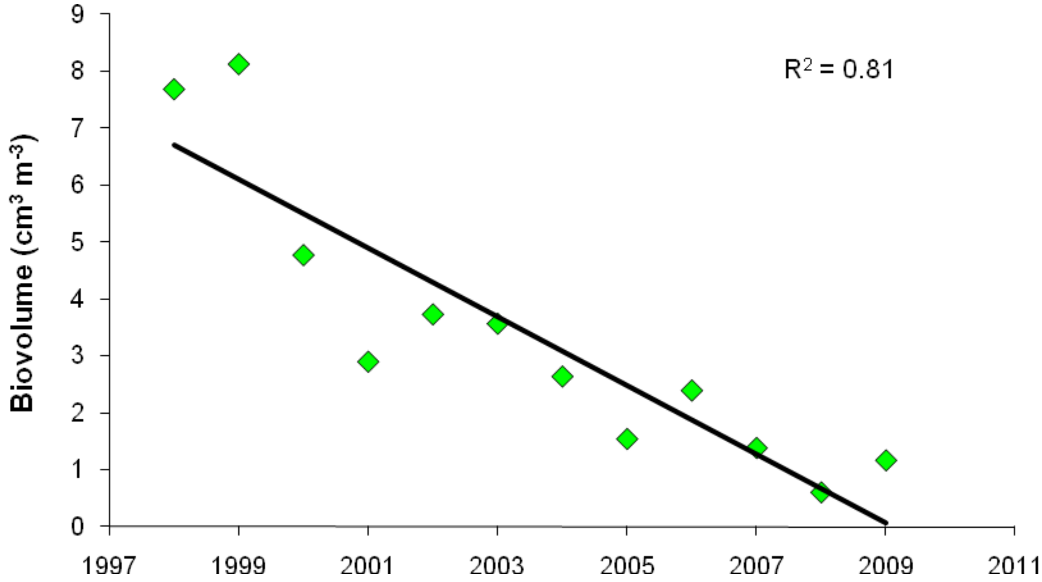


Figure 11A. Temporal trend of average annual biovolume (April-October) of phytoplankton divisions in Onondaga Lake from 1998-2008. The phytoplankton community of Onondaga Lake consists of Bacillariophyta, Chlorophyta, Chrysophyta, Cryptophyta, Cyanophyta, Pyrrhophyta, Euglenophyta, and "miscellaneous microflagellates". 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, and 2009. 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.

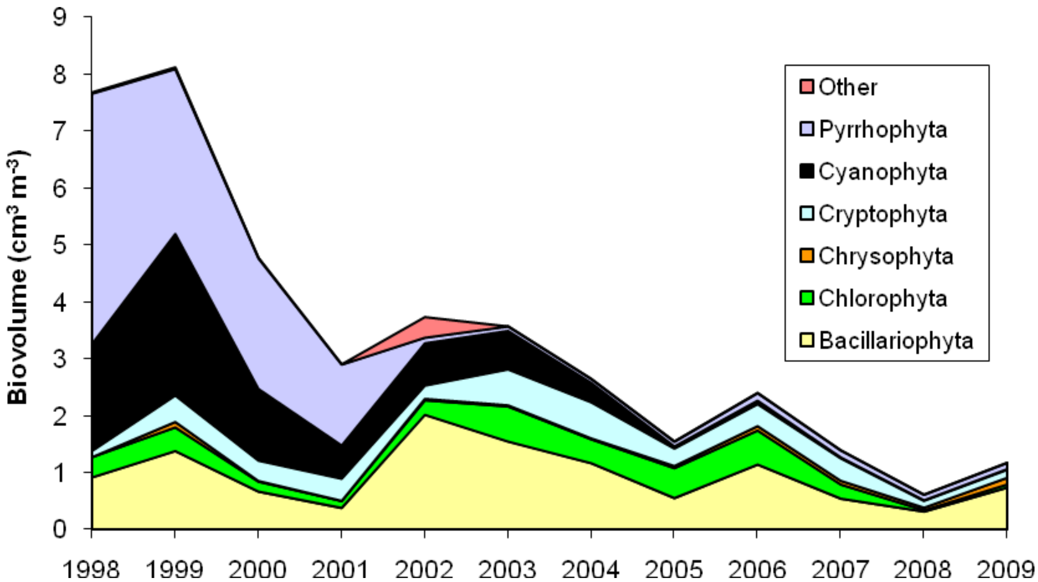


Figure 11B. Time trend of mean annual biovolume of cyanobacteria genera in Onondaga Lake from 1998 to 2009.

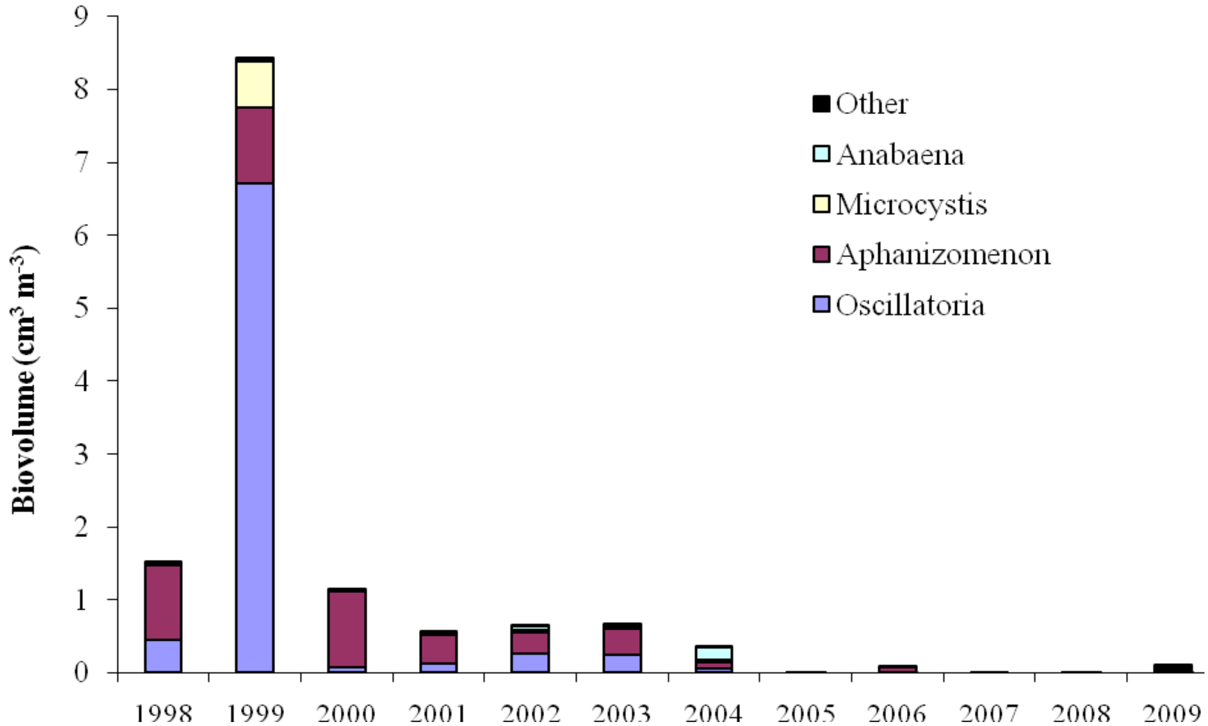


Figure 12. Temporal trend of average annual proportional biovolume of phytoplankton divisions in Onondaga Lake from 1998-2009. Chrysophytes, cryptophytes and diatoms increased in proportional biovolume over this period, while cyanobacteria (Cyanophyta) and dinoflagellates (Pyrrhophyta) decreased (linear regressions, all $p<0.05$).

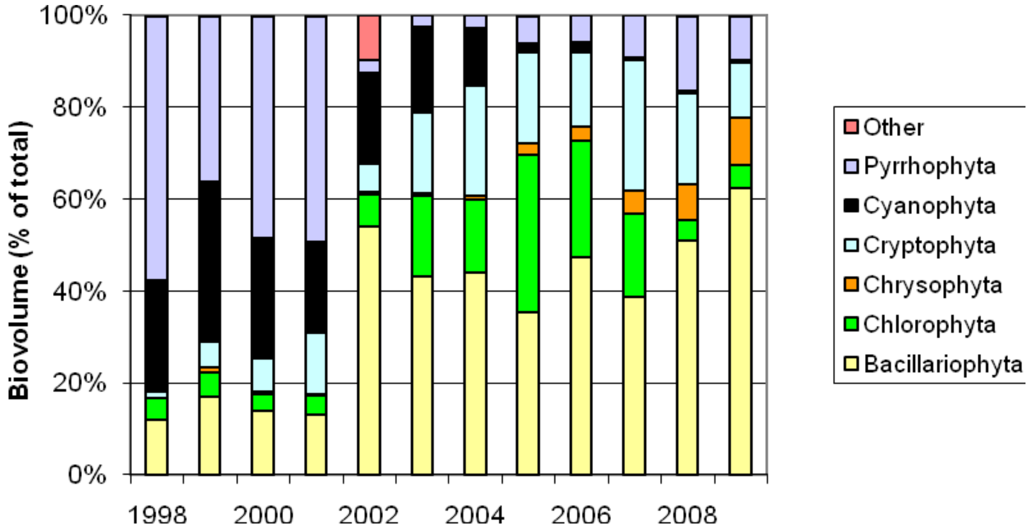
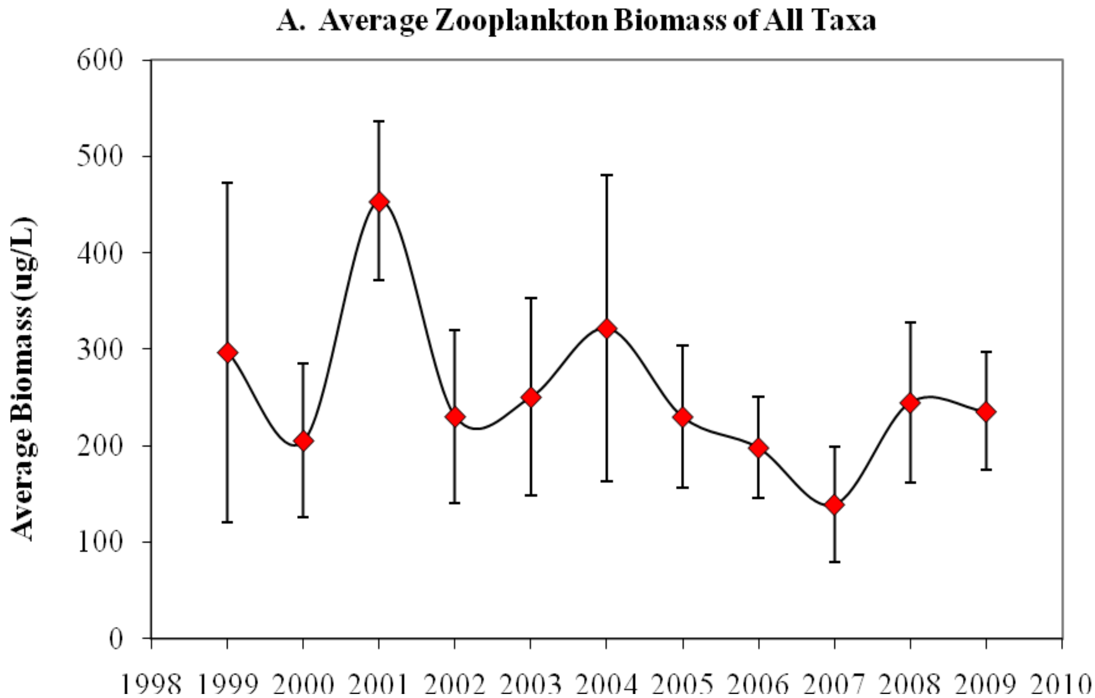


Figure 13. Average biomass of zooplankton (all taxa combined) and the proportion of major taxa in Onondaga Lake from April through October in 1999-2009. For consistency across time, all densities are based on the 2008 sampling schedule (integrated samples during the mixed period, and upper mixed layer 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 changes in late summer of 2009 suggest a return of high alewife abundance and a strong 2009 year class.


A. Average Zooplankton Biomass of All Taxa
Average Biomass (ug/L)
600
500
400
300
200
100
0
1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010

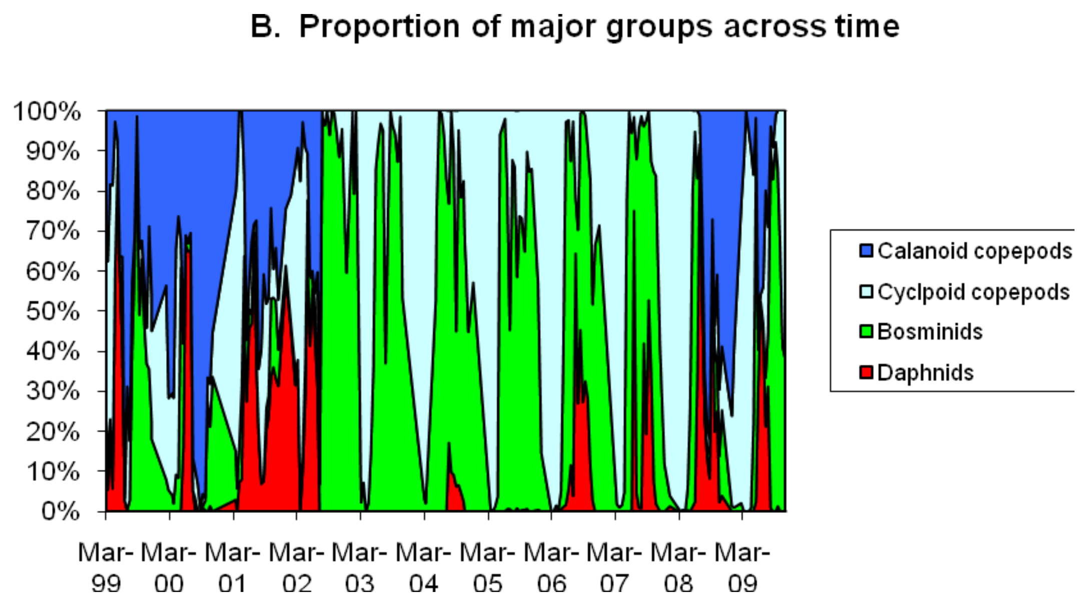
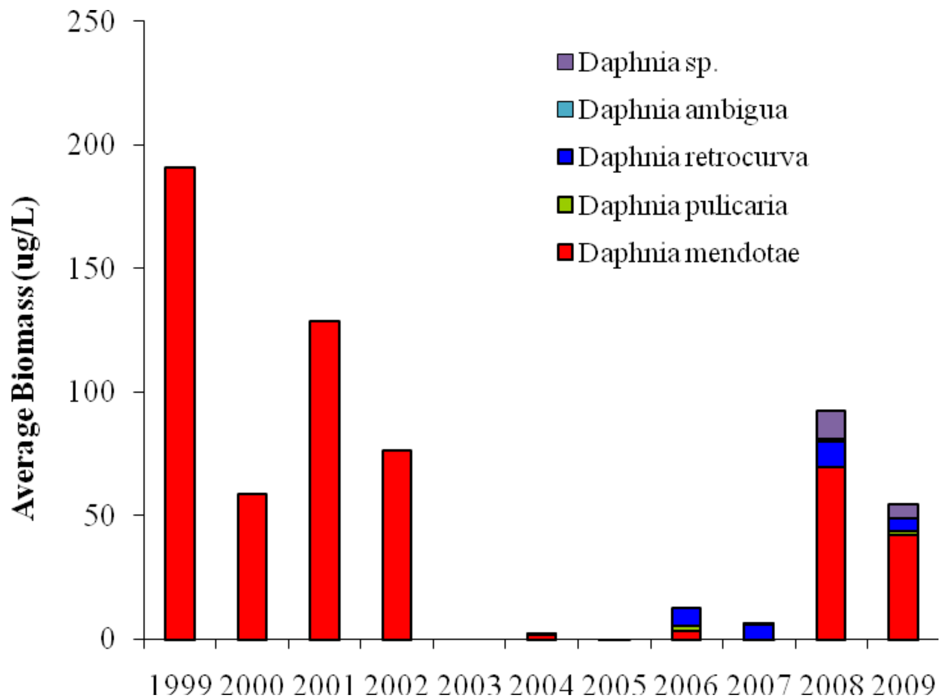

B. Proportion of major groups across time
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Mar-99 Mar-00 Mar-01 Mar-02 Mar-03 Mar-04 Mar-05 Mar-06 Mar-07 Mar-08 Mar-09
Calanoid copepods
Cyclpoid copepods
Bosminids
Daphnids

Figure 14. Biomass of different Daphnia species in Onondaga Lake. *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 lack of *Daphnia* in the years between 2003 and 2007 is attributed to the presence of abundant alewife during this time period. *Daphni*a was again 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 based on standard sites only (see Fig 13). Also shown are more detailed time series for all *Daphnia* combined.



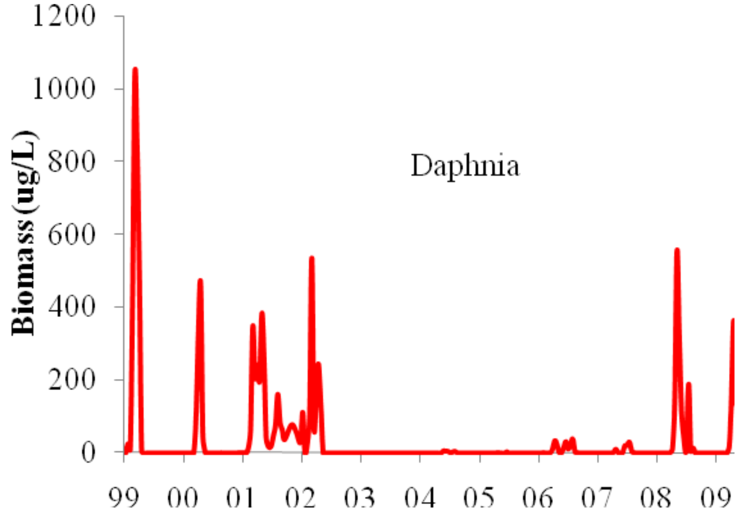

1200
1000
800
600
400
200
0
Biomass (ug/L)
Daphnia
99
00
01
02
03
04
05
06
07
08
09

Figure 15. Time trends in average size of all crustaceans from 1999 to 2009 in Onondaga Lake. Data is extracted from the Onondaga Lake Bio Database. Error bars are one SE.

Note the return to almost pre-2002 average lengths in 2008 and 2009. These lengths include nauplii. Based on all crustacean zooplankton measured in the South Deep station in April – October with the sampling regime used in 2008 and 2009, excluding *Cercopagis pengoi*.

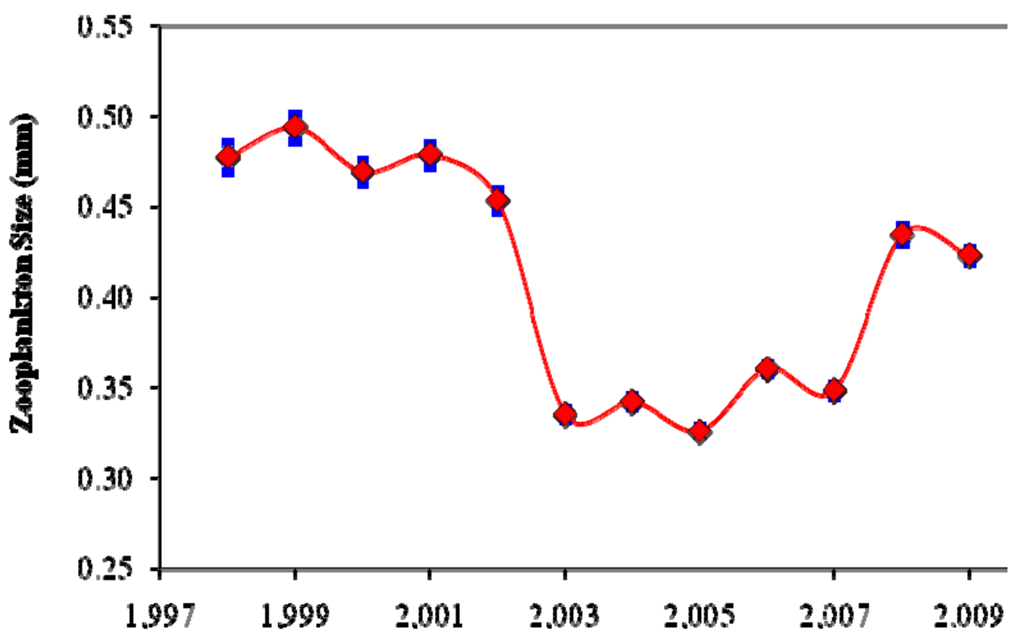
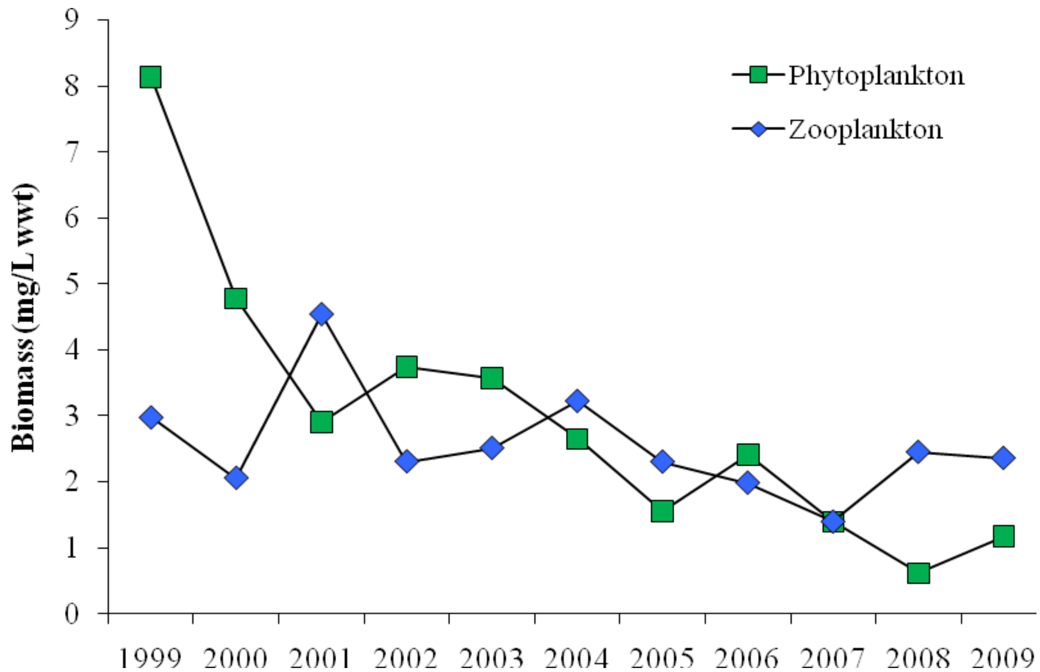


Figure 16. Time trend of zooplankton and phytoplankton biomass in Onondaga Lake 1999 to 2009 (April-October). Zooplankton biomass was converted to wet weight assuming a dry to weight ratio of 10%. For zooplankton biomass in dry weight, see Figure 13.



Significant Findings

The average and peak algal biomass in Onondaga Lake is declining. Although average algal biomass in 2009 was twice that in 2008, the average algal biovolume in 2009 (1.2 mg/L) is still at lower than expected from meso-eutrophic systems (3-5 mg/L, Wetzel 2001). Peak algal biomass did not exceed 3.5 mg/L. Average biomass was similar to 2007 (1.15 mg/L), the second lowest year on record. For April-October period, the 2009 average biomass is lower than 2007 (Figure 10). The time trend shows a continuous decline in algal biomass since 1998 that is highly significant. Improved phosphorus removal coupled with increased grazing by mussels and large zooplankton accounts for the low biomass in 2008 and 2009.

Large bluegreens (cyanobacteria) have almost disappeared from the lake. Only small species are now present (Figure 11B). The main species in the past was *Aphanizomenon flos-aquae*. This species historically occurred July through October (1996) but blooms decreased in duration to July – August in 1997-2000. In 2009, *Aphanizomenon* (*A. gracile* and *A. flos-aquae*) was not found in significant numbers. Peak cyanobacteria abundance was only 0.03 mg/L in 2009, similar to 2008.

Diatoms had the highest biovolume of all algae groups and showed three peaks, an early spring peak, a summer peak in July, and a fall peak 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 fall diatom bloom. This species is an exotic that has been in Lake Ontario since 1938 (Stoermer et al. 1985, Mills et al. 1993). The other common genera in 2009 were also common in 2008 (Table 3).

Average total zooplankton biomass (dry wt) was 219 ug/L in Onondaga Lake for the April-October time period, which is slightly lower than in 2008. In both 2008 and 2009, as had been the case from 1997-2003, average total zooplankton biomass 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 2009 was 740 ug/L on 6/16 and dominated by bosminids. Biomass on the same day at the north site was lower (257 ug/L). The average size of the total zooplankton community in Onondaga Lake throughout the year in 2009 (0.52 mm, calculated as the average of weekly samples) is larger than values observed in 2003-2007 (0.29 mm). The species and size composition is similar to 2008 and to the one present in 2000-2002. There was a decrease in large daphnids and calanoids in later summer of 2009 indicating a return to high planktivory rate (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). Catches and acoustic densities were lower in the spring of 2008 than in the previous 3 years (2005-2007). Catches in the spring of 2009 were even lower. Acoustic analysis for the spring of 2009 indicated lower abundance than in any year since the start of the acoustic surveys in 2005. Also, the alewife grew exceptionally well in 2008. Preliminary data from 2010 indicate a strong year class of alewife hatched in 2009 as a large proportion of the fish were age 1 in the spring of 2010. 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). *Cercopagis pengoi* and *Leptodora kindtii* were not observed in 2009.

Populations of *Daphnia* have a capability to exert strong influence on the phytoplankton community (Sommer et al. 1986, Mills and Forney 1988). As in 2008, it is therefore reasonable to assume that the decline in phytoplankton biomass in the summer of 2008 was due to grazing by *Daphnia mendotae*. Although this is likely part of the explanation for low summer phytoplankton abundance in the lake and clear water through August, *D. mendotae* (again as in 2008) increased after the early summer phytoplankton bloom had declined. The main zooplankton species that increased at the time of the decline was *Bosmina longirostris*, a species that is not known for strong grazing effects on phytoplankton. Other explanations for the decline in the early summer bloom include silica depletion and zebra mussel grazing. 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). We note that quagga mussels are becoming dominant in the lake, and that this species likely have a higher filtering rate at low temperatures than zebra mussels. They may also become more abundant.

The development of the *Daphnia* peak relatively late in the summer of 2009 is similar to the timing in 2008. As in 2008, this suggests continued planktivory by alewife into the early summer of 2008 followed by a decline in alewife abundance at that time. This late peak (7/14 in 2009 and 7/24 in 2008) is unusual for temperate lakes. A typical seasonal succession includes a midsummer decline in *Daphnia* associated with the increase in predation from young-of-year fish, possibly from invertebrates, and depletion of the spring bloom by *Daphnia* (Sommers et al. 1986, DeStasio et al 1995). This seasonal pattern is typically found in the nearby Oneida Lake when young-of-year abundance of yellow perch and gizzard shad is high (Mills and Forney 1988, Roseman et al. 1996).

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