Pre- and Post-Alum Treatment Survey of Honeoye Lake Macrobenthos

Comprehensive Field Inventory and Data Summary
July 2005 and November 2006

by

Dr. Bruce Gilman
Department of Environmental Conservation and Horticulture
Finger Lakes Community College
4355 Lakeshore Drive
Canandaigua, New York 14424-8395

Continuing the Role of Finger Lakes Community College
in assisting the
Honeoye Valley Association, Honeoye Lake Watershed Taskforce
and the
Ontario County Planning Department

Executive Summary

Frequent episodes of benthic anoxia result in the release of deepwater sediment phosphorus into Honeoye Lake. This internal nutrient loading is a significant portion of the lake's total phosphorus budget and contributes to the lake's eutrophic status. Alum treatment of deepwater substrates was selected as a nutrient management technique, with the chemical application undertaken during September 2006. To assess possible impacts on benthic organisms, a pre-treatment survey was conducted in July 2005 and a post-treatment survey was conducted in November 2006. Both surveys assessed benthic species richness and total abundance of organisms, and led to the calculation of several biotic community health indices. In both surveys, replicates from three different water depths were collected by standard Ponar dredge. Eighteen samples were taken within the 400 hectare treatment zone and nine were in the immediately adjacent deep edge of the littoral zone.

Pre-treatment survey results: Excluding benthic resting stages, sediment at deep sites (9 m) had the lowest richness (6 taxa) with a density of 960 individuals/m^2. Midge fly larvae (*Chironomus* sp.) and annelid worms (*Branchiura sowerbyi*) dominated while phantom midge larvae (*Chaoborus punctipennas*) were frequent. Sediment from moderately deep sites (7 m) had intermediate richness (9 taxa) with a density of 833 individuals/m^2. These samples also had abundant midge fly larvae, annelids and finger nail clams (*Pisidium* sp.). Sediment of shallow sites (5 m) had the highest pre-treatment richness (17 taxa) with a density of 1528 individuals/m^2. In addition to midge fly larvae and annelids, these sites also contained adult zebra mussels (*Dreissena polymorpha*), banded mystery snails (*Viviparous georgianus*), two other snails (*Valvata tricarinata* and *Physa* sp.), a leech (Hirudinea), aquatic sowbugs (*Asellus* sp.), scuds (*Gammarus* sp.), alder fly larvae (*Sialis* sp.) and a roundworm (Nematoda). Benthic resting stages were dominated by abundant cladoceran ephippium and statoblasts of the bryozoan, *Pectinatella magnifica*. Incidental capture of pelagic organisms while the dredge was traveling to the bottom sediment revealed a variety of zooplankton and even one fish!

Post-treatment survey results: Excluding benthic resting stages, sediment at deep sites (9 m) contained 14 taxa with a density of 1125 individuals/m^2. Midge fly larvae (*Chironomus* sp. and *Procladius* sp.) and phantom midge larvae (*Chaoborus punctipennas*) dominated while annelid worms (*Branchiura sowerbyi*) were frequent. These replicates also contained finger nail clams (*Pisidium* sp.) and ostracods (c.f. *Darwinula* sp.). Sediment from moderately deep sites (7 m) contained 18 taxa with a density of 1850 individuals/m^2. These samples had abundant midge fly larvae, phantom midge larvae, annelids, finger nail clams, adult zebra mussels (*Dreissena polymorpha*) and ostracods. Sediment of shallow sites (5 m) had the highest richness (22 taxa) and greatest density (6690 individuals/m^2). These sites were dominated by adult zebra mussels but also contained banded mystery snails (*Viviparous georgianus*), three other snails (*Valvata tricarinata*, *Gyraulus* sp. and *Physa* sp.), a leech (Hirudinea), aquatic sowbugs (*Asellus* sp.), scuds (*Gammarus* sp.) and alder fly larvae (*Sialis* sp.). Benthic resting stages included extremely large numbers of Cladoceran ephippium with abundant statoblasts of the bryozoan, *Pectinatella magnifica*. Incidental capture of pelagic organisms while the dredge was traveling to the bottom sediment again revealed a variety of zooplankton.

Compared to the pre-treatment dredge samples, the post-treatment collections consistently had greater species richness and higher numbers of organisms at all water depths. One possible explanation for greater richness involves the difference in the time of the year when sampling occurred. Late season sampling may capture more species because it coincides with dispersal stages in the life cycle of several macro-invertebrates. The random dispersal of typically shallow water species into deep water sites that was detected here, however, does not guarantee long-term survival and persistence in those deep water locations, especially when harsh environmental conditions are known to occur at such depths under the winter ice. The ultimate fate of these colonizers is unknown. One possible explanation for the higher numbers of organisms in the post-treatment samples is that samples were taken at the end of the growing season allowing a longer time for reproduction and the resulting increase in population size for a given species. This seems particularly relevant to the extremely large increases in adult zebra mussels in the 5 m depth zone during November.

Despite these changes in species richness and total abundance, a comparison of the relative dominance of species before and after alum treatment suggests little change in macrobenthos community structure and no apparent negative impact from the chemical treatment of the substrate with alum. Rather, changes detected seem attributable to the differences in the individual life histories of dominant species in the community, revealed here because of the two distinct times of the year when samples were collected. In the future, it would be instructive to repeat sampling at one or both of the time periods used in these surveys, thereby allowing for a more valid comparison.

Introduction

Benthic macro-invertebrates are large organisms that live in aquatic sediments, including worms, insects, snails, clams, mussels and crustaceans. They have aquatic stages in their life history that usually last between one and two years. They are ideal indicators of environmental quality due to their sensitivity to habitat conditions such as dissolved oxygen levels and nutrient concentrations. Sampling benthic communities is a scientifically established method of assessing stream health (Bode et al. 2002) and has recently been added to the lake manager's "tool box" to survey conditions in large water bodies (Doyle 2005). This report compares pre- and post-alum treatment dredge surveys of the deepwater macrobenthos of Honeoye Lake. If all other conditions within the lake remain relatively unchanged, the comparison between surveys might document the indirect impact of the alum precipitation of sediment phosphorus in the deepwater substrate on the populations of benthic organisms. However, if lake conditions naturally change due to timing of the two surveys, it may be problematic to identify a "cause and effect" relationship between alum treatment and any detectable negative impacts. Other studies (Cooke and Kennedy 1978, Narf 1985, Smeltzer 1990, James et al. 1991, Cooke et al. 1993, Welch and Schrieve 1994) have described positive impacts on deepwater macrobenthos following alum inactivation of sediment phosphorus.

Methods

Pre-treatment sediment samples were collected by standard Ponar dredge from Honeoye Lake on July 22 and July 25, 2005 while post-treatment sediment samples were collected on November 1, 5, 8, 9 and 10, 2006. The 2006 samples were collected along the three transects established with GPS coordinates during the 2005 survey, each beginning in the deepest area of the lake and then extending into shallower water (Figure 1). The northern and southern transects (A and C, respectively) extended westward while the middle transect (B) extended eastward. Along each transect, three replicates were collected at each of the following approximate depths: 5 m, 7 m and 9 m, resulting in a grand total of 27 samples.

Vertical profiles for dissolved oxygen, temperature, conductivity and pH were monitored at 1m intervals at each sample location with a YSI data-logger and water quality sonde. During the pre-treatment survey, integrated water column samples collected at each location through use of weighted Tygon tubing were analyzed for total alkalinity.

In both surveys, dredged sediment was sieved *in situ* through a U.S. Standard No. 30, 500 µm mesh wash frame. In 2006, some samples were washed a second time using a 500 µm soil sieve in the laboratory to remove most remaining substrate silts. The macro-invertebrates and coarse particulate organic matter (CPOM) were transferred to storage containers and preserved with 70% ethyl alcohol. Samples were stained with Rose Bengal in 2005; no stain was applied in 2006. All samples were refrigerated until macro-invertebrate identifications began.

Individual samples were sorted under a stereo-dissecting microscope using low magnification, and tentative identifications were made to the lowest practical taxon using Thorp and Covich (2001), Needham and Needham (1962) and Peckarsky et al. (1990). In both surveys, taxonomic determinations were verified through assistance provided by experts at the New York State Museum. Active benthic organisms, benthic resting stages and pelagic species, captured when the dredge dropped through the water column on the way to the bottom, were present in the samples. All organisms were counted and identified. For future reference, vouchers are permanently housed in the aquatic collections at Finger Lakes Community College.

Species-area curves were constructed to validate that adequate replicate sampling had occurred at each water depth. Replicates were treated as sub-samples for that analysis. Pooled data were subsequently used to characterize the macrobenthic community found at each depth, with abundance information expressed as density per square meter. Student's t-Test was used to determine if significant differences in richness and abundance existed between the pre- and post-treatment data sets within each depth zone (McBean and Rovers 1998). The data analysis package of Microsoft Excel © was used to perform the two sample, two-tails analyses with the assumption of unequal variances.

FIGURE 1 – Deepwater macrobenthos sampling locations in Honeoye Lake, New York.

Seven indices were used to estimate benthic macro-invertebrate community health as recommended by Bode et al. (2002). Species richness refers to the number of different species present in the pooled data while NCO richness indicates only the non-chironomid and non-oligochaete species present. Higher richness values are often associated with cleaner water conditions. Total abundance was the count of all individuals, regardless of species, and is presented as density per square meter. Community diversity was estimated using the H' index (Shannon and Weaver 1948). This index combines species richness with community balance (evenness). High scores indicate diverse, balanced communities while low scores suggest environmentally stressed communities. Dominance is a measure of the lack of community balance. Dominance-3 is the combined percent contribution of the three most numerous species. The percent oligochaetes index reveals the relative dominance of annelid worms in the sample. Finally, percent model affinity (PMA) is a similarity measure to a "model, non-impacted community" based on percent abundance in seven major groups. For Ponar dredge samples collected from lake bottoms, the PMA model is: 20% Oligochaeta, 15% Mollusca, 15% Crustacea, 20% non-Chironomidae Insecta, 20% Chironomidae and 10% Other.

<u>Results</u>

A grand total of 33 different taxa of macro-invertebrates were identified during these surveys, including 28 benthic species (26 active organisms and two resting stages) and five pelagic organisms collected as the dredge traveled to the lake bottom. The number of species detected was slightly greater during the November 2006 post-alum treatment survey where seven "new" species (not observed in the July 2005 pre-alum treatment survey) were collected.

Overall, midge fly larvae (*Chirononus* sp., *Procladius* sp. and Tanypodinae sp.) and annelid worms (*Branchiura sowerbyi*) were abundant. Less frequently encountered were finger nail clams (*Pisidium* sp. and *Sphaerium* sp.), statoblasts of the bryozoan, *Pectinatella magnifica,* adult zebra mussels (*Dreissena polymorpha*), another mussel (*Elliptio complanatus*), banded mystery snails (*Viviparous georgianus*), three other snails (*Valvata tricarinata*, *Gyraulus* sp. and *Physa* sp.), a species of leech (Hirudinea), aquatic sowbugs (*Asellus* sp.), scuds (*Gammarus* sp.), ostracods (c.f. *Darwinula* sp.), alder fly larvae (*Sialis* sp.), phantom midge fly larvae (*Chaoborus punctipennas*), true fly pupae (*Dixa* sp.), dragon fly nymphs (Odonata), a may fly nymph (Ephemeroptera), a case-building caddis fly larvae (Trichoptera), a beetle larvae (Coleoptera), and a species of roundworm (Nematoda). Another annelid and a different Diptera pupae were collected but could not be identified. Pelagic organisms accidentally captured as the dredge traveled through the water towards the bottom included two species of water flea (*Leptodora kindtii* and *Daphnia pulicaria*), a cyclopoid copepod (*Cyclops* sp.), water mites (*Hydrachna* sp.) and even a fish fry (Centrarchidae)! Distributional patterns and statistical summaries for both surveys are provided in the Appendix.

In the two surveys, abundance of organisms varied within replicates while pooled community data suggested patterns in structure and composition along a water depth gradient (Figures 2 and 3). In the pre-treatment survey, sediment at deep sites (9 m) had the lowest richness (6 taxa) with a density of 960 individuals/m^2. Midge fly larvae (*Chironomus* sp.) and annelid worms (*Branchiura sowerbyi*) dominated while phantom midge larvae (*Chaoborus punctipennas*) were frequent. Sediment from moderately deep sites (7 m) had intermediate richness (9 taxa) with a density of 833 individuals/m^2. These samples also contained abundant midge fly larvae and annelids, as well as finger nail clams (*Pisidium* sp.) and statoblasts of the bryozoan, *Pectinatella magnifica*. Sediment of shallow sites (5 m) had the highest richness (17 taxa) with a density of 1528 individuals/m^2. In addition to midge fly larvae and annelids, these sites also contained adult zebra mussels (*Dreissena polymorpha*), banded mystery snails (*Viviparous georgianus*), two other snails (*Valvata tricarinata* and *Physa* sp.), a leech (Hirudinea), aquatic sowbugs (*Asellus* sp.), scuds (*Gammarus* sp.), alder fly pupae (*Sialis* sp.) and a roundworm (Nematoda).

In the post-treatment survey, sediment dredged from deep sites (9 m) contained 14 taxa with a density of 1125 individuals/m^2. Midge fly larvae (*Chironomus* sp. and *Procladius* sp.) and phantom midge larvae (*Chaoborus punctipennas*) dominated while annelid worms (*Branchiura sowerbyi*) were frequent. These replicates also contained finger nail clams (*Pisidium* sp.) and ostracods (c.f. *Darwinula* sp.). Sediment from moderately deep sites (7 m) contained 18 taxa with a density of 1850 individuals/m^2. These samples had abundant midge fly larvae, phantom midge larvae, annelids, finger nail clams, adult zebra mussels (*Dreissena polymorpha*) and ostracods. Sediment of shallow sites (5 m) had the highest richness (22 taxa) and greatest density (6690 individuals/m^2). These sites were dominated by adult zebra mussels but also contained numerous banded mystery snails (*Viviparous georgianus*), three other snails (*Valvata tricarinata*, *Gyraulus* sp. and *Physa* sp.), a leech (Hirudinea), aquatic sowbugs (*Asellus* sp.), scuds (*Gammarus* sp.) and alder fly larvae (*Sialis* sp.).

In both surveys, benthic resting stages included extremely large numbers of Cladoceran ephippium and abundant statoblasts of the bryozoan, *Pectinatella magnifica*. Incidental capture of pelagic organisms while the dredge was traveling to the bottom sediment revealed a variety of zooplankton.

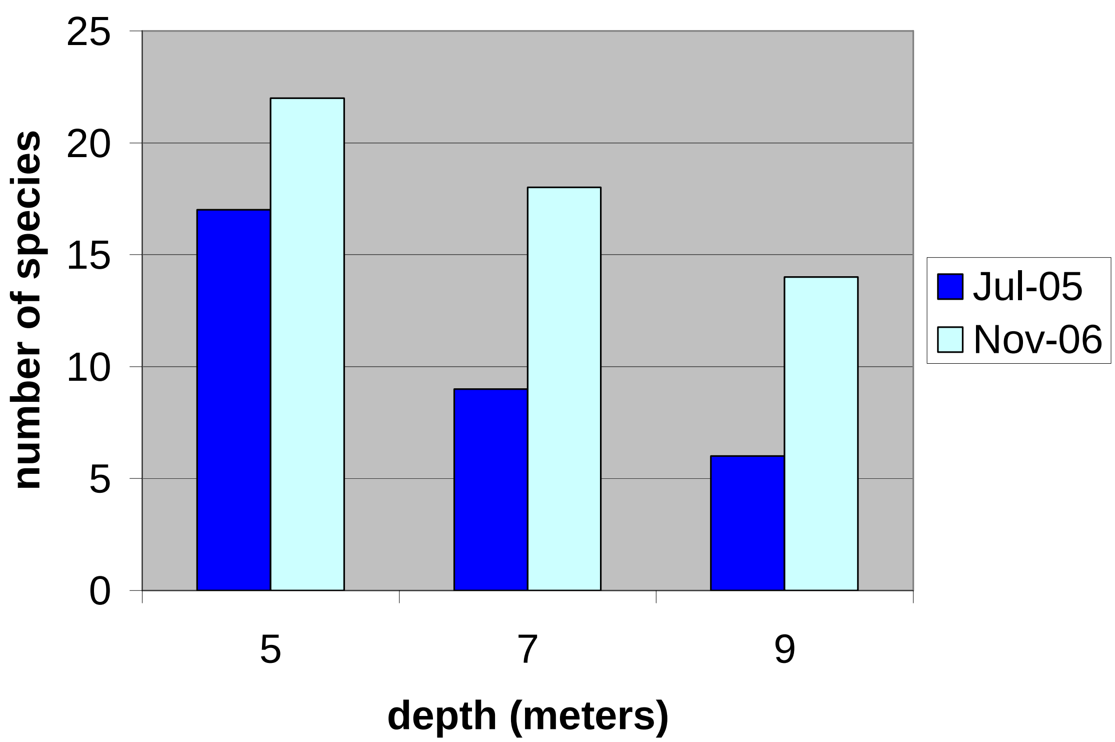

FIGURE 2 – Richness before and after alum treatment, based on pooled replicates (n = 9) dredged from three water depth zones in Honeoye Lake.

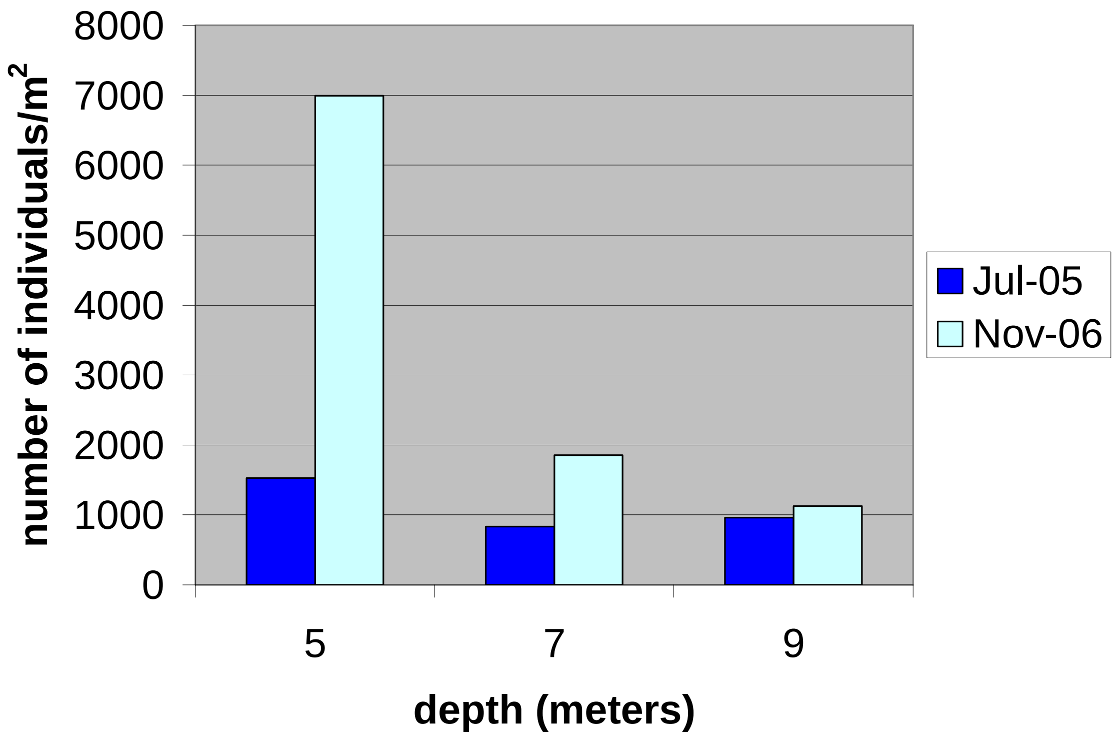

FIGURE 3 – Density before and after alum treatment, based on pooled replicates (n = 9) dredged from three water depth zones in Honeoye Lake. In November 2006, zebra mussel densities (number of individuals/m^2) were 4899, 186 and 13 for the 5 meter, 7 meter and 9 meter zone, respectively.

Data from July 2005 water quality profiles detected a weak thermal stratification with a fragile metalimnion between 5 and 6 m (Table 1). The resistance to mixing at this depth zone is moderate but strong winds could disrupt the stratification. Dissolved oxygen levels declined with depth, with conditions most stressful to the benthic community occurring in the 9 m zone (Table 2). Conductivity averaged 244 µS, increasing slightly near the bottom. Lake water pH averaged 8.30 and lake water alkalinity averaged 75 mg $CaCO_3$/L. The secchi disk readings for the two July 2005 sampling days averaged 3.8 m of clarity.

TRANSECT "A" TEMPERATURE PROFILES (C°)			
	5 m	7 m	9 m
surface 0	27.29	27.29	27.50
1	27.25	27.29	27.49
2	27.20	27.27	27.47
3	27.16	27.21	27.44
4	27.09	27.17	27.28
5	26.79	26.04	25.33
6		24.09	23.97
7		21.98	21.92
8			19.95
bottom 9			19.57
TRANSECT "B" TEMPERATURE PROFILES (C°)			
	5 m	7 m	9 m
surface 0	27.74	27.60	27.50
1	27.74	27.59	27.50
2	27.72	27.56	27.49
3	27.68	27.53	27.45
4	27.61	27.51	27.50
5	25.71	25.91	25.47
6		24.66	24.61
7		20.83	22.33
8			19.84
bottom 9			19.38
TRANSECT "C" TEMPERATURE PROFILES (C°)			
	5 m	7 m	9 m
surface 0	27.30	27.06	27.21
1	27.22	27.06	27.16
2	27.07	27.03	27.07
3	27.02	26.99	26.82
4	26.91	26.91	26.64
5	26.52	26.78	26.14
6		25.86	25.95
7		22.10	22.24
8			19.87
bottom 9			19.71

TABLE 1 – Temperature profiles taken at 1 meter intervals from three water depth zones along transects in Honeoye Lake during the pre-treatment survey, July 2005.

TRANSECT "A" DISSOLVED OXYGEN PROFILES (mg/L)			
	5 m	7 m	9 m
surface 0	8.23	8.50	8.28
1	8.13	8.36	8.20
2	8.22	8.31	8.11
3	8.18	8.28	7.91
4	7.60	8.27	7.46
5	6.25	5.27	2.73
6		1.89	1.18
7		0.87	0.61
8			0.63
bottom 9			0.68
TRANSECT "B" DISSOLVED OXYGEN PROFILES (mg/L)			
	5 m	7 m	9 m
Surface 0	8.81	8.65	8.78
1	8.79	8.64	8.72
2	8.78	8.64	8.68
3	8.78	8.65	8.45
4	8.75	8.61	8.61
5	3.09	4.56	3.93
6		2.43	2.65
7		0.90	0.71
8			0.64
bottom 9			0.58
TRANSECT "C" DISSOLVED OXYGEN PROFILES (mg/L)			
	5 m	7 m	9 m
Surface 0	8.56	8.14	8.26
1	8.40	8.12	8.21
2	8.19	8.07	8.14
3	7.93	7.99	7.88
4	7.78	7.88	7.60
5	7.06	7.72	6.59
6		5.34	5.89
7		0.79	0.82
8			0.56
bottom 9			0.45

TABLE 2 – Dissolved oxygen profiles taken at 1 meter intervals from three water depth zones along transects in Honeoye Lake during the pre-treatment survey, July 2005.

Temperature profiles from November 2006 indicate near isothermal conditions in the lake (Table 3). At this time of the year, acquired summer heat content is diffusing back to a cool autumn atmosphere and the resistance to mixing is quite low (i.e., no stratification in the water column) so gentle winds can circulate water top to bottom and keep lake conditions nearly uniform. The subtle differences among the three depth zone temperature profiles are due to data collection a few days apart.

Dissolved oxygen levels in November 2006 are also nearly uniform within each water depth profile (Table 4). Absolute oxygen content is higher when compared to July 2005 data, an effect caused by ongoing sources of aeration (e.g., wave action, aquatic plant photosynthesis and contribution from tributary streams) coupled with greater oxygen solubility in colder water. Only in the 9 meter profile of transect C was a slight depression in dissolved oxygen observed at the bottom. This is likely caused by decay processes that consume dissolved oxygen but it does not approach the anoxia measured at that depth in July 2005. Conductivity averaged 216 μS and was fairly uniform throughout the water column. This is slightly lower than the July 2005 average and may reflect less seasonal fine sediment input from tributary streams as well as ionic uptake from the water by living organisms during the 2006 growing season. Lake water pH averaged 7.88 and exhibited a pattern of decline with increasing depth. A pH value of 7.45 occurred at 9 m in transect C, within the alum treatment zone, but the lowest pH value in any sample was 7.42 in transect A at a 5 m depth, outside the alum treatment zone. The November 2006 pH values generally were lower than the July 2005 data. This seasonal downward trend is found in many temperate lakes, including neighboring Canandaigua Lake, and is thought to be the result of phytoplankton use of bicarbonate

TRANSECT "A" TEMPERATURE PROFILES (C°)			
	5 m	7 m	9 m
surface 0	7.73	8.87	9.30
1	7.70	8.85	9.30
2	7.68	8.83	9.30
3	7.68	8.81	9.29
4	7.66	8.60	9.29
5	7.70	8.58	9.29
6		8.57	9.28
7		8.58	9.28
8			9.17
bottom 9			
TRANSECT "B" TEMPERATURE PROFILES (C°)			
	5 m	7 m	9 m
surface 0	8.27	8.21	7.72
1	8.24	7.79	7.71
2	8.22	7.68	7.71
3	8.22	7.65	7.70
4	8.22	7.65	7.69
5	8.21	7.63	7.67
6		7.60	7.64
7		7.64	7.62
8			7.57
bottom 9			7.56
TRANSECT "C" TEMPERATURE PROFILES (C°)			
	5 m	7 m	9 m
surface 0	8.21	8.32	8.25
1	8.20	8.29	8.19
2	8.20	8.08	8.15
3	8.21	7.87	8.03
4	8.21	7.82	8.01
5	8.06	7.75	8.00
6		7.66	8.00
7		7.66	7.99
8			7.99
bottom 9			7.73

TABLE 3 – Temperature profiles taken at 1 meter intervals from three water depth zones along transects in Honeoye Lake during the post-treatment survey, November 2006.

TRANSECT "A" DISSOLVED OXYGEN PROFILES (mg/L)			
	5 m	7 m	9 m
surface 0	10.37	10.34	10.26
1	10.13	10.22	10.12
2	9.98	10.19	10.09
3	9.97	10.17	10.06
4	9.95	10.11	10.05
5	8.41	10.02	10.04
6		9.94	10.04
7		9.90	10.03
8			9.86
bottom 9			
TRANSECT "B" DISSOLVED OXYGEN PROFILES (mg/L)			
	5 m	7 m	9 m
surface 0	10.42	10.32	10.32
1	10.41	10.44	10.17
2	10.40	10.45	10.14
3	10.38	10.38	10.13
4	10.36	10.35	10.12
5	10.31	10.38	10.13
6		10.42	10.13
7		10.36	10.13
8			10.14
bottom 9			10.14
TRANSECT "C" DISSOLVED OXYGEN PROFILES (mg/L)			
	5 m	7 m	9 m
surface 0	10.65	10.78	10.55
1	10.60	10.66	10.48
2	10.58	10.62	10.46
3	10.56	10.53	10.45
4	10.54	10.47	10.40
5	10.46	10.43	10.38
6		10.27	10.35
7		10.10	10.32
8			10.31
bottom 9			7.11

TABLE 4 – Dissolved oxygen profiles taken at 1 meter intervals from three water depth zones along transects in Honeoye Lake during the post-treatment survey, November 2006.

buffers as a source of photosynthetic CO_2, combined with the release of weak organic acids associated with breakdown of sediment detritus that has been accumulating during the current growing season. In either case, based on readings collected during the post treatment survey, pH values did not drop below the neutral point. The secchi disk readings for the November sample days averaged 4.5 m of clarity, a slight improvement when compared to July 2005 readings. Again, temperate lakes can experience an autumn clearing event as plankton populations decline for a variety of reasons.

Indices of benthic macro-invertebrate community health summarized by depth zones are presented in Table 5. In both surveys, all indices show progressive deterioration in health moving from shallow sites to the deep locations. Of particular significance are the consistently low scores during July 2005 for species richness, density, diversity (H') and percent model affinity (PMA) in the 9 m depth zone.

INDEX	5 m	7 m	9 m
2005 species richness	17	9	6
2006 species richness	22	18	14
2005 NCO richness	13	6	3
2006 NCO richness	16	12	8
2005 density (m^2)	1528	833	960
2006 density (m^2)	6990	1850	1125
2005 H'	1.8248	1.2266	0.8479
2006 H'	1.3451	2.2374	1.8121
2005 dominance-3	67.4	90.8	97.8
2006 dominance-3	80.7	49.3	72.7
2005 % Oligochaetes	15.3	47.8	24.5
2006 % Oligochaetes	2.2	12.3	12.4
2005 PMA	66.8	52.3	46.6
2006 PMA	30.8	62.2	48.2

TABLE 5 – Indices of benthic macro-invertebrate community health before and after alum treatment, for three water depth zones sampled in Honeoye Lake. Analyses based on pooled replicate data for each depth zone.

Statistical comparisons between pre- and post-treatment data revealed significant differences for qualitative results (richness) and quantitative results (abundance) for all cases except abundance within the 9 meter depth zone. These statistical comparisons are presented in Table 6 and are based on Student's t-Test analyses with a standard probability level ($\alpha = 0.05$).

RICHNESS			
Depth zone	2005	2006	Significance
5 meter	6.7 ± 2.5	13.8 ± 3.4	p < 0.01
7 meter	4.3 ± 1.0	10.7 ± 3.0	p < 0.01
9 meter	3.2 ± 0.7	6.6 ± 9.0	p < 0.02
ABUNDANCE			
Depth zone	2005	2006	Significance
5 meter	80.1 ± 4295	366.6 ± 41873	p < 0.01
7 meter	43.7 ± 452	97.0 ± 2604	p < 0.02
9 meter	50.3 ± 513	59.0 ± 1847	none

TABLE 6 – Detection of significant differences before and after alum treatment, for three water depth zones sampled in Honeoye Lake. Analyses based on 9 replicates within each depth zone.

Discussion

The mixing regime on Honeoye Lake has been variously described as cold, monomicitc to polymictic. The lake is winter-stratified beneath a thick ice layer that can approach 50 cm. After ice-out in late March, surface water warms to 4ºC and a density driven spring turnover event occurs. Over the summer months (e.g., July 2005), a weak thermocline may establish but, due to the lake's shallow nature, it is fragile at best. Winds may overcome the resistance to mixing of this fragile thermocline but wind effectiveness depends on several factors. Because the long axis of the lake is perpendicular to the prevailing wind direction and because the lake basin has high surrounding topography, strong summer winds along the lake surface are uncommon and unpredictable. Without wind-generated mixing during the summer, anoxia in the deeper zones is a common phenomenon that can last for several weeks until it is disrupted by one of those rare strong surface winds, and it appears to have a significant effect on the macrobenthos. In autumn (e.g., November 2006), lake heat is lost to the atmosphere, biological processes slow in the cooling water, and dissolved oxygen levels gradually improve throughout the water column. Benthic anoxia is less common during autumn but may return as water stagnates under thick ice during the winter season.

For both surveys, pooled benthic richness decreases with depth in Honeoye Lake, probably related to stress created by the low dissolved oxygen levels associated with the periodic, prolonged episodes of anoxia. As a result of the high primary productivity of the lake, significant accumulations of detritus (CPOM) buildup on the lake bottom raising the organic matter content of the substrate as well as its biochemical oxygen demand (BOD_5). The organic detritus represents a major food source for microbes that utilize dissolved oxygen during their role as decomposer organisms. Only the most adapted macro-invertebrates, like chironomid larvae with their high levels of hemoglobin, are able to successfully compete and co-exist with the microbial decomposers in the deeper regions of Honeoye Lake.

Compared to the pre-treatment dredge samples, the post-treatment collections consistently had greater species richness at all water depths (Figure 2). These increases involved a few occurrences of uncommon species while the dominant species both years remained similar. One possible explanation for greater richness involves the difference in the time of the year when sampling occurred. Late season sampling may capture more species because it coincides with dispersal stages in the life cycles of several macro-invertebrates. The random dispersal of typically shallow water species into deep water sites that was detected here, however, does not guarantee long-term survival and persistence in those deep water locations, especially when harsh environmental conditions are known to occur at such depths under the winter ice. While the fate of these colonizers is unknown, it is likely that the post-treatment increases in richness may be short-lived. At this time, the richness increases appear to be associated with dispersal strategies of the macro-benthos rather than a positive impact of the alum treatment.

Overall abundance more than tripled in the post-treatment survey (Figure 3), with an actual count of 4703 individuals in November 2006 compared to 1567 individuals in July 2005. This increase was caused by significantly more zebra mussels, especially in the 5 m depth zone. There were also increases in finger nail clams, snails, scuds and phantom midge larvae. Living ostracods appeared in the post-treatment samples while only empty shells were observed in the pre-treatment survey. One possible explanation for greater numbers in the post-treatment samples is that the sampling took place at the end of the growing season in 2006 allowing a longer time for reproduction and the resulting increase in population size for a given species. Decreases in annelid numbers were detected in the November 2006 survey. Density per m^2 at a depth of 5 m declined from 238 to 148 (down 37.8%), at the 7 m depth from 398 to 222 (down 44.2%) and in the 9 m depth from 233 to 133 (down 42.9%). Because these declines are present in similar proportions at all sampling locations within the lake, both inside and outside the alum treatment zone, it is suspected that the declines are a normal seasonal pattern. Details on all species abundances are presented in the Appendix.

Pooled depth distribution patterns of abundance were pronounced in the post-treatment survey, with fewer individuals found with increasing depth. This trend was not as strong in the pre-treatment survey. In both surveys, high variability among the individual replicate samples from the same depth was likely caused by the clumped distribution of organisms such as zebra mussels. Table 7 compares the relative abundances of the common macro-invertebrates with and without zebra mussels in the analyses.

Abundance in each replicate may also be affected by small scale variability in the texture of the bottom substrate, ranging from extremely soft, fluffy sediment to rather coarse particles (e.g., shell fragments, woody debris, allochthonous input). More patterning in sediment type was observed in the 5 m dredge samples. Softer sediment seemed to have a higher carrying capacity for macro-invertebrates like midge fly larvae, while harder substrates, with their associated hiding places, contained higher numbers of crustaceans like amphipods and aquatic sow bugs.

5 Meter DEPTH ZONE				
	2005		2006	
Zebra mussel	29.1%	-	70.1%	-
Midge fly larvae	24.7	34.8%	3.6	12.0%
Sow bug	17.7	25.0	2.3	7.6
Annelid worm	15.2	21.5	2.2	7.1
Scud	10.1	14.3	3.2	10.6
Finger nail clam	0.5	0.7	2.5	8.2
Banded mystery snail	0.3	0.4	5.2	17.2
Valvate snail	0.1	0.2	5.5	18.2
Other	2.2	3.0	5.6	19.0
7 Meter DEPTH ZONE				
	2005		2006	
Annelid worm	47.8%	48.0%	12.2%	13.6%
Midge fly larvae	39.9	40.0	35.9	39.9
Finger nail clam	5.9	5.9	10.2	11.4
Phantom midge larvae	4.3	4.3	14.3	15.9
Leech	1.0	1.0	0.0	0.0
Zebra mussel	0.5	-	10.1	-
Ostracod	0.0	0.0	8.4	9.3
Other	0.7	0.7	8.9	9.9
9 meter DEPTH ZONE				
	2005		2006	
Midge fly larvae	68.9%	68.9%	51.2%	51.8%
Annelid worm	24.5	24.5	12.4	12.5
Phantom midge larvae	4.6	4.6	20.5	20.8
Finger nail clam	1.1	1.1	5.9	5.9
Nematode	0.8	0.8	0.7	0.7
Ostracod	0.0	0.0	4.5	4.6
Zebra mussel	0.0	0.0	1.2	-
Other	0.1	0.1	3.6	3.7

TABLE 7 - Shifts in relative abundances (%) when excluding zebra mussels from analyses for both pre- and post-alum treatment data.

Despite these changes in richness and abundance, indicies of community health based on survey data collected before and after alum treatment suggests only minor change in macrobenthos structure and no apparent negative impact from the alum treatment of the substrate. Percent model affinity (PMA) and community diversity (H') increased in the 7 and 9 meter depth zones of November 2006 when compared to July 2005 because more species were detected (higher richness) and resources were more evenly shared (lower dominance-3) among the species. This was not observed in the 5 meter depth zone, but only because of the high fecundity and clumped distribution of zebra mussels.

In addition, the richness and abundance of Honeoye Lake's macrobenthos can be used to indicate water quality. Although slight improvements were detected in 2006, the 7 m and 9 m depth zones are judged to be severely impacted based on low species richness, low diversity (H') and the high dominance-3 indices and moderately impacted based on the intermediate PMA scores. There are noticeable improvements in the 5 m depth zone during mid-summer but then some deterioration in autumn as zebra mussels assert dominance. This zone is judged to be slightly impacted based on high species richness and high diversity (H'), but moderately impacted based on the dominance-3 index and the PMA score. The PMA score at 5 meters is particularly sensitive to dispersal and dominance by zebra mussels, and is reduced by more than half when comparing November data to July data (Table 5).

In stream studies, biological indicators (e.g., Type I, II and III macro-invertebrates) are most often related to anthropomorphic pollution events. In Honeoye Lake, the deepwater macrobenthos indicators suggest instead an environment severely stressed by natural, repeated episodes of anoxia brought on by the combination of high lake productivity, large rates of biological decay and warm water temperatures during the summer months. There are limited opportunities for benthic oxygen replenishment during the summer due to infrequent and unpredictable wind generated mixing events, and little or no contribution from tributary streams due to their reduced or absent flow.

The pre- and post-alum treatment changes in the macrobenthos of Honeoye Lake detected in these two surveys seem attributable to the differences in the individual life histories of dominant species in the community, revealed here because of the two distinct times of the year when samples were collected. In the future, it would be instructive to repeat sampling at one or both of the time periods used in these surveys, thereby allowing for a more meaningful comparison.

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Appendix

Capture data and statistical summaries for three water depth zones in Honeoye Lake during July 2005.

	(all dredge samples taken from a water depth = 5 meters)									POOLED	DENSITY
	A	A	A	B	B	B	C	C	C		
July 2005 benthic organisms	3-1	3-2	3-3	3-1	3-2	3-3	3-1	3-2	3-3	TOTAL	per m2
Branchiura sowerbyi	12	6	5	8	24	13	11	24	7	110	233
unidentified annelid	0	0	0	0	0	0	0	0	0	0	0
Chironomus sp.	28	24	74	0	0	0	12	9	1	148	314
Procladius sp.	4	0	14	4	3	1	0	2	0	28	59
Tanypodinae sp.	0	0	2	0	0	0	0	0	0	2	4
Dreisenna polymorpha	1	1	2	0	34	169	0	0	3	210	445
Pisidium sp.	0	0	0	4	0	0	0	0	0	4	8
Sphaerium sp.	1	0	0	0	0	0	0	0	0	1	2
Vivaparous georgianus	0	0	0	1	0	0	0	0	1	2	4
Valvata tricarinata	0	0	0	0	0	0	0	0	1	1	2
Physa sp.	0	0	2	0	0	1	0	0	0	3	6
Gammarus sp.	2	17	27	1	8	16	0	0	2	73	155
Asellus sp.	37	46	32	1	7	3	1	1	0	128	271
nematode	0	0	0	0	0	0	0	0	0	0	0
Sialis sp.	0	0	0	0	1	1	1	0	1	4	8
Chaoborus punctipennas	0	0	0	0	0	0	1	0	0	1	2
Diptera (Dixa?) pupae	0	1	1	0	0	0	0	0	0	2	4
Diptera sp. 2 pupae	0	0	1	0	0	0	0	0	0	1	2
leech	0	0	0	2	0	0	1	0	0	3	6
RICHNESS	7	6	10	7	6	7	6	4	7	17	
ABUNDANCE	85	95	160	21	77	204	27	36	16	721	1528
benthic resting stages											
bryozoan statoblasts	19	14	6	8	13	0	2	0	0	62	131
cladoceran ephippium	6	0	14	25	9	1	1	0	0	56	119
pelagic organisms											
daphnid water fleas	13	2	0	7	0	0	6	3	4	35	74
Leptodora water fleas	0	0	0	0	0	0	0	0	0	0	0
water mite	0	0	0	0	1	0	0	0	0	1	2
fish fry	0	0	0	0	0	0	0	0	0	0	0
RICHNESS	1	1	0	1	1	0	1	1	1	2	
ABUNDANCE	13	2	0	7	1	0	6	3	4	36	76

	(all dredge samples taken from a water depth = 7 meters)									POOLED	DENSITY
	A	A	A	B	B	B	C	C	C		
July 2005 benthic organisms	2-1	2-2	2-3	2-1	2-2	2-3	2-1	2-2	2-3	TOTAL	per m2
Branchiura sowerbyi	44	22	43	2	14	8	26	13	16	188	398
unidentified annelid	0	0	0	0	0	0	0	0	0	0	0
Chironomus sp.	25	26	22	0	12	1	20	19	21	146	309
Procladius sp.	0	0	4	2	0	3	0	2	0	11	23
Tanypodinae sp.	0	0	0	0	0	0	0	0	0	0	0
Dreisenna polymorpha	0	0	0	0	0	0	0	0	2	2	4
Pisidium sp.	1	1	1	5	14	1	0	0	0	23	49
Sphaerium sp.	0	0	0	0	0	0	0	0	0	0	0
Vivaparous georgianus	0	0	0	0	0	0	0	0	0	0	0
Valvata tricarinata	0	0	0	0	0	0	0	0	0	0	0
Physa sp.	0	0	0	0	0	0	0	0	0	0	0
Gammarus sp.	0	0	0	0	0	0	0	0	0	0	0
Asellus sp.	0	0	0	0	0	0	0	0	0	0	0
nematode	0	0	0	1	0	0	0	0	0	1	2
Sialis sp.	0	0	0	0	0	0	0	0	0	0	0
Chaoborus punctipennas	0	3	6	0	3	2	1	1	1	17	36
Diptera (Dixa?) pupae	0	0	0	0	0	0	0	1	0	1	2
Diptera sp. 2 pupae	0	0	0	0	0	0	0	0	0	0	0
leech	0	0	0	1	0	3	0	0	0	4	8
RICHNESS	3	4	5	5	4	6	3	5	4	9	
ABUNDANCE	70	52	76	11	43	18	47	36	40	393	833
benthic resting stages											
bryozoan statoblasts	0	0	0	12	7	17	0	2	0	38	81
cladoceran ephippium	14	6	11	24	46	144	0	1	0	246	521
pelagic organisms											
daphnid water fleas	12	12	140	102	222	617	32	21	21	1179	2498
Leptodora water fleas	0	0	0	2	0	0	0	0	0	2	4
water mite	0	0	0	0	0	1	0	0	0	1	2
fish fry	0	0	1	0	0	0	0	0	0	1	2
RICHNESS	1	1	2	2	1	2	1	1	1	4	
ABUNDANCE	12	12	141	104	222	618	32	21	21	1183	2507

	(all dredge samples taken from a water depth = 9 meters)									POOLED	DENSITY
	A	A	A	B	B	B	C	C	C		
July 2005 benthic organisms	1-1	1-2	1-3	1-1	1-2	1-3	1-1	1-2	1-3	TOTAL	per m2
Branchiura sowerbyi	11	8	25	4	8	16	18	14	6	110	233
unidentified annelid	0	0	1	0	0	0	0	0	0	1	2
Chironomus sp.	42	36	55	23	19	38	57	40	2	312	661
Procladius sp.	0	0	0	0	0	0	0	0	0	0	0
Tanypodinae sp.	0	0	0	0	0	0	0	0	0	0	0
Dreisenna polymorpha	0	0	0	0	0	0	0	0	0	0	0
Pisidium sp.	0	0	0	0	1	0	0	0	4	5	11
Sphaerium sp.	0	0	0	0	0	0	0	0	0	0	0
Vivaparous georgianus	0	0	0	0	0	0	0	0	0	0	0
Valvata tricarinata	0	0	0	0	0	0	0	0	0	0	0
Physa sp.	0	0	0	0	0	0	0	0	0	0	0
Gammarus sp.	0	0	0	0	0	0	0	0	0	0	0
Asellus sp.	0	0	0	0	0	0	0	0	0	0	0
nematode	0	0	0	1	2	1	0	0	0	4	8
Sialis sp.	0	0	0	0	0	0	0	0	0	0	0
Chaoborus punctipennas	6	6	4	0	0	2	0	0	3	21	44
Diptera (Dixa?) pupae	0	0	0	0	0	0	0	0	0	0	0
Diptera sp. 2 pupae	0	0	0	0	0	0	0	0	0	0	0
leech	0	0	0	0	0	0	0	0	0	0	0
RICHNESS	3	3	4	3	4	4	2	2	4	6	
ABUNDANCE	59	50	85	28	30	57	75	54	15	453	960
benthic resting stages											
bryozoan statoblasts	0	0	0	0	0	1	0	4	4	9	19
cladoceran ephippium	12	16	28	2	30	7	5	1	23	124	263
pelagic organisms											
Daphnia pulicaria	20	16	29	8	4	1	1	0	3	82	174
Leptodora kindtii	0	0	0	0	0	0	0	0	0	0	0
water mite	0	0	0	0	0	0	0	0	0	0	0
fish fry	0	0	0	0	0	0	0	0	0	0	0
RICHNESS	1	1	1	1	1	1	1	0	1	1	
ABUNDANCE	20	16	29	8	4	1	1	0	3	82	174

Capture data and statistical summaries for three water depth zones in Honeoye Lake during November 2006.

	(all dredge samples taken from a water depth = 5 meters)									POOLED	DENSITY
November 2006	A	A	A	B	B	B	C	C	C		
benthic organisms	3-1	3-2	3-3	3-1	3-2	3-3	3-1	3-2	3-3	TOTAL	per m2
Branchiura sowerbyi	9	2	1	6	7	0	21	7	17	70	148
unidentified annelid	0	0	0	0	0	0	3	0	1	4	8
Chironomus sp.	0	0	0	2	1	13	11	1	3	31	66
Procladius sp.	1	0	24	11	9	6	13	7	9	80	170
Tanypodinae sp.	0	0	0	2	0	1	3	1	0	7	15
Dreisenna polymorpha	598	384	38	340	308	12	256	236	140	2312	4899
Elliptio complanatus	0	0	0	0	0	0	0	1	0	1	2
Pisidium sp.	28	24	20	0	0	0	6	1	2	81	172
Sphaerium sp.	0	0	0	0	0	0	0	0	0	0	0
Vivaparous georgianus	54	42	16	10	12	7	15	10	4	170	360
Valvata tricarinata	20	3	8	1	3	1	63	65	16	180	381
Gyraulus sp.	0	0	0	0	1	2	2	0	1	6	13
Physa sp.	1	4	1	1	2	0	4	9	3	25	53
Gammarus sp.	6	4	3	16	17	4	29	14	12	105	222
Asellus sp.	4	3	0	14	8	1	16	24	5	75	159
Ostracoda	0	0	0	4	5	8	5	13	6	41	87
nematode	0	3	0	0	0	0	1	0	0	4	8
Sialis sp.	6	13	8	4	6	8	0	2	0	47	100
Chaoborus punctipennas	13	15	4	1	0	7	2	3	3	48	102
Diptera (Dixa?) pupae	0	1	0	0	0	0	0	0	0	1	2
Diptera sp. 2 pupae	0	0	0	0	0	0	0	0	0	0	0
Ephemeroptera nymph	1	0	0	1	0	1	0	1	0	4	8
Odonata nymph	1	0	0	0	0	1	0	0	0	2	4
Trichoptera larvae	0	0	0	0	0	0	0	0	0	0	0
Coleoptera larvae	0	0	0	0	0	0	0	0	0	0	0
leech	0	0	1	0	2	0	0	2	0	5	11
RICHNESS	13	12	11	14	13	14	16	17	14	22	
ABUNDANCE	742	498	124	413	381	72	450	397	222	3299	6990
benthic resting stages											
bryozoan statoblasts	12	0	65	11	21	13	6	57	9	194	411
cladoceran ephippium	56	84	161	119	114	172	95	62	248	1111	2354
pelagic organisms											
daphnid water fleas	0	0	0	0	0	0	0	0	0	0	0
Leptodora water fleas	0	0	0	0	0	0	0	0	0	0	0
Cyclops sp.	0	0	0	0	0	0	1	3	0	4	8
water mite	0	0	2	0	0	0	0	0	0	2	4
fish fry	0	0	0	0	0	0	0	0	0	0	0
RICHNESS	0	0	1	0	0	0	1	1	0	2	
ABUNDANCE	0	0	2	0	0	0	1	3	0	6	13

November 2006 benthic organisms	(all dredge samples taken from a water depth = 7 meters) A 2-1	A 2-2	A 2-3	B 2-1	B 2-2	B 2-3	C 2-1	C 2-2	C 2-3	POOLED TOTAL	DENSITY per m2
Branchiura sowerbyi	0	13	9	15	6	0	12	39	11	105	222
unidentified annelid	0	0	0	0	0	0	2	0	0	2	4
Chironomus sp.	6	7	7	4	1	6	29	38	34	132	280
Procladius sp.	21	20	17	14	8	5	22	29	37	173	367
Tanypodinae sp.	5	1	0	0	0	0	2	0	0	8	17
Dreisenna polymorpha	0	5	2	2	10	27	2	9	31	88	186
Elliptio complanatus	0	0	0	0	0	0	0	0	0	0	0
Pisidium sp.	10	10	12	0	1	2	15	14	25	89	189
Sphaerium sp.	0	0	0	0	0	0	0	0	0	0	0
Vivaparous georgianus	0	0	0	0	0	1	2	0	3	6	13
Valvata tricarinata	2	1	1	2	1	1	0	2	2	12	25
Gyraulus sp.	0	0	0	0	1	0	0	1	1	3	6
Physa sp.	0	0	0	0	0	0	0	0	0	0	0
Gammarus sp.	0	4	0	6	3	4	4	3	5	29	61
Asellus sp.	0	1	0	1	0	12	2	0	0	16	34
Ostracoda	3	2	3	1	5	22	14	11	12	73	155
nematode	0	0	0	0	0	0	0	0	0	0	0
Sialis sp.	1	1	0	1	5	1	0	0	0	9	19
Chaoborus punctipennas	10	1	9	9	18	12	16	28	22	125	265
Diptera (Dixa?) pupae	0	1	0	0	0	0	0	0	0	1	2
Diptera sp. 2 pupae	0	0	0	0	0	0	0	0	0	0	0
Ephemeroptera nymph	0	0	0	0	0	0	0	0	0	0	0
Odonata nymph	0	0	0	0	0	0	0	0	0	0	0
Trichoptera larvae	0	1	0	0	0	0	0	0	0	1	2
Coleoptera larvae	1	0	0	0	0	0	0	0	0	1	2
leech	0	0	0	0	0	0	0	0	0	0	0
RICHNESS	9	14	8	10	11	11	12	10	11	18	
ABUNDANCE	59	68	60	55	59	93	122	174	183	873	1850
benthic resting stages											
bryozoan statoblasts	2	2	0	2	5	129	2	3	3	148	314
cladoceran ephippium	203	57	63	56	230	231	213	315	244	1612	3415
pelagic organisms											
daphnid water fleas	0	0	0	0	0	0	5	21	4	30	64
Leptodora water fleas	0	0	0	0	0	0	0	0	0	0	0
Cyclops sp.	0	0	0	0	1	0	0	3	4	8	17
water mite	0	0	0	0	0	0	1	2	0	3	6
fish fry	0	0	0	0	0	0	0	0	0	0	0
RICHNESS	0	0	0	0	1	0	2	3	2	3	
ABUNDANCE	0	0	0	0	1	0	6	26	8	41	87

	(all dredge samples taken from a water depth = 9 meters)									POOLED	DENSITY
November 2006	A	A	A	B	B	B	C	C	C		
benthic organisms	1-1	1-2	1-3	1-1	1-2	1-3	1-1	1-2	1-3	TOTAL	per m2
Branchiura sowerbyi	2	2	0	6	8	6	24	4	11	63	133
unidentified annelid	0	0	0	0	0	0	3	0	0	3	6
Chironomus sp.	3	3	0	44	19	50	26	39	30	214	453
Procladius sp.	0	0	0	2	0	1	25	10	7	45	95
Tanypodinae sp.	0	0	0	0	0	0	2	7	4	13	28
Dreisenna polymorpha	1	2	0	1	0	2	0	0	0	6	13
Elliptio complanatus	0	0	0	0	0	0	0	0	0	0	0
Pisidium sp.	7	1	0	1	2	1	2	8	9	31	66
Sphaerium sp.	0	0	0	0	0	0	0	0	0	0	0
Vivaparous georgianus	0	1	0	0	0	0	0	0	0	1	2
Valvata tricarinata	1	0	0	0	0	0	0	0	0	1	2
Gyraulus sp.	0	0	0	0	0	0	0	0	0	0	0
Physa sp.	0	0	0	0	0	0	0	0	0	0	0
Gammarus sp.	1	3	0	0	0	0	1	9	1	15	32
Asellus sp.	0	0	0	0	0	0	0	0	0	0	0
Ostracoda	0	0	0	0	0	0	10	8	6	24	51
nematode	2	1	0	0	0	0	0	0	1	4	8
Sialis sp.	2	0	0	0	0	0	0	0	0	2	4
Chaoborus punctipennas	5	4	0	16	2	11	29	24	18	109	231
Diptera (Dixa?) pupae	0	0	0	0	0	0	0	0	0	0	0
Diptera sp. 2 pupae	0	0	0	0	0	0	0	0	0	0	0
Ephemeroptera nymph	0	0	0	0	0	0	0	0	0	0	0
Odonata nymph	0	0	0	0	0	0	0	0	0	0	0
Trichoptera larvae	0	0	0	0	0	0	0	0	0	0	0
Coleoptera larvae	0	0	0	0	0	0	0	0	0	0	0
leech	0	0	0	0	0	0	0	0	0	0	0
RICHNESS	9	8	0	6	4	6	9	8	9	14	
ABUNDANCE	24	17	0	70	31	71	122	109	87	531	1125
benthic resting stages											
bryozoan statoblasts	17	26	42	3	10	51	2	30	10	191	405
cladoceran ephippium	276	174	298	106	273	507	709	900	978	4221	8943
pelagic organisms											
Daphnia pulicaria	1	0	0	0	3	0	65	26	57	152	322
Leptodora kindtii	0	0	0	0	0	0	0	0	0	0	0
Cyclops sp.	0	0	0	0	0	3	44	23	26	96	203
water mite	0	0	0	0	0	0	0	0	1	1	2
fish fry	0	0	0	0	0	0	0	0	0	0	0
RICHNESS	1	0	0	0	1	1	2	2	3	3	
ABUNDANCE	1	0	0	0	3	3	109	49	84	249	528