



Significance of Deep Bottom Sediment
to
Phosphorus Dynamics
in
Honeoye Lake

by

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Executive Summary

Lake eutrophication has historically been linked to human activities that contribute phosphorus to a lake basin. These activities occur either in the watershed or along the shoreline. Because these activities occur outside of the lake basin, they are considered external nutrient loading factors. However, in shallow lakes that experience seasonal benthic anoxia, phosphorus is known to be released from lake sediment, appropriately named an internal nutrient loading factor. When lake restoration efforts primarily consist of the use of best management practices in the watershed, the question arises - will reductions in external phosphorus loading make a difference in eutrophic lakes that regularly experience internal loading? Quantification of phosphorus concentrations in lake sediment is the first step required to document the possible significance of internal loading. Once sediment phosphorus levels are known, that information can be coupled with the frequency of benthic anoxia, to suggest when and, potentially how much, nutrient might be released to the water column. Then, comparisons to nutrient contributions obtained from tributary monitoring programs should clarify the relative importance of internal versus external nutrient loading factors.

Deep sediment work began on Honeoye Lake during August 2000. Thirty-three sediment cores were extracted with a piston sampler from the deepest region of the basin. For comparative purposes, an additional sediment core was collected in an adjacent macrophyte community. All cores were subdivided into top, middle and bottom sections, then each section was analyzed for percent moisture, percent organic matter content, pH, total phosphorus and available phosphorus.

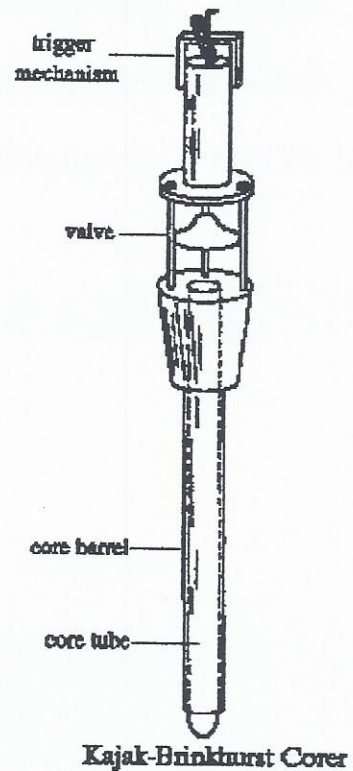
Moisture content of all sections averaged 68%, indicating deep sediment has a loose structure that might be easily disrupted by lake currents. Mean organic matter content was slightly above nine percent. Sediment pH was slightly acidic, with a mean value of 6.87. Total phosphorus concentrations were extremely high in the sediment, averaging 855.33 mg/L. Available phosphorus averaged 2.90 mg/L. Differences were noted among the modern (top section), middle-aged and old (bottom section) sediment for some properties.

Available phosphorus was negatively correlated with substrate pH when all sections were considered. When only top section data were statistically analyzed, the relationship was again significant but in a positive direction. Available phosphorus was positively correlated to total phosphorus in the top section but negatively correlated to total phosphorus in the bottom section.

Phosphorus release from deep lake sediment has the potential to contribute significantly to the overall productivity and trophic condition of Honeoye Lake. Data from this study helps confirm historic models that exist in the scientific literature for Honeoye Lake. In the future, comparisons between these data and the results of tributary monitoring during storm events should provide insight on phosphorus dynamics in Honeoye Lake.

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Laboratory analyses for moisture content, organic content and pH were completed in the Department of Science and Technology at Finger Lakes Community College. A sincere thank you to Lynn McGrath for the use of laboratory space and equipment. Determinations of total phosphorus and available phosphorus were conducted at the SUNY College of Environmental Science and Forestry in Syracuse under the direction of Donald Bickelhaupt. His role in the success of this research is gratefully acknowledged.

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INTRODUCTION

Phosphorus dynamics in shallow lakes can be influenced by lake morphometry, seasonal changes in lake conditions, lake sediment, natural contributions from tributary streams, and human activities in the watershed. Shallow lakes are most often known to be enriched with phosphorus but the relative importance of influencing factors is seldom well understood. Complex models have been developed to suggest how lake nutrients cycle, and these models can be verified when appropriate field data is collected. When one goal of lake restoration efforts is the reduction of nutrient budgets, sediment analyses may provide essential modern and historic information.

Honeoye Lake is one of the smallest of the western Finger Lakes, having a maximum length of 4.10 miles (6.60 kilometers), maximum width of 0.88 miles (1.42 kilometers) and maximum depth of 30.2 feet (9.2 meters). The basin has an estimated volume of 9.2 billion gallons (34.8 million cubic meters) and a hydraulic retention time of less than one year. Honeoye is classified as a cold, monomictic lake. It has a winter-stratified temperature profile beneath the complete ice cover of December through March. The lake has a spring turnover driven by density changes after ice-out occurs. Due to the shallowness of the basin, any summer stratification is ephemeral, and readily broken apart by frequent wind-generated mixing events. Honeoye Lake is eutrophic, with high phosphorus levels supporting luxuriant and diverse macrophyte communities, periodic algal blooms, and large populations of invertebrates and warmwater fishes. Nutrient sources are thought to include natural runoff, historic contamination stored in the sediment, and modern contributions from human activities in the watershed. Actual nutrient data for the lake and its tributaries are scarce, anecdotal or outdated.

Honeoye Lake occupies the center of a 36.7 square mile (95 square kilometer) watershed. The underlying bedrock consists of horizontally bedded sedimentary rocks of Upper Devonian age. The Honeoye valley was deepened by selective linear erosion during the advance of the Wisconsin ice sheet, and hummocky till deposits were left across the valley floor upon ice retreat. Glacial till and native bedrock comprise the parent materials for local soils. Watershed land uses based on 1971 information include forest (85%), agriculture (10%), abandoned agriculture (4%) and residential (2%). Less than one percent of the watershed is publicly owned but significant conservation lands exist, especially in the Honeoye Inlet sub-basin. Watershed population has nearly tripled since 1930, with 1990 census data indicating a human population of 2116 people. Much of this increase has been accompanied by the conversion of seasonal cottages to year-round residences.

The Department of Environmental Conservation/Outdoor Recreation at Finger Lakes Community College conducted its first intensive research, a lake-wide inventory of macrophyte communities, in Honeoye Lake in 1984. That inventory was repeated in 1994. Over the years, the College has conducted fisheries inventories, studied zebra mussels and monitored lake water quality. The College has a long-term interest in the biology of Honeoye Lake, and with the recent acquisition of the Muller Conservation Field Station near the south end of the lake, the College will continue to be actively involved in Honeoye Lake research in the future. The College also serves as a technical advisor to the Honeoye Lake Watershed Taskforce.

METHODS

Three transects across the deep basin of Honeoye Lake and one station in an adjacent macrophyte community were selected for sediment coring (Figure 1). Each transect contained eleven stations, and each station was referenced by GPS coordinates. A depth profile of sediments was collected at each station with a Kajak-Brinkhurst (K-B) sampler. The core tube was 20 inches (50 centimeters) in length, and was allowed to free-fall into the sediment from a height of 10-12 feet (3-4 meters). A valve at the top of the sampler was closed by messenger, creating a vacuum seal that prevented sediment washout during retrieval. On the boat, sediment released from the core tube was equally subdivided into top, middle and bottom sections. An inspection was made of all sections for odor, color patterns, macro-invertebrates and recognizable detritus. Each core section was stored in sealed polyethylene bags, refrigerated, and transferred to the college for laboratory analyses.

Core sections were immediately measured for pH with an Orion electronic meter. Next, subsamples of each core section were placed in tared ceramic crucibles. Moisture content was calculated by subtracting the dry sediment weight (weight after 12 hours in a 105°C drying oven) from the wet sediment weight (weight after returning from the field), then dividing by the wet sediment weight and multiplying by 100 to express as a percent. Dried sediment samples in crucibles were then placed in a muffle furnace. Loss-on-ignition at 550°C was used to determine % organic matter content (Dean 1974). The remaining wet sediment core sections were air dried in the college greenhouse (approximately 5-7 days), processed to their original particle sizes and then stored in sealed polyethylene bags. Samples were delivered to the SUNY College of Environmental Science and Forestry for nutrient testing. Available phosphorus, the fraction

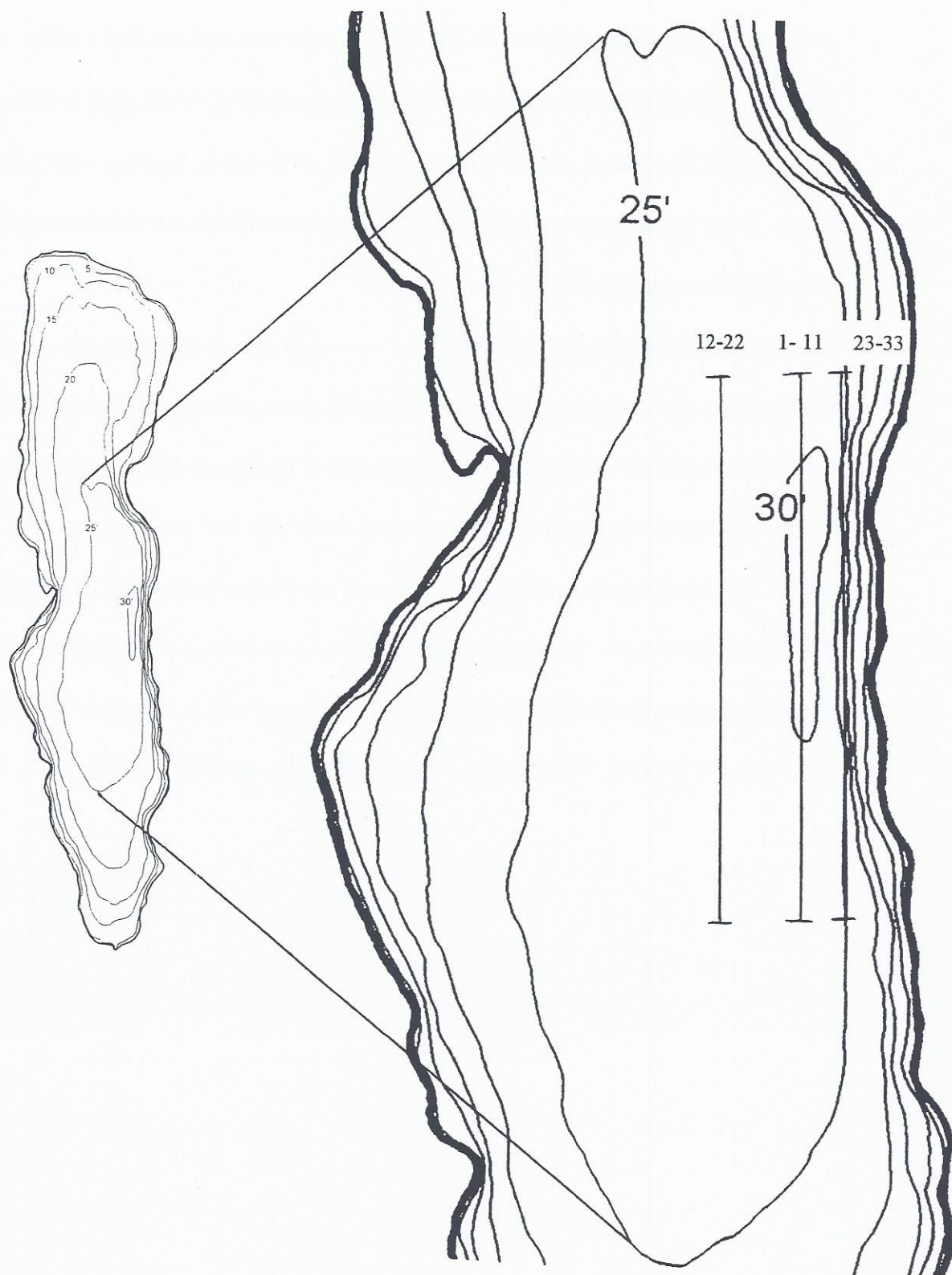


FIGURE 1 - Location of sediment sampling transects in Honeoye Lake, New York.

loosely associated with sediment Fe and Ca, was determined by the HCl + NH₄F extraction method. Total phosphorus was determined by the method of Aspila et al. (1976); briefly, sediment was combusted at 550°C for 90 minutes, followed by leaching with 1 N HCl for 24 hours. Then, orthophosphate levels in the leachate were measured with the standard phosphoantimonymolybdenum blue method.

Statistical analyses of sediment data were used to summarize results and examine relationships among sediment properties. Properties were evaluated through calculation of individual correlation coefficients and multiple linear regression equations. Correlation coefficients were compared to critical values at the $\rho=.05$ and $\rho=.01$ levels.

Lake water quality profile measurements were taken in the deep basin periodically during the 2000 calendar year. Using a HYDROLAB sampler, data was recorded on temperature, dissolved oxygen, % oxygen saturation, conductivity and pH, at one meter intervals from the surface to the bottom. Water clarity was measured as secchi disk depth(m).

RESULTS

Typical sediment cores had a fine texture, and varied in color from a medium gray in the top section to a dark gray in the bottom section. Brown mottling and fibrous structure was frequently noted in the top section. Detritus was most common in the top section and consisted of leaves, leaf petioles, needles and cone fragments. Sulfur odors increased with depth in most cores. *Chironomid* larvae were observed in the top sections of most cores, annelid worms were infrequent. No other aquatic invertebrates were seen.

The relationship between core depth and age may reveal if recent shoreline development and watershed activities have increased sediment nutrient content. Sediment age depends on basin accumulation rates, a process that may be adversely affected by any disruption of normal stratification along the lake bottom. Accumulation rates were attempted by Lajewski (1999) utilizing ^{210}Pb and ^{137}Cs dating techniques on a single 60 cm sediment core. The amount of lead and cesium were constant throughout his sediment record, indicating that the sediment at his particular site had been uniformly mixed by lake currents. Aging, therefore, was not possible. Fortunately, deep basin ^{137}Cs data from Proctor (1978) suggests a sediment accumulation rate of approximately 0.16 cm/year. Given that accumulation rate, the bottom of the 50 cm cores used in this study would have an approximate origin around the year 1685 A.D.

Summaries of sediment data are presented in Tables 1 through 5, and Figure 2. Individual core section results are located in the Appendix. Sediment pH (Table 1) was near neutral, decreasing slightly and becoming more acidic with depth. Parent materials in the watershed are largely non-calcareous, so acidic sediment pH was expected. Additionally, sediment pH is similar to lake water pH, which typically is near 7.00 and slightly acidifies during the growing season.

TABLE 1 - Sediment pH by core section (n=33).

	mean \pm 1 s.d.	minimum	maximum
Top section	7.15 \pm 0.13	6.85	7.41
Middle section	6.84 \pm 0.21	6.48	7.24
Bottom section	6.63 \pm 0.21	6.21	7.15

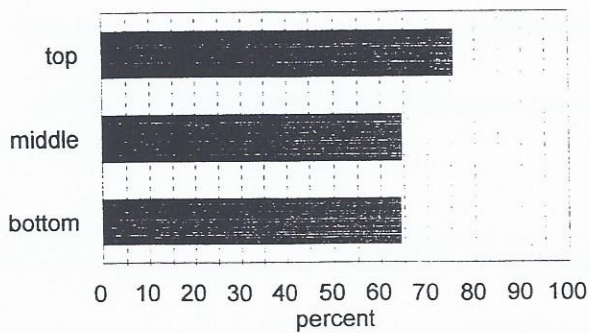
Sediment percent moisture (Table 2) was greatest in the top section, where sediment was in contact with overlying waters. Overall, lake bottom sediment was found to have a loose structure indicating its potential susceptibility to disturbance by lake currents. Lake turbidity, therefore, can result from suspended sediment delivered by tributary streams, the occurrence of dense plankton populations and the resuspension of bottom sediments.

TABLE 2 - Sediment percent moisture by core section (n=33).

	mean \pm 1 s.d.	minimum	maximum
Top section	75.60 \pm 2.18	69.82	79.21
Middle section	64.53 \pm 1.93	61.31	68.24
Bottom section	64.22 \pm 4.05	52.85	71.08

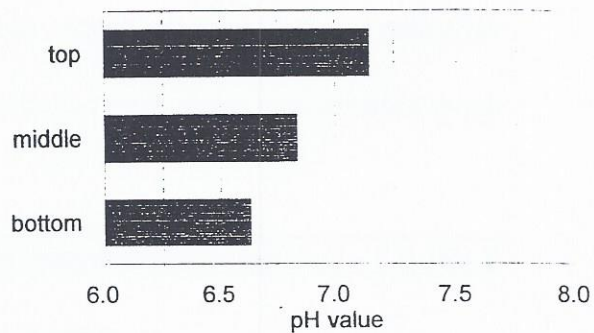
Substrate % moisture

by section



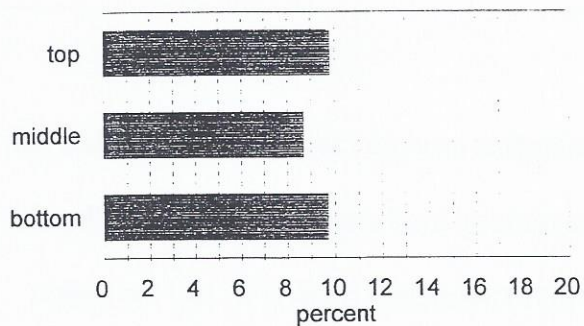
Substrate pH

by section



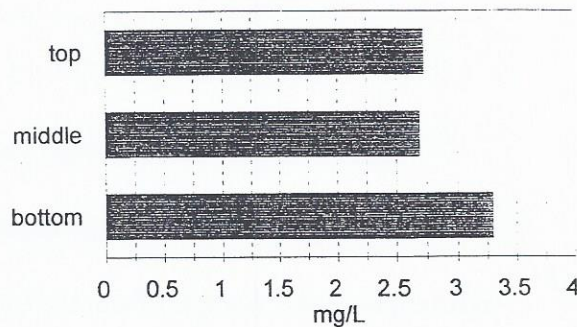
Substrate % organic

by section



Available Phosphorus

by section



Total Phosphorus

by section

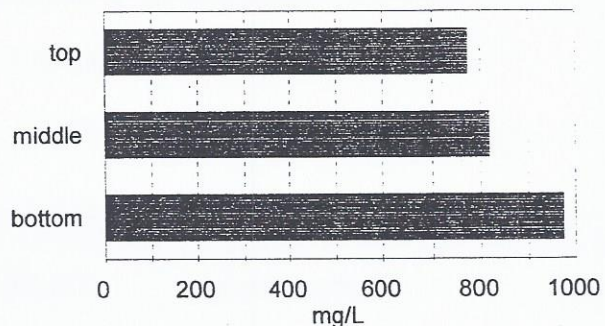


FIGURE 2 - Properties of sediment from Honeoye Lake, New York. Data presented for top, middle and bottom sections of a 20 inch core.

Organic matter content (Table 3) showed little difference among sections. The greatest variability was noted for the deeper, older sections of the core. Less variability in the middle and upper sections may result from periodic sediment mixing associated with turbulent lake currents.

TABLE 3 - Sediment percent organic matter by core section (n=33).

	mean \pm 1 s.d.	minimum	maximum
Top section	9.78 \pm 0.52	8.69	10.82
Middle section	8.69 \pm 0.33	8.06	9.35
Bottom section	9.69 \pm 1.19	5.85	11.70

Sediment total phosphorus (Table 4) had the highest average value in the top section but was extremely variable from individual site to site, suggesting local conditions strongly influence nutrient content. Samples from the transect closest to the shoreline (transect 2) had the lowest values while samples from the deepest region (transect 1) had the highest values. Overall, these data represent extremely high total phosphorus content in Honeoye Lake sediment.

TABLE 4 - Sediment total phosphorus (mg/L) by core section (n=33).

	mean \pm 1 s.d.	minimum	maximum
Top section	974.34 \pm 211.22	336.84	1282.37
Middle section	818.03 \pm 129.49	415.02	1036.28
Bottom section	773.63 \pm 125.73	465.28	1186.78

Analyses of sediment available phosphorus (Table 5) revealed a slight increase with depth, however, variability within each section was high. Available phosphorus averaged 0.36 percent of the total phosphorus, with a range of 0.16 to 1.46 percent. Even though a relatively small percentage of the total phosphorus is in the available form, the extremely high total phosphorus content of the sediment (Table 4) apparently can produce available phosphorus levels that are several orders of magnitude higher than the desirable standard (EPA guidelines for total phosphorus in eutrophic lake water = 0.026 mg/L, available phosphorus = virtually absent).

TABLE 5 - Sediment available phosphorus (mg/L) by core section (n=33).

	mean \pm 1 s.d.	minimum	maximum
Top section	2.73 \pm 0.83	1.07	5.05
Middle section	2.69 \pm 1.60	1.16	8.04
Bottom section	3.30 \pm 0.91	2.02	5.32

Simple linear correlation analyses between available phosphorus and sediment properties is presented in Table 6. Multiple linear regressions produced no significant results.

TABLE 6 - Correlation between available phosphorus and sediment properties.

	All sections	Top section	Middle section	Bottom section
Substrate pH	-0.198*	0.362*	-0.289	-0.018
Percent moisture	-0.087	0.340	-0.064	-0.049
Percent organic	0.019	-0.143	-0.093	-0.030
Total phosphorus	-0.020	0.544**	-0.050	-0.450**
	*p=.05	**p=.01		

DISCUSSION

Deep basin sediment in Honeoye Lake is clearly high in phosphorus content. Similar levels of sediment phosphorus have been reported from other eutrophic lakes in North America (i.e., Lake Mendota, Wisconsin [Frey 1966 in Wetzel 1983], Shagawa Lake, Minnesota [Larsen et al. 1981], and Long Lake, Washington [Jacoby et al. 1982]). Welch and Cooke (1995) provide a review of the importance of sediment to internal phosphorus loading in shallow, eutrophic lakes throughout the world.

It is unclear how much of the sediment phosphorus in Honeoye Lake has an anthropogenic source. Total phosphorus increased with core depth by nearly 20 percent (Figure 2). High phosphorus content in core bottom sections that predate significant European colonization of the region suggests that natural processes contributed to the eutrophication of Honeoye Lake prior to settlement. Although expected, there is no indication of an increase in sediment phosphorus at the time of timbering of the primeval forest. The absence of this anticipated marker in the sediment may be partly explained by the compensatory uptake of phosphorus in the lake's plant community. Sediment mixing, whether caused by spring turnover or bottom turbulence, may also confuse the chronology of the sediment core thereby masking patterns in phosphorus accumulation rates. Available phosphorus also increased with core depth (Figure 2), but this could be explained by the rapid turnover (loss) of phosphorus from the surface sediment to the overlying waters. Based on limited water quality profile sampling conducted in recent years (Figure 3), the greatest deep basin phosphorus concentrations occur during the late summer when water temperatures are at their peak, biochemical oxygen demand is high, and the metabolic rates of benthic decomposers are maximized. If this phosphorus has been released from the sediment, internal loading is at work.

Nutrient Availability

total phosphorus

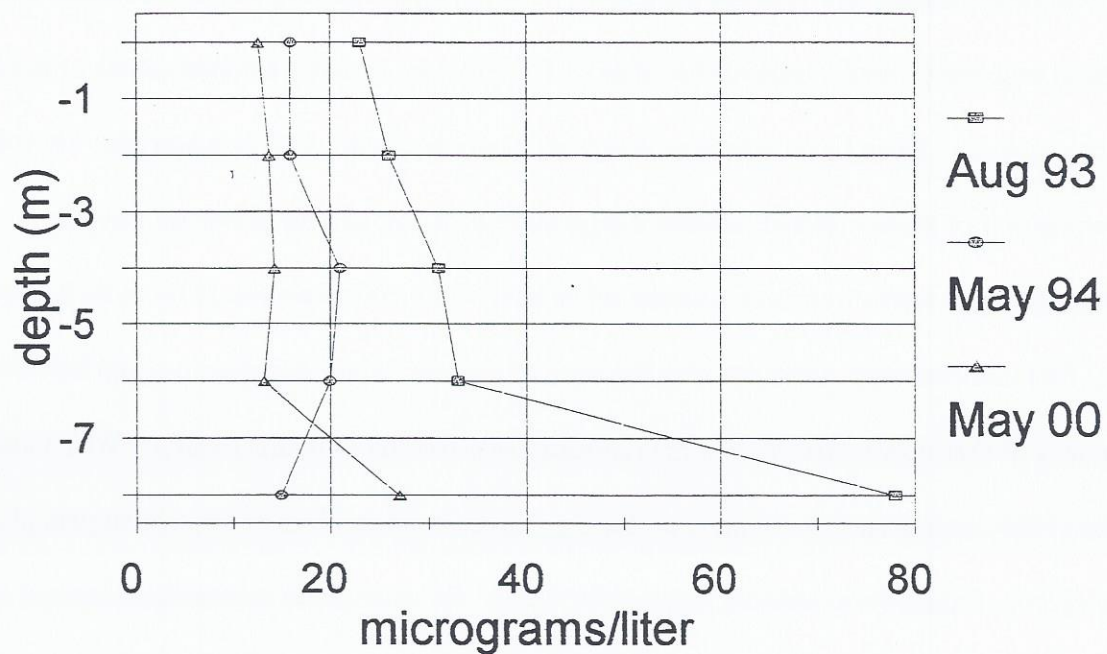


FIGURE 3 - Water profile analyses for nutrient availability in Honeoye Lake, New York.

Internal loading of phosphorus depends on reducing conditions in deep basin sediment. Based on the classic work of Mortimer in the 1940's, available phosphorus and ferrous iron increase simultaneously in lake water when redox potential of the bottom muds falls below 0.2 volt. If bottom sediment is oxidized, sediment minerals (largely ferric iron) react with phosphorus and temporarily trap it. When sediment minerals are reduced, their valence state changes and the phosphorus trap is reversed (i.e., phosphorus is released to the water column, a process known as internal loading). Dissolved oxygen profiles for the year 2000 revealed that reducing conditions (benthic anoxia) occurred beneath winter ice when contact with atmospheric gases was blocked and during late summer when lake temperatures reached their seasonal maxima (Figure 4). Of these two time periods, late summer appears to have the longer lasting and more serious oxygen depletion problem (Gilman, unpublished data). The problem is partly a consequence of the lake's high productivity. Deep basin sediment is regularly enriched with organic materials. Microbial decomposition of these materials creates a high biological demand for dissolved oxygen, particularly in the warm waters of summer when bacterial metabolism would be at its highest level. This unfortunately coincides with the time of the year when dissolved oxygen levels are potentially at their lowest because of the reduced gas solubility in warmer water. Welch and Cooke (1995) summarize by stating that there are at least six mechanisms by which phosphorus recycles from sediments in shallow, unstratified lakes. Because these mechanisms interact at the same time, and vary in importance from lake to lake, there has been little success in determining their relative importance. However, three mechanisms appear to be significant in most studies: resuspension of flocculent phosphorus-laden particles (wind creates turbulence that resuspends sediment), benthic decomposition and calm weather that allows for temporary benthic anoxia.

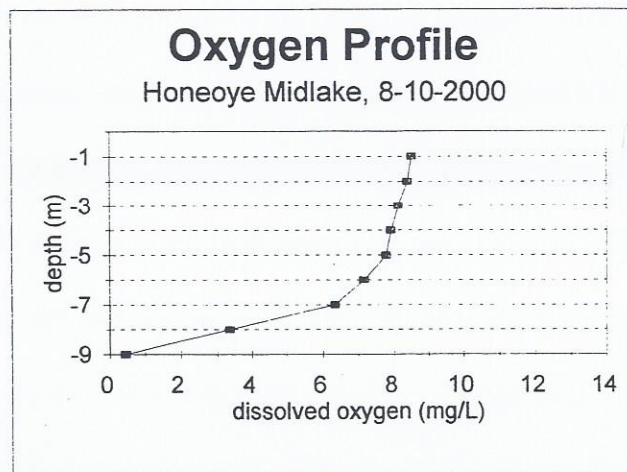
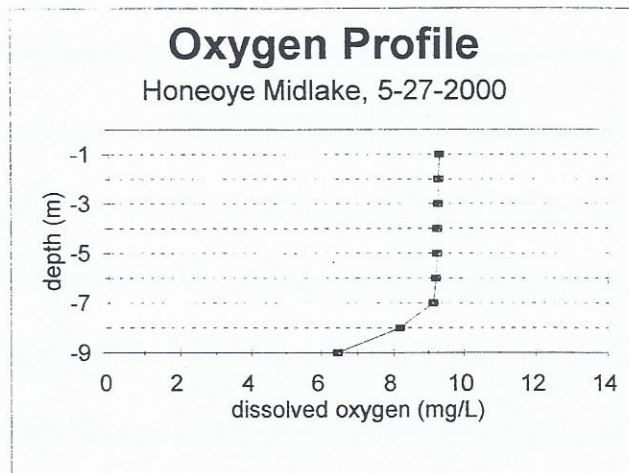
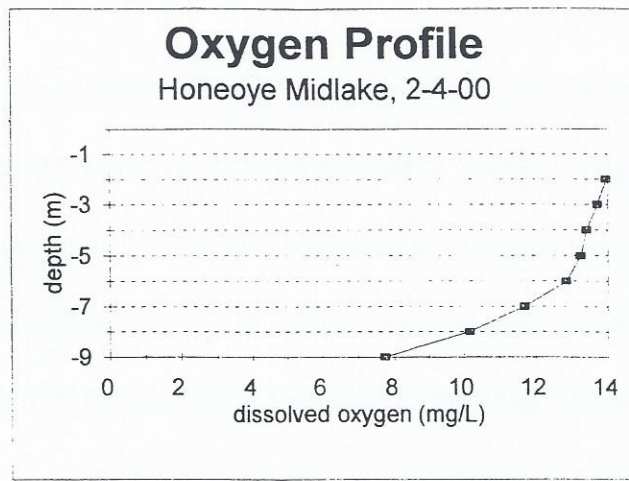


FIGURE 4 - Seasonal dissolved oxygen profiles in Honeoye Lake, New York.

Minor contributing factors include low Fe/P ratios, high pH conditions and summer senescence of macrophytes. Honeoye Lake is subject to the first three mechanisms: sediment resuspension, benthic decomposition and temporary benthic anoxia. Of the remaining factors, iron levels appear adequate and pH is never high. Only summer dieback in the weedbed communities seems plausible, however, its relative significance is lessened by the amount of macrophyte biomass removed annually through the County sponsored harvesting program.

Is there a realistic strategy to control Honeoye Lake's internal loading? One possibility might be dredging nutrient-rich sediment from the deep basin of Honeoye Lake. This is a costly approach and this research suggests that the buried sediment contains as much or more phosphorus as the surface sediment. Another approach could be the addition of dissolved oxygen to the bottom sediment during periods of benthic anoxia. In other lakes this has been accomplished with solar-powered compressors that delivered air to diffusers laid in a grid across the deeper basin of a shallow lake. This delivery system prevents reducing conditions in the sediment but may cause turbulence that resuspends bottom materials. In nearby Irondequoit Bay, phosphorus was "permanently" trapped to artificially added minerals, a process called alum precipitation. However, if a lake basin experiences rapid siltation, "permanently" trapped sediment is soon buried by new materials and internal loading can resume. Additionally, alum has toxic side effects that, to be avoided, require careful dosages in a lake treatment program. Breaking the cycle of internal loading might better be accomplished by reducing the sedimentation of organic materials on the lake bottom. This has been achieved through external load reduction in some lakes (i.e., less nutrients flowing to the lake, less biological production in the lake) but the desired effect has taken over twenty years to appear due to the high sediment phosphorus levels.

Likewise, the removal of macrophyte biomass through mechanical harvesting should reduce organic sedimentation on the lake bottom, but is the reduction large enough to produce the desired effect soon enough? After a decade of harvesting on Honeoye Lake, macrophyte biomass in the weedbeds has been slightly reduced based on a unit area comparison between 1984 and 1994 (Gilman 1985, Gilman 1994). Unfortunately, over that same time period, lake clarity has improved and the areal extent of the weedbed communities has grown by 50 percent. The impression is that the weed problem is worse, not because the beds are denser (data indicates they are less dense), but because they are more widespread.

The most realistic strategy to manage internal loading in Honeoye Lake may be an integrated approach that attempts to reduce the nutrient budget on several fronts. Understanding the phosphorus cycle is fundamental to success. The phosphorus cycle in Honeoye Lake involves the following processes:

1. uptake of phosphorus from water by littoral macrophytes when plants are rapidly growing in the spring and early summer. This phosphorus most likely originates from shoreline and watershed activities, and is dispersed in lake during spring turnover.
2. liberation of phosphorus into the upper waters of the littoral zone, largely from the decay of macrophytes during late summer and fall.
3. uptake of liberated phosphorus by phytoplankton, often producing a fall algal bloom of cyanobacteria (formerly known as blue-green algae).
4. sedimentation of phytoplankton, seston and macrophytes into the deeper waters of the basin, where phosphorus is temporarily bound to iron in the sediment.
5. release of phosphorus from sedimenting seston before it reaches the bottom.

6. diffusion of phosphorus from sediments into the water at those depths where the sediment lacks an oxidized microzone.

Reductions in external loading will affect the first process in this cycle. Efforts involving public education and local code enforcement would be most helpful in reaching this goal. The second process is curtailed to some degree by the removal of macrophytes through harvesting before they have the chance to dieback and sink to the lake bottom. Removing harvested biomass from the watershed is a good practice. Preventing terrestrial biomass from entering the lake would also be beneficial. The third process may have less impact if removal of macrophyte biomass continues or, oddly enough, if weedbeds continue to expand and the macrophytes sequester the nutrients so much that little phosphorus is left to support a fall algal bloom. The fourth and fifth processes can not be effectively managed, but the sixth process can be approached through the possibilities mentioned earlier.

In Honeoye's nutrient budget, how does internal loading of phosphorus compare to external contributions of nutrients? The answer to this question will become apparent in the near future. Automated stream samplers will provide data characterizing baseflow conditions as well as storm contributions for perennial tributaries to Honeoye Lake. These records can be compared to the understanding of internal loading revealed in this report. Modeling based on the mass balance equation used previously by Schaffner and Oglesby (1978) can be updated, and priorities can be established for an integrated strategy of lake restoration.

In summary, sediment analyses for the deep basin of Honeoye Lake indicate extremely high nutrient content which, under anoxic conditions, can result in significant internal loading of phosphorus and result in a stimulation of the lake's plant communities.

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APPENDIX

Individual Sediment Core Data - Top Section

Sample	Depth	pH	wet weight	dry weight	%moisture	LOI wt	%organic	total phosphorus	available phosphorus	% phosphorus
1.1	28.0	7.01	20.011	5.133	74.35	4.645	9.51	894.185	2.104	0.24
2.1	28.0	7.19	17.291	3.742	78.36	3.347	10.56	1102.398	2.624	0.24
3.1	27.0	6.85	19.318	4.745	75.44	4.285	9.69	961.064	2.193	0.23
4.1	26.0	6.91	18.496	4.706	74.56	4.220	10.33	739.321	1.538	0.21
5.1	27.0	6.87	17.528	5.290	69.82	4.827	8.75	752.945	1.807	0.24
6.1	28.0	6.87	16.147	4.649	71.21	4.245	8.69	917.789	2.435	0.27
7.1	29.5	7.23	16.496	3.987	75.83	3.621	9.18	1020.745	3.065	0.30
8.1	28.0	7.21	16.897	3.699	78.11	3.335	9.84	1150.290	3.399	0.30
9.1	27.2	7.26	15.545	3.626	76.67	3.272	9.76	1184.065	3.153	0.27
10.1	26.7	7.24	17.244	4.207	75.60	3.806	9.53	1238.091	5.049	0.41
11.1	25.8	7.13	18.616	4.785	74.30	4.330	9.51	988.099	3.699	0.37
12.1	25.6	7.20	20.002	4.681	76.60	4.243	9.36	1206.412	3.203	0.27
13.1	26.3	7.07	18.776	4.734	74.79	4.272	9.76	1134.037	3.142	0.28
14.1	26.1	7.06	18.383	4.295	76.64	3.880	9.66	1151.869	2.619	0.23
15.1	26.9	7.18	16.526	3.589	78.28	3.231	9.97	1238.308	3.203	0.26
16.1	27.7	7.14	19.390	5.322	72.55	4.833	9.19	972.749	2.892	0.30
17.1	27.3	7.23	18.531	4.568	75.35	4.097	10.31	552.593	2.968	0.54
18.1	28.2	7.16	17.500	4.396	74.88	3.982	9.42	962.488	2.076	0.22
19.1	27.8	7.14	18.555	4.142	77.68	3.731	9.92	1155.378	2.962	0.26
20.1	28.2	7.21	16.171	3.362	79.21	3.032	9.82	844.929	2.534	0.30
21.1	27.6	7.18	19.961	4.731	76.30	4.270	9.74	1131.461	2.363	0.21
22.1	27.5	7.14	16.315	3.925	75.94	3.541	9.78	1075.876	2.528	0.23
23.1	23.3	7.41	17.677	4.076	76.94	3.635	10.82	929.725	1.502	0.16
24.1	25.6	7.29	16.673	3.738	77.58	3.334	10.81	1071.009	2.526	0.24
25.1	23.8	7.19	19.321	5.201	73.08	4.709	9.46	889.371	2.349	0.26
26.1	24.8	7.23	19.673	4.425	77.51	3.948	10.78	900.870	2.358	0.26
27.1	26.3	7.03	21.395	5.613	73.76	5.048	10.07	336.843	1.071	0.32
28.1	24.9	7.14	18.355	4.551	75.21	4.104	9.82	675.309	2.272	0.34
29.1	23.7	7.22	20.478	5.483	73.22	4.959	9.56	958.117	2.101	0.22
30.1	25.5	7.24	15.913	3.789	76.19	3.416	9.84	1126.919	4.521	0.40
31.1	23.2	7.26	15.698	3.299	78.98	2.985	9.52	729.891	4.004	0.55
32.1	24.4	7.24	19.632	5.207	73.48	4.708	9.58	877.712	2.358	0.27
33.1	23.5	7.19	15.085	3.556	76.43	3.189	10.32	1282.373	3.342	0.26

Individual Sediment Core Data - Middle Section

Sample	Depth	pH	wet weight	dry weight	%moisture	LOI wt	%organic	total phosphorus	available phosphorus	% phosphorus
1.2	28.0	6.65	16.767	6.413	61.75	5.896	8.06	480.676	7.031	1.46
2.2	28.0	6.48	17.741	6.864	61.31	6.303	8.17	799.978	2.528	0.32
3.2	27.0	6.50	16.210	6.043	62.72	5.545	8.24	855.868	1.333	0.16
4.2	26.0	6.60	19.632	7.316	62.73	6.710	8.28	861.276	3.652	0.42
5.2	27.0	6.58	17.694	6.770	61.74	6.196	8.48	985.542	3.478	0.35
6.2	28.0	6.51	15.786	5.948	62.32	5.435	8.62	766.842	2.109	0.28
7.2	29.5	6.60	17.474	6.172	64.68	5.627	8.83	871.113	2.166	0.25
8.2	28.0	6.68	18.334	6.138	66.52	5.609	8.62	769.746	1.844	0.24
9.2	27.2	6.61	15.777	5.421	65.64	4.956	8.58	846.215	3.161	0.37
10.2	26.7	6.55	18.152	6.224	65.71	5.665	8.98	802.805	8.040	1.00
11.2	25.8	6.81	16.652	6.320	62.05	5.779	8.56	881.131	2.190	0.25
12.2	25.6	6.98	18.717	5.945	68.24	5.439	8.51	929.515	4.882	0.53
13.2	26.3	6.70	17.479	5.835	66.62	5.300	9.17	860.540	2.344	0.27
14.2	26.1	6.95	16.727	5.700	65.92	5.191	8.93	910.674	2.625	0.29
15.2	26.9	7.13	20.043	6.868	65.73	6.254	8.94	1036.283	1.759	0.17
16.2	27.7	6.81	16.082	5.614	65.09	5.089	9.35	972.180	5.467	0.56
17.2	27.3	7.00	17.669	6.021	65.92	5.466	9.22	880.596	1.988	0.23
18.2	28.2	6.82	17.056	6.100	64.24	5.555	8.93	1033.745	2.078	0.20
19.2	27.8	6.97	16.668	5.511	66.94	5.038	8.58	846.215	1.591	0.19
20.2	28.2	6.95	16.372	5.693	65.23	5.193	8.78	817.244	1.666	0.20
21.2	27.6	6.77	16.282	5.715	64.90	5.216	8.73	885.083	1.678	0.19
22.2	27.5	6.90	18.498	6.120	66.92	5.574	8.92	415.016	2.020	0.49
23.2	23.3	6.99	16.804	5.624	66.53	5.100	9.32	670.900	1.330	0.20
24.2	25.6	7.07	18.110	6.189	65.83	5.659	8.56	831.991	1.589	0.19
25.2	23.8	7.09	17.857	6.870	61.53	6.314	8.09	745.536	3.331	0.45
26.2	24.8	7.07	18.314	6.255	65.85	5.719	8.57	778.072	1.806	0.23
27.2	26.3	6.85	19.660	7.338	62.68	6.715	8.49	745.271	1.506	0.20
28.2	24.9	6.96	20.807	7.077	65.99	6.452	8.83	680.905	1.331	0.20
29.2	23.7	7.09	17.775	6.841	61.51	6.255	8.57	724.482	1.160	0.16
30.2	25.5	7.09	17.343	6.208	64.20	5.683	8.46	862.916	3.434	0.40
31.2	23.2	7.24	18.270	6.660	63.55	6.084	8.65	787.889	2.804	0.36
32.2	24.4	6.96	18.198	6.611	63.67	6.047	8.53	804.789	2.263	0.28
33.2	23.5	6.79	18.305	6.371	65.20	5.793	9.07	853.854	2.532	0.30

Individual Sediment Core Data - Bottom Section

Sample	Depth	pH	wet weight	dry weight	%moisture	LOI wt	%organic	total phosphorus	available phosphorus	% phosphorus
1.3	28.0	6.47	17.047	6.403	62.44	5.888	8.04	893.101	2.966	0.33
2.3	28.0	6.69	18.265	6.643	63.63	5.973	10.09	779.844	3.253	0.42
3.3	27.0	6.44	17.309	6.551	62.15	5.969	8.88	739.604	2.620	0.35
4.3	26.0	6.49	19.105	7.397	61.28	6.730	9.02	847.923	3.826	0.45
5.3	27.0	6.41	15.595	5.606	64.05	5.078	9.42	738.282	3.885	0.53
6.3	28.0	6.40	15.838	5.542	65.01	5.005	9.69	671.682	5.024	0.75
7.3	29.5	6.61	14.308	4.402	69.23	3.928	10.77	687.941	2.983	0.43
8.3	28.0	6.21	17.272	5.797	66.44	5.210	10.13	723.609	2.448	0.34
9.3	27.2	6.55	16.988	6.034	64.48	5.429	10.03	729.954	3.746	0.51
10.3	26.7	6.68	15.042	5.254	65.07	4.727	10.03	731.709	3.313	0.45
11.3	25.8	6.34	18.137	6.787	62.58	6.150	9.39	888.552	2.022	0.23
12.3	25.6	6.63	17.010	5.951	65.01	5.389	9.44	862.250	3.699	0.43
13.3	26.3	6.61	16.503	4.990	69.76	4.434	11.14	631.448	2.870	0.45
14.3	26.1	6.47	17.349	5.237	69.81	4.641	11.38	705.522	2.450	0.35
15.3	26.9	6.67	18.540	5.676	69.39	5.032	11.35	754.223	2.443	0.32
16.3	27.7	6.61	15.974	5.128	67.90	4.554	11.19	687.432	5.321	0.77
17.3	27.3	6.65	14.456	4.620	68.04	4.111	11.02	776.260	5.323	0.69
18.3	28.2	6.36	14.859	5.026	66.18	4.514	10.19	748.466	3.573	0.48
19.3	27.8	6.44	16.056	5.525	65.59	5.013	9.27	779.591	2.839	0.36
20.3	28.2	6.74	16.074	5.293	67.07	4.763	10.01	794.670	3.390	0.43
21.3	27.6	6.42	15.496	4.654	69.97	4.135	11.15	707.127	3.611	0.51
22.3	27.5	6.55	16.997	4.915	71.08	4.340	11.70	576.565	2.712	0.47
23.3	23.3	6.79	16.773	6.510	61.19	5.946	8.66	889.870	2.186	0.25
24.3	25.6	6.92	17.040	6.475	62.00	5.893	8.99	877.196	2.704	0.31
25.3	23.8	6.98	18.083	7.537	58.32	6.923	8.15	822.230	3.741	0.45
26.3	24.8	6.79	18.633	7.415	60.21	6.767	8.74	877.712	2.104	0.24
27.3	26.3	6.68	15.557	5.852	62.38	5.309	9.28	898.959	2.881	0.32
28.3	24.9	6.68	17.182	6.790	60.48	6.149	9.44	587.322	4.523	0.77
29.3	23.7	6.90	15.768	6.071	61.50	5.530	8.91	811.243	2.624	0.32
30.3	25.5	6.93	19.327	9.113	52.85	8.580	5.85	465.282	4.953	1.06
31.3	23.2	7.15	18.241	7.719	57.68	7.034	8.87	1186.783	2.446	0.21
32.3	24.4	6.76	16.938	6.173	63.56	5.574	9.70	813.249	2.794	0.34
33.3	23.5	6.85	16.455	6.098	62.94	5.495	9.89	844.114	3.478	0.41