Honeoye Lake Sediment Internal Phosphorus Release and Algae Blooms
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Introduction

Honeoye Lake has experienced algae blooms for over 60 years. The severity of these blooms varies from year to year, although they seem to have become more severe over the past few years. This phenomenon is not exclusive to Honeoye Lake. Most of the other shallow lakes in our region have experienced a similar problem (Figure 1).

Figure 1

Lake	Max Depth
Chautauqua South Basin	19
Waneta	29
Honeoye	30
Silver	37

The reason for the prevalence of algae blooms in shallow lakes is well understood in the scientific community. It occurs because shallow lakes have an additional major source of phosphorus referred to as internal anoxic sediment phosphorus, which is not a major factor in deeper lakes. When the lake bottom in a shallow lake goes anoxic the bottom sediment releases phosphorus. If this stayed at the bottom it would not be a problem, but during the summer months shallow lakes develop weak thermocline, which are broken by wind or significant rainfall, causing bottom waters to mix with near surface waters. This mixing makes phosphorus originally stored in the sediment to become available for algae growth in the warmer waters near the surface. By contrast, deep lakes develop a strong thermocline during the summer months which is not broken until fall, as the surface waters cool and promotes mixing. As a result for deep lakes this phosphorus source from the sediment is not available to promote summer algae blooms. In addition most deep lakes do not become anoxic at the bottom sediment.

External sources of phosphorus such as runoff are highly dependent on characteristics of the watershed and weather which are similar for both deep and shallow lakes. Efforts to reduce external sources such as sewage and runoff have been successful in many lakes including Honeoye. Remediation of these external sources, although they can be expensive, generally last a long time. For Honeoye these projects included perimeter sewers, Lake Inlet Remediation Project, and numerous other smaller projects to reduce external sources related to steep slopes and highways and their ditches. Reducing external loading is always an important goal since phosphorus from any source promotes algae growth. In addition, external phosphorus eventually becomes legacy phosphorus as it sinks to the bottom sediment

For Honeoye Lake and most other shallow lakes internal anoxic sediment loading during summer months is the major driver of its algae blooms. It is important to understand that phosphorus from internal anoxic sediment loading is made available to near surface water at the same time when other conditions suitable for algae growth, such as temperature, sunlight, and calm waters exist.

Summary

Figure 7 & 8 summarizes the average over the past ten years of phosphorus loading by month from internal and external sources which indicate that internal anoxic sediment phosphorus is the major contributor to the lakes phosphorus during the summer months when algae blooms occur. It shows that on average in August 71% of the total phosphorus load is from internal anoxic sediment.

Hence, only by significantly reducing internal phosphorus release from the sediment, can one hope to reduce algae blooms, regardless of how much external phosphorus might be reduced. The real problem is one of timing since sediment anoxic phosphorus is greater than anything else during the summer months while external sources are greatest during spring and fall when conditions are not suitable for algae growth.

Alum and sediment oxygenation are the two most commonly used techniques to reduce internal sediment anoxic release of phosphorus (Princeton Hydro 2003).

Models of Phosphors Input

Princeton Hydro developed a model in 2007 (Princeton Hydro 2007), prior to the alum application, to estimate both internal and external phosphorus loading. In 2014 an improved model (Princeton Hydro 2014) for external loading was created prior to the Honeoye Inlet Restoration Project. The external loading model in both 2007 and 2014 are complex models that account for precipitation, land cover, groundwater etc. The 2007 Model also estimated internal anoxic sediment loading with a simple formula (sediment anoxic phosphorus=6.0 mg phosphorus/m^2/day). However to apply this simple formula requires an estimate of the duration and extent of anoxia. In 2007 only a couple of years of measured dissolved oxygen (DO) data during the summer months were available and assumptions had to be made regarding the magnitude and extent of anoxia. This report includes a new "2017 JS Model" that uses the external loading from the 2014 Model, and the internal loading formula from the 2007 Model but uses measured data on the duration and extent of anoxia from the last 10 years of DO measurements. As such this new model just uses enhanced data as input to the older models to determine the magnitude of internal anoxic sediment phosphorus loading.

Results of Models

The improved PH 2014 Model showed significantly lower external loading than the PH 2007 Model as indicated in Figure 2. This is attributed to including soil infiltration and other improvements in the PH 2014 Model. Likewise the internal sediment anoxic phosphorus loading in the JS 2017 Model is significantly lower than the 2007 Model due to using more realistic data on the duration and extent of anoxia. The most important result of this data is the high levels phosphorus due to internal anoxic sediment during the summer months. This will also be evident in some of the later figures.

Figure 2 Model Results

Model Results	PH 2007	PH 2014	DO<2 JS 2017	DO<1 JS 2017
External phosphorus runoff	2547	1005	1005	1005
Other external	695		695	695
Total external phosphorus (kg)	3242		1700	1700
Internal anoxic sediment phosphorus (kg}	1652		771	594
Other Internal	520		520	520
Total Internal phosphorus (kg)	2172		1291	1114
Total phosphorus Load (kg}	5414		2991	2814
% Internal anoxic sediment phosphorus on annual basis	30.5		25.8	21.1
% Internal anoxic sediment phosphorus load July-Sep			**51.5**	**47.1**
% Internal anoxic sediment phosphorus load in Aug			**71.0**	**63.0**

The annual total internal anoxic phosphorus load is shown in Figure 3 for the past 10 years. This was calculated assuming anoxia at two levels DO<2 and DO<1. These two curves are quite similar, and obviously the load using anoxia defined by DO<2 is greater than for DO<1. The data shows there has also been a trend over the past ten years toward greater anoxia and hence greater internal anoxic sediment phosphorus load.

Figure 3 Total Internal Sediment Anoxic Phosphorus by Year

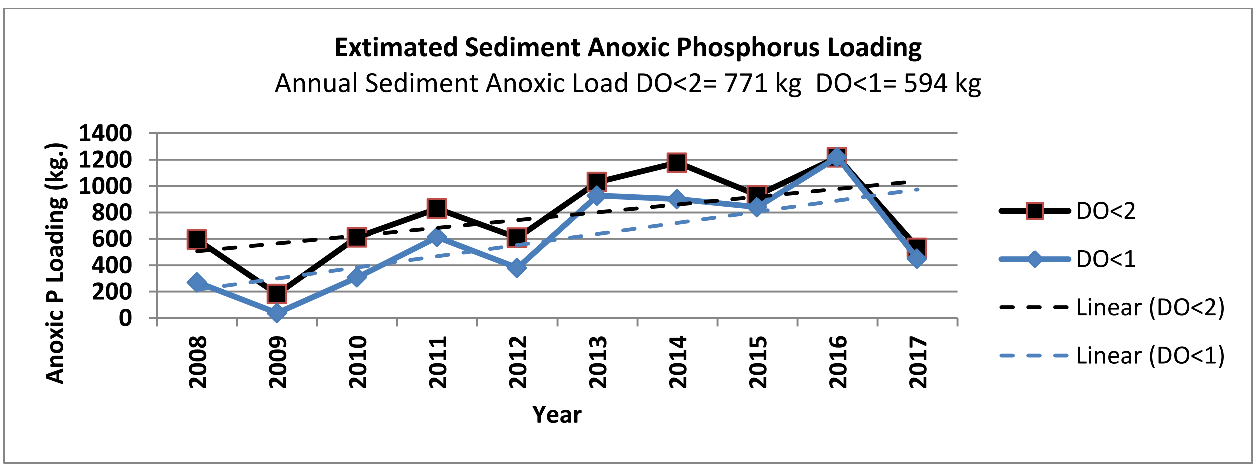


Figure 4 summarizes the different sources of external phosphorus which are dominated by runoff in the spring and fall as a result of higher precipitation. Figure 5 summarizes sources of internal phosphorus which are dominated by phosphorus release from anoxic sediments during the summer, with negligible amounts during the rest of the year.

Figure 4 Sources of External Phosphorus

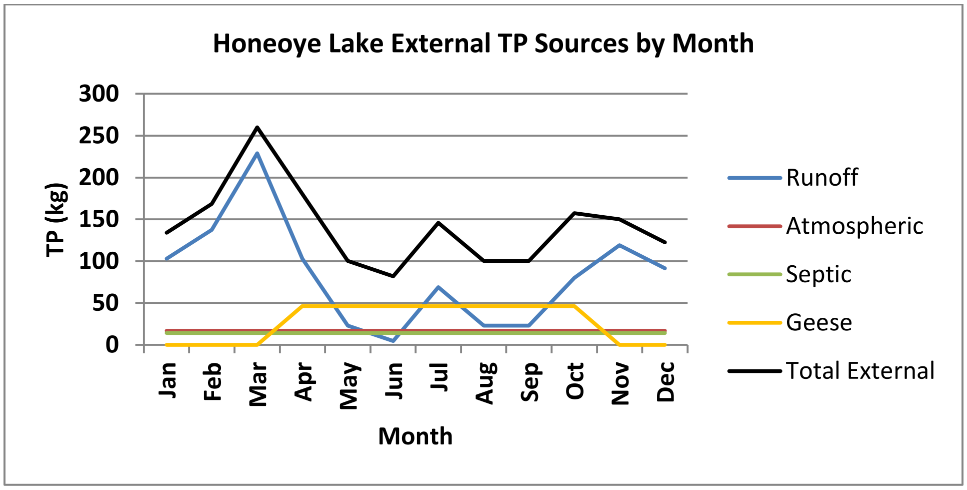


Figure 5 Sources of Internal Phosphorus DO<2

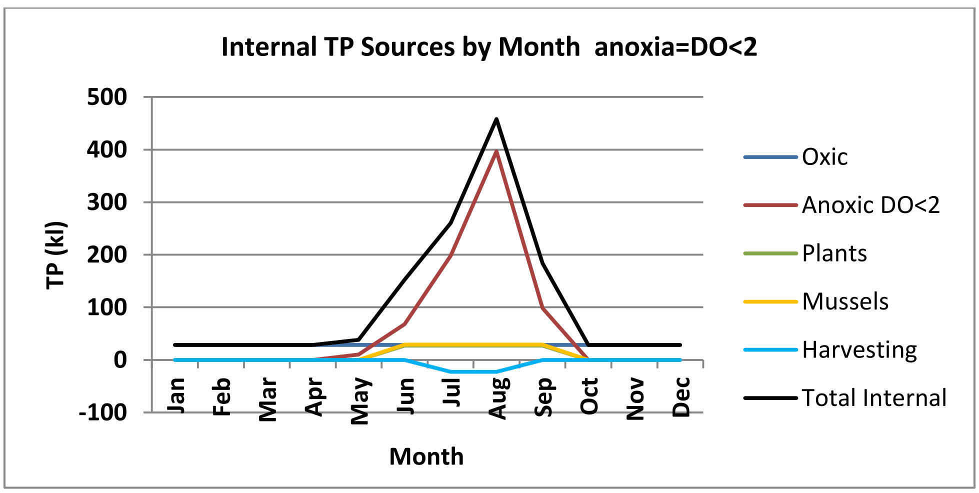
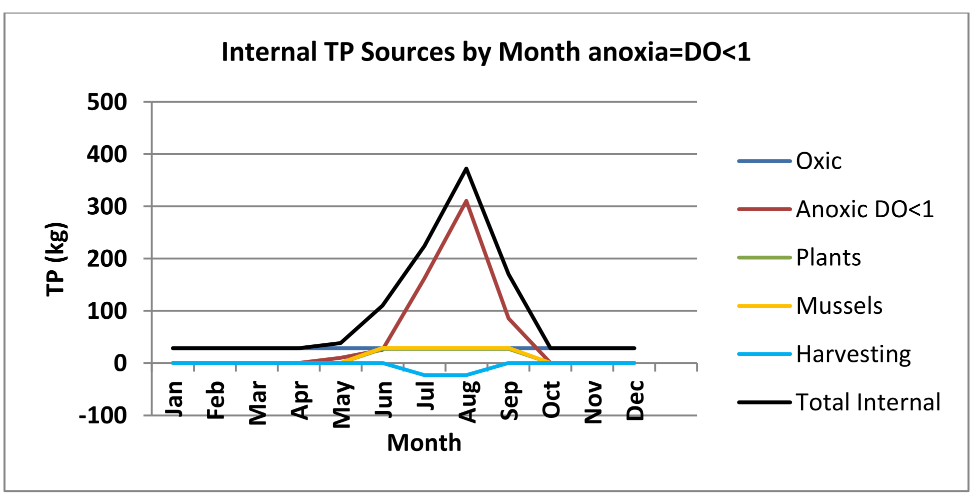


Figure 6 Sources of Internal Phosphorus DO<1



Figures 7 & 8 summarize all of the sources of phosphorus which clearly shows that internal sediment anoxic phosphorus is the major contributor during the summer months when temperatures and sunlight are adequate for algae growth. In August 71% of the total phosphorus input to the lake comes from anoxic sediment release.

These results are clear evidence that the only way to minimize algae blooms is to significantly reduce the internal anoxic phosphorus loading during the summer months. **While reducing external phosphorus loading is a noble goal, nothing that is done to reduce external loading has a chance to reduce algae blooms since during the summer the external phosphorus loading is minimal while the internal load is extremely high. Attacking internal anoxic phosphorus seems to be the only way to significantly reduce algae blooms.**

Figure 7 Phosphorus Loading by Month DO<2

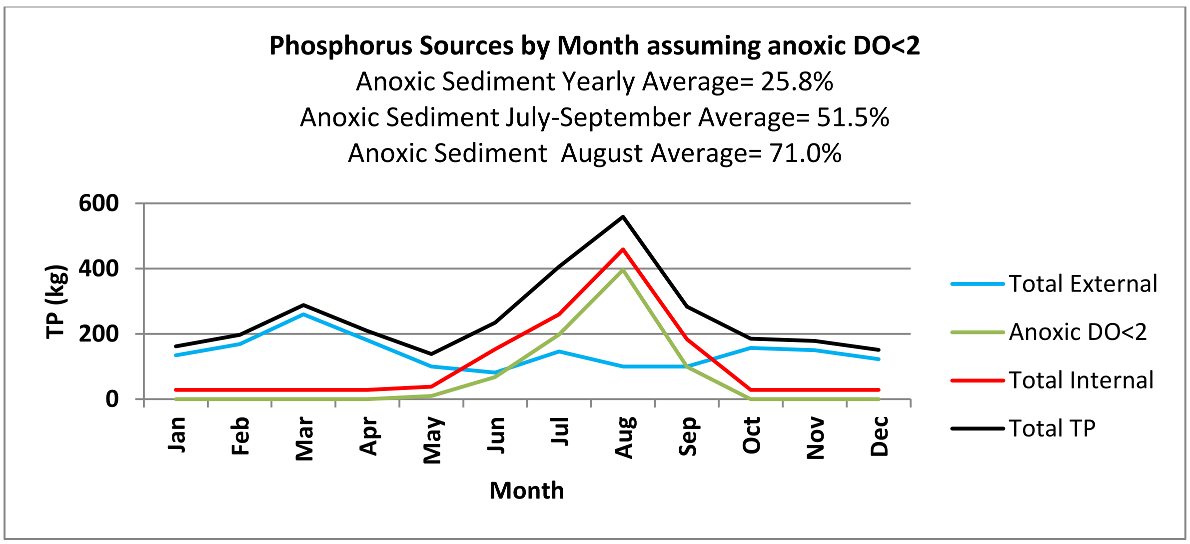
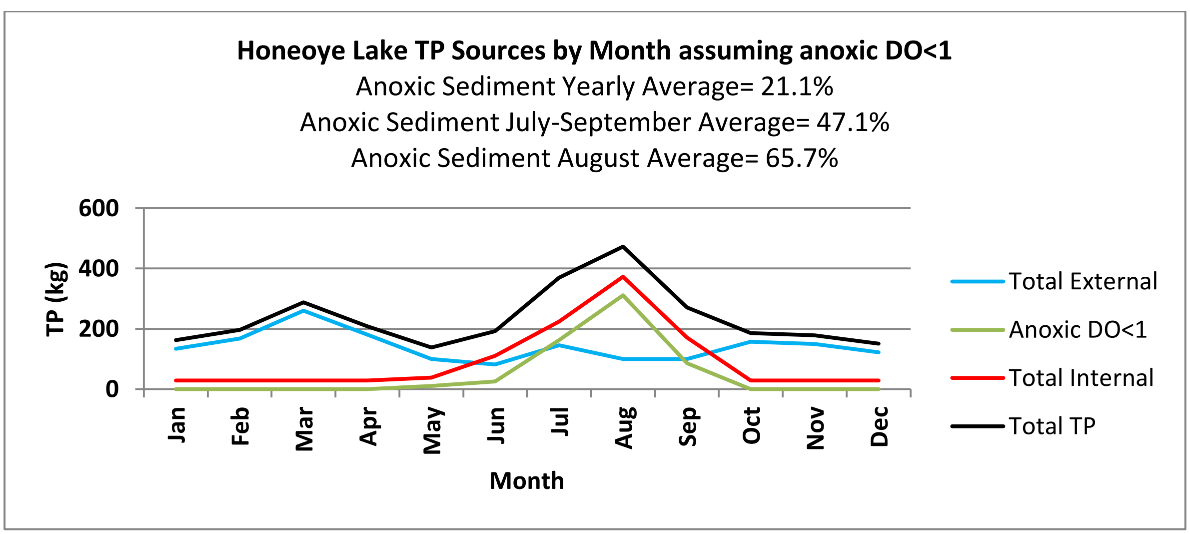


Figure 8 Phosphorus Loading by Month DO<1



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