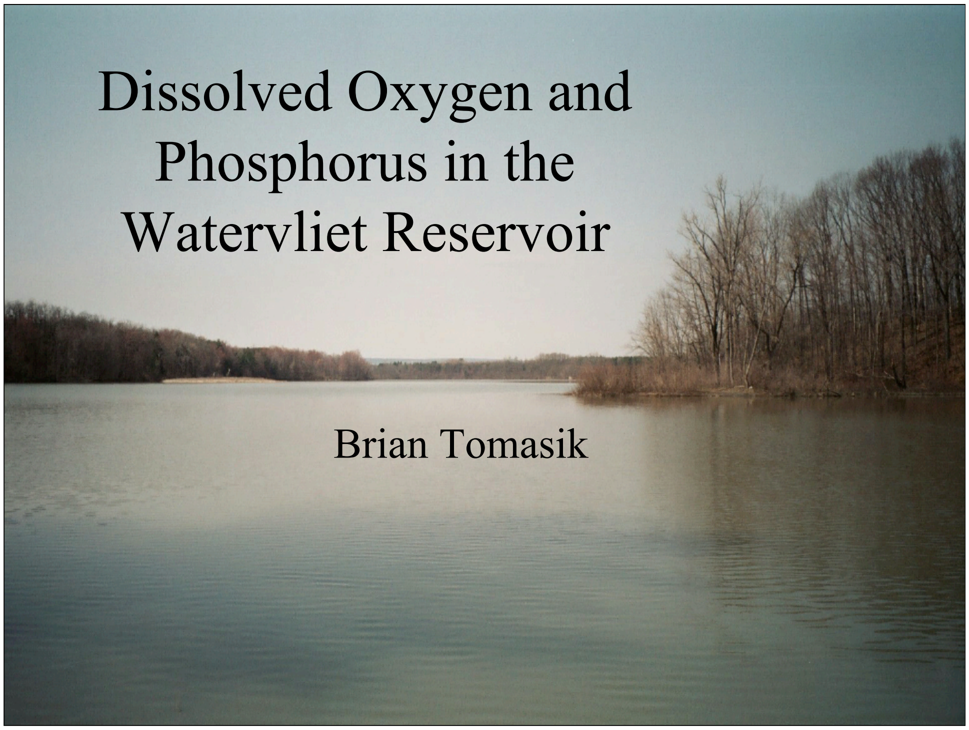


(This document gives the text and notes of a presentation I gave to the Albany County Water Quality Coordinating Committee in Fall 2004.)

Thank you. I thought I would begin by explaining how I got involved in research on the Watervliet Reservoir and then go into my findings.

When I was in tenth grade, I had Tom Mikulka as my chemistry teacher. Dr. Mikulka required all of the students in my class to carry out a yearlong independent chemistry research project on any one of twenty possible topics; because it was an important concern that no one had ever before chosen to study, I decided to measure phosphorus levels in the Watervliet Reservoir. To get access to the reservoir for sampling, I contacted Steve Wilson for permission to use his rowboat. I also arranged to test my samples at the Keck Water Research Lab at RPI. I finished sampling and testing in April 2003, and presented my results in June.

Since I had spent so much time learning about phosphorus, I decided that I might as well continue my research over the summer. So, I took another set of samples in August 2003 and tested them at RPI as before. Unfortunately, my summer data showed a strange pattern that rendered them inconclusive.

For that reason, I repeated my experiment with some modifications over summer 2004, and it was this study that provided the most useful results.

Background

Before I get into those results, though, I'll present a little background information which most of you probably already know.

Phosphorus

- Often the limiting nutrient
- Mean summer total-phosphorus concentration above 20 ppb generally means eutrophy

Phosphorus is a macronutrient that plants need to live and grow. Because of its relative scarcity, phosphorus is the limiting nutrient in most fresh water bodies, which means that phosphorus availability is typically the sole factor restricting further plant growth.

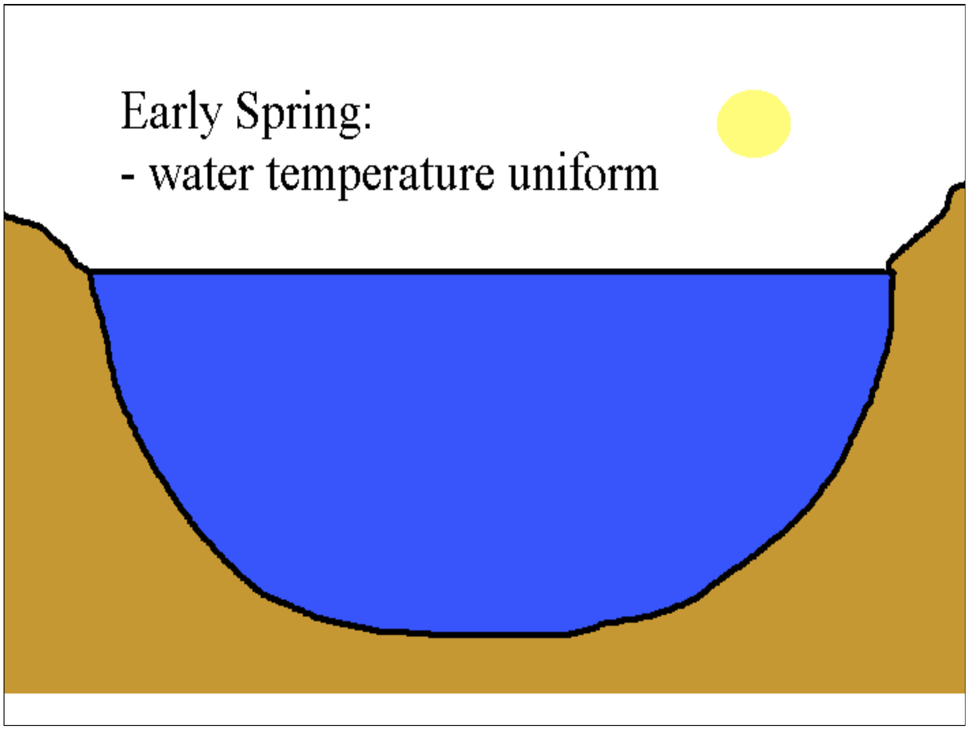
Many researchers have tried to identify a mean summer total-phosphorus concentration that can be generally called the dividing line between when a lake is mesotrophic and when it is eutrophic, but the one most often cited is 20 ppb. This is also the guidance value set by the NYS DEC for lakes and reservoirs in New York.

Thermal Stratification

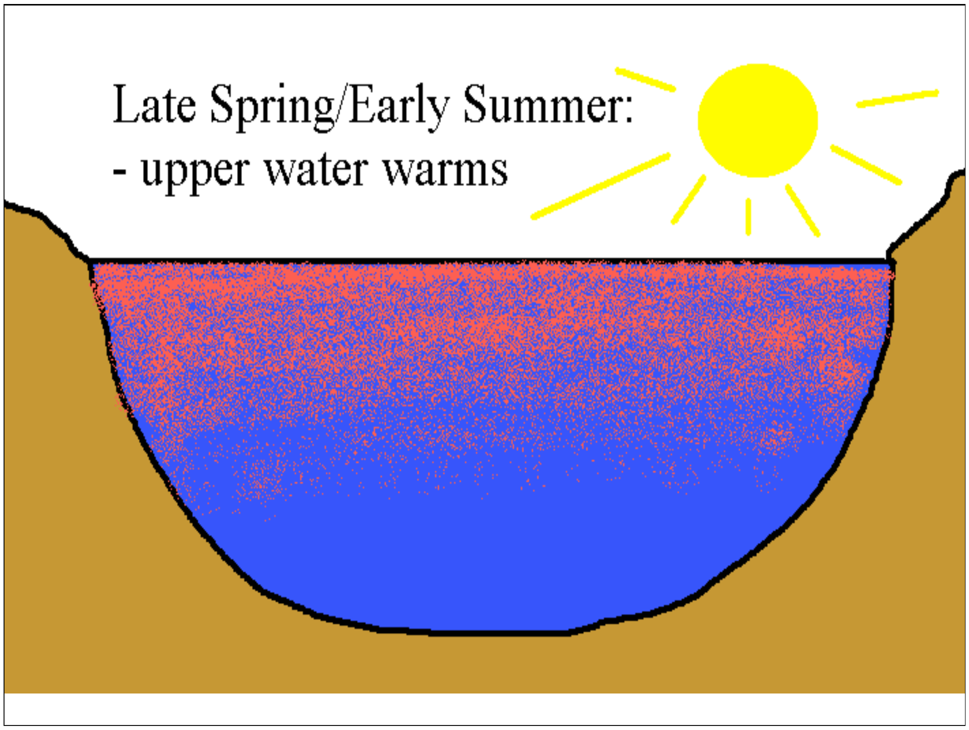
- Natural process that happens during the summer
- Generally found in temperate water bodies that are at least 5 m to 7 m deep

One process that sometimes affects the amount of phosphorus in a reservoir is thermal stratification.

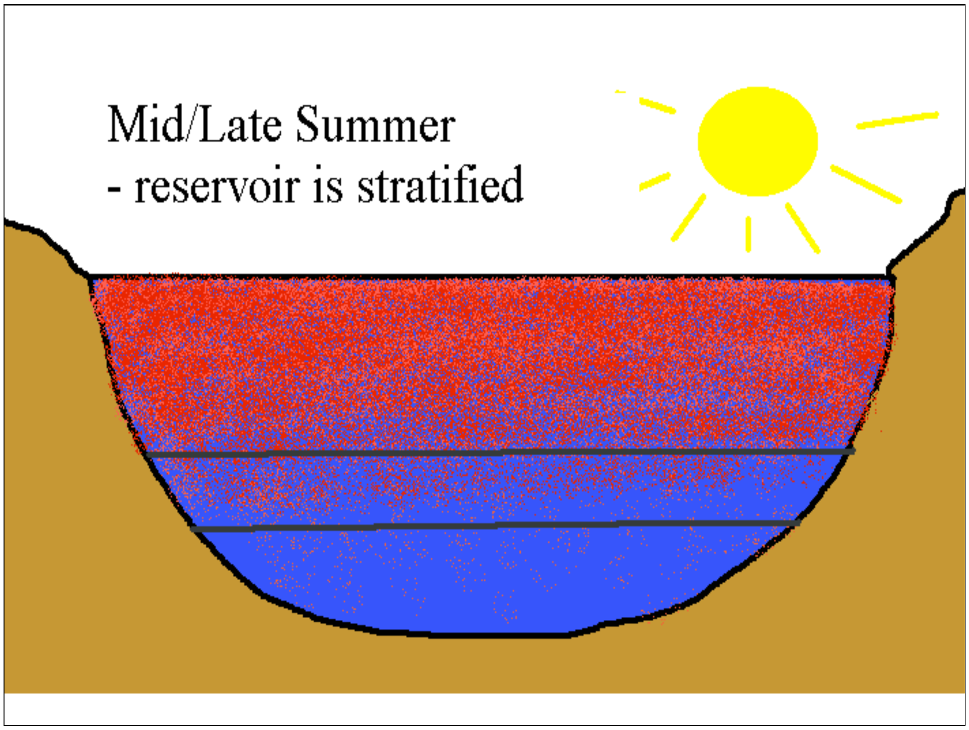
Thermal stratification is a natural condition that develops during the late spring and early summer in temperate water bodies that are at least 5 m to 7 m in depth.



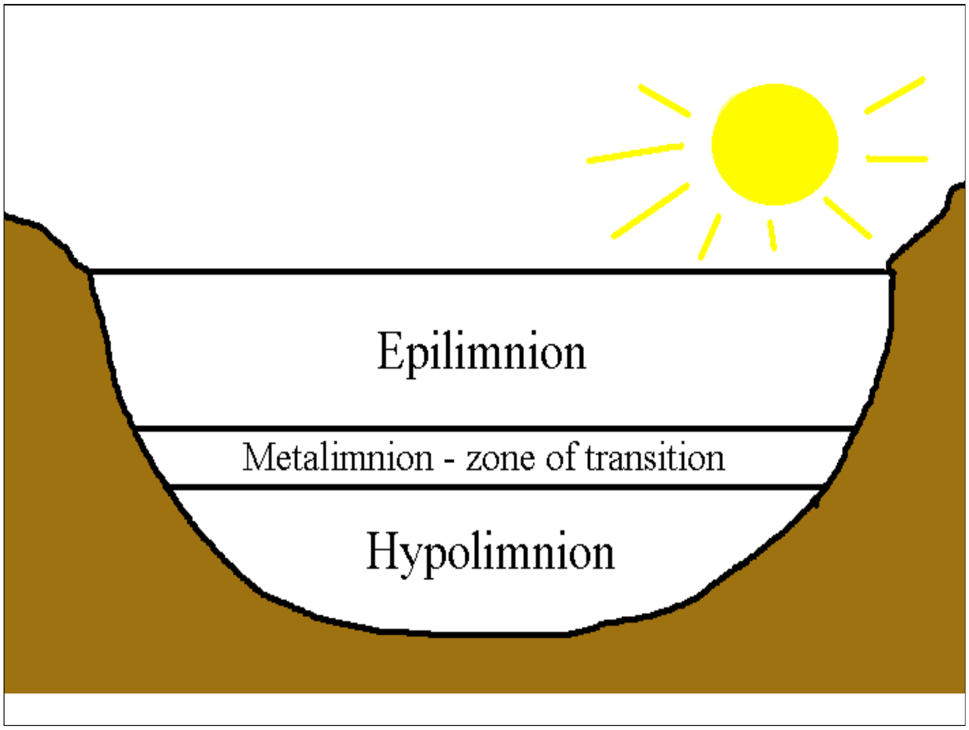
This picture shows a reservoir prior to stratification. The surface ice has just melted and the water temperature is uniform. Therefore, the entire reservoir is able to mix.



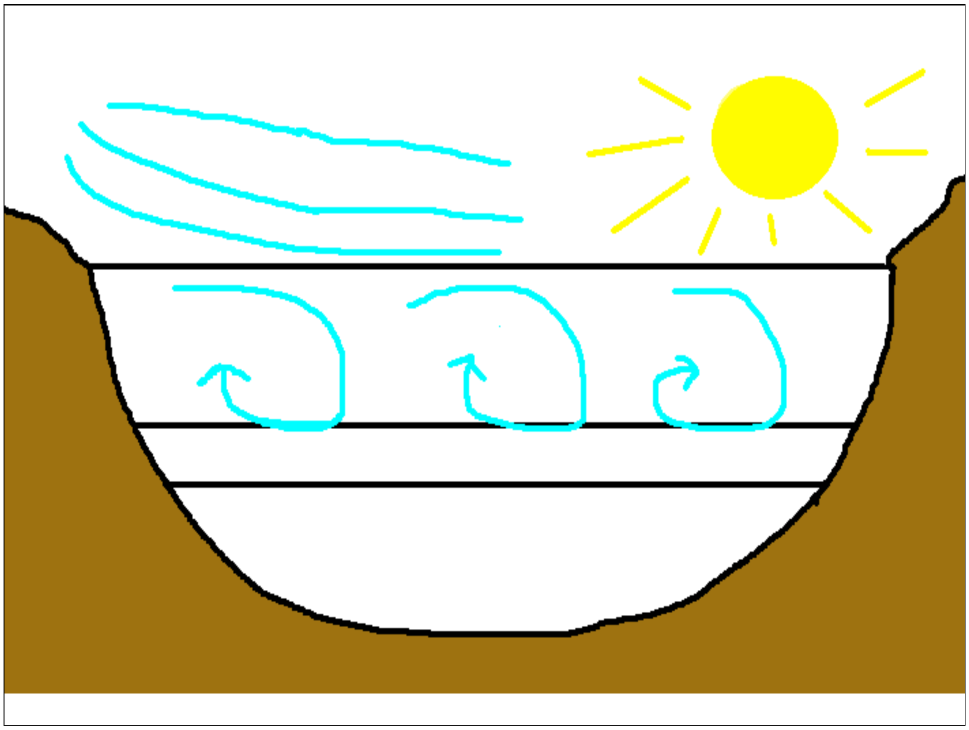
Now the reservoir is beginning to stratify, because incoming heat is quickly raising the temperature of water at the surface but not at the bottom.



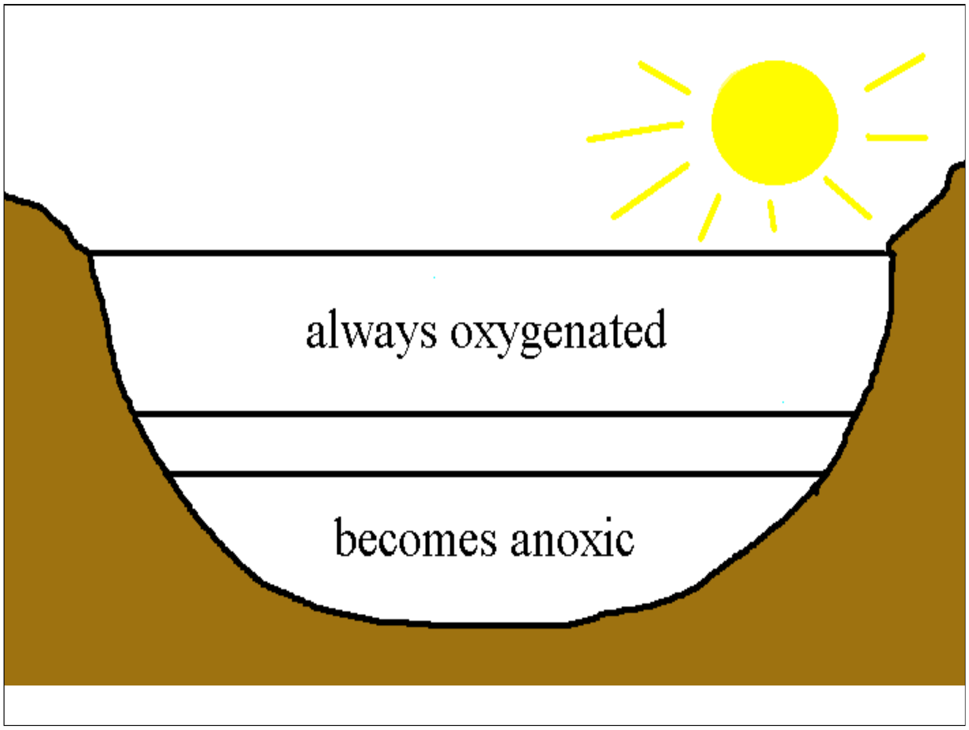
By mid- to late summer, the reservoir is fully stratified into three distinct zones.



The upper layer is the warm epilimnion. The bottom layer is the cool hypolimnion. The short layer in between is the metalimnion, a zone of rapid temperature transition.

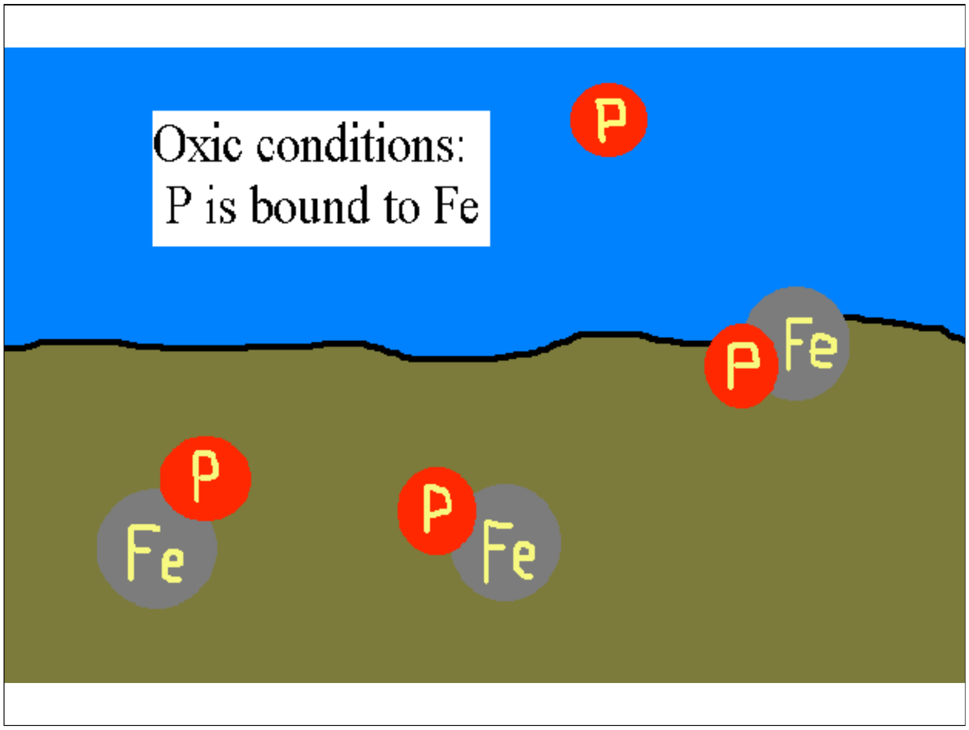


The mixing of water layers of different densities requires energy, and a greater difference in density requires more energy. Since the epilimnion is directly exposed to the wind, it is thoroughly mixed and well oxygenated. However, when this mixing energy reaches the metalimnion, it is effectively stopped by that layer's sharp density gradients. As you can see, the hypolimnion has no exposure to the air; hence, it is not reoxygenated.

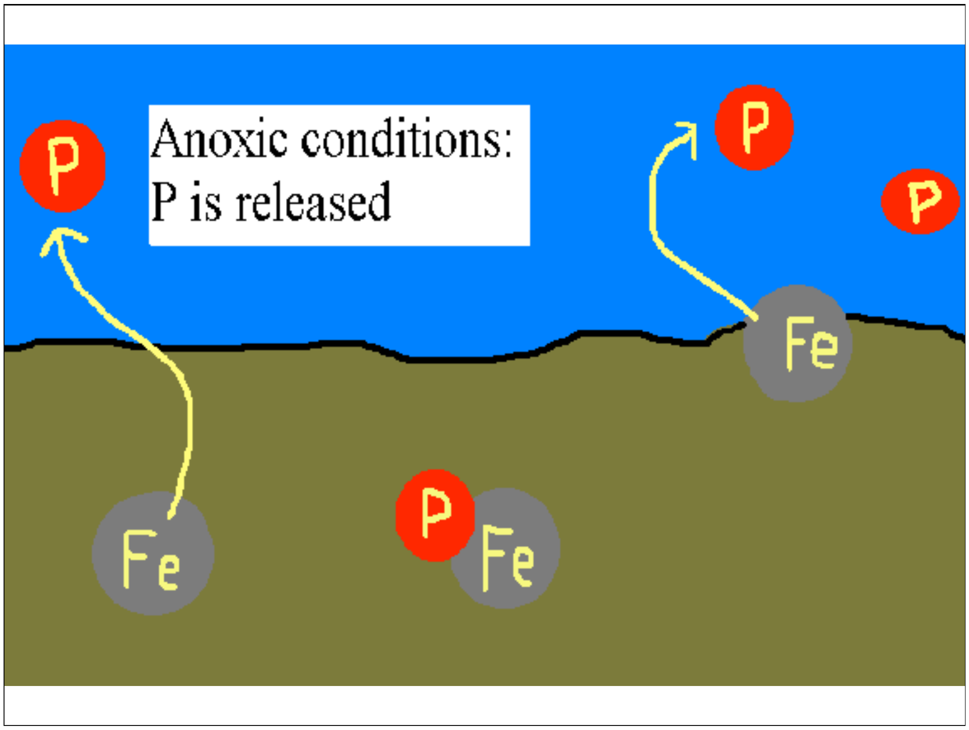


A eutrophic reservoir tends to have lots of dead organic matter collected at its bottom, and the decomposition of this detritus requires oxygen. Because the hypolimnion is unable to replenish its oxygen supply by contact with the surface, it soon becomes anoxic—meaning that dissolved-oxygen levels approach 0 ppm.

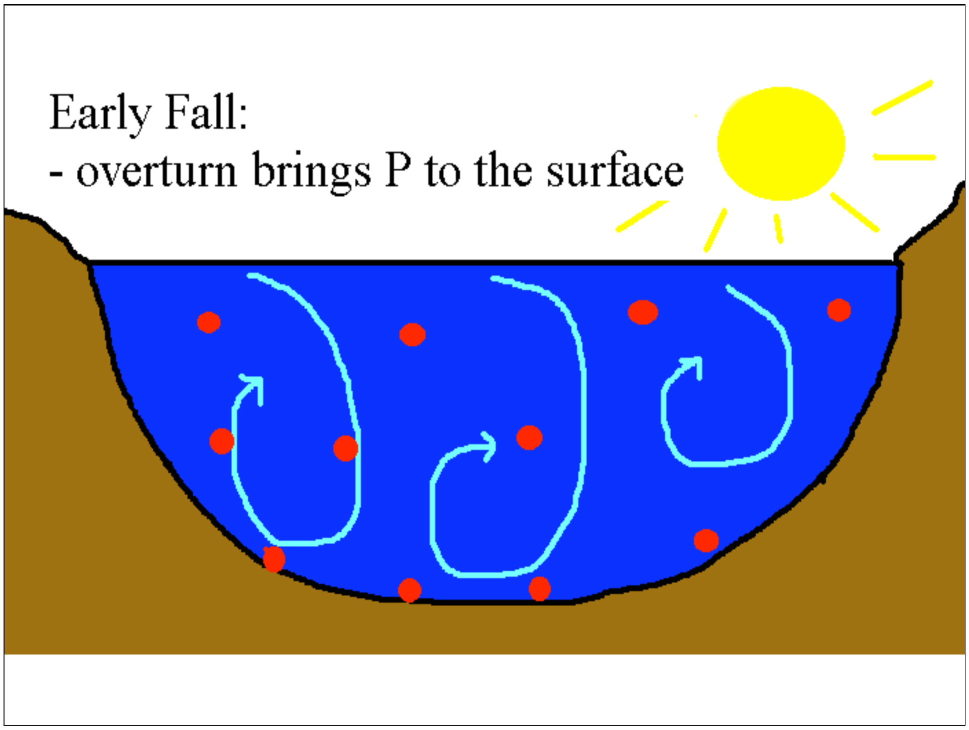
One of the many consequences of such anoxia is that it often triggers the release of nutrients from the sediment.



This picture shows the sediment-water interface when the reservoir is fully oxygenated. Most of the phosphorus in the reservoir is bound to the sediment, particularly to iron.



However, when concentrations of dissolved oxygen in the hypolimnion drop below 1 ppm, some of the iron is usually reduced and phosphorus is consequently released into the surrounding water.



In the early fall, the reservoir's water temperature becomes uniform once more. As the bottom water once again mixes with the surface water, some of the released phosphorus travels to the surface, where it may exacerbate late-season algal blooms.

My Results

Now I'll get into my own findings.

Trophic Status of Watervliet Reservoir

- Mean surface-water total-phosphorus concentrations:
  - Spring 2003: 20. ppb
  - Summer 2003: 19 ppb
- This places the Reservoir directly between mesotrophy and eutrophy

The data here are from my first and second measurements on the Reservoir, in the spring and summer of 2003. The mean total-phosphorus concentration of the surface water was 20. ppb in spring 2003 and 19 ppb in summer 2003. According to the 20-ppb delineation that I mentioned earlier, the Reservoir is right between mesotrophy and eutrophy.

Summer-2004 Study

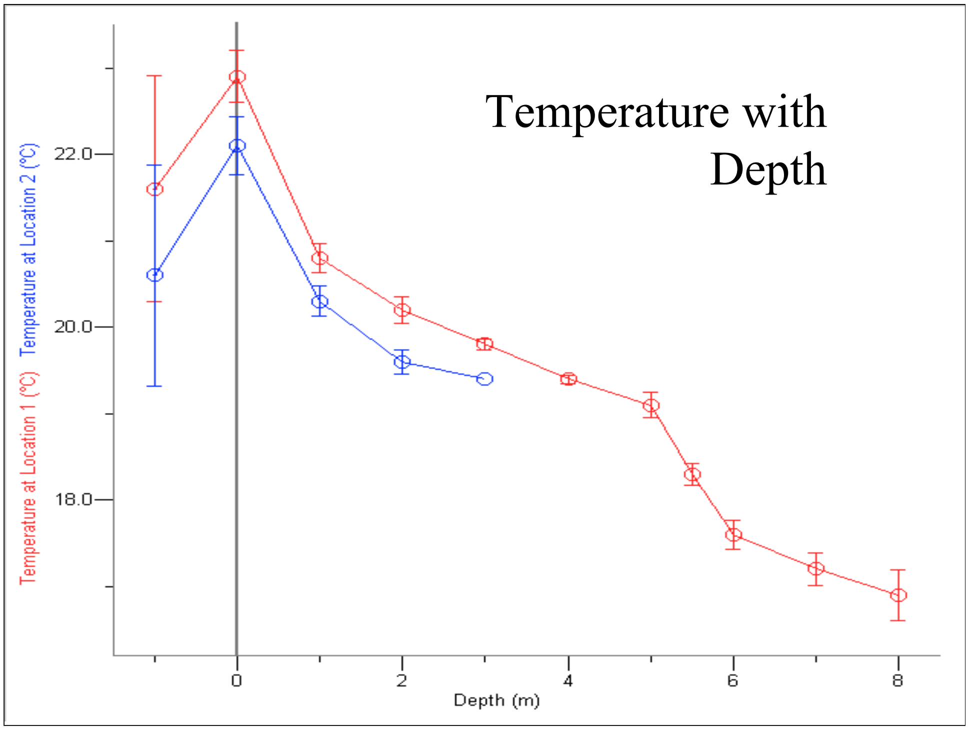
- Hypotheses:
  - The reservoir will be stratified
  - The hypolimnion will be anoxic
  - Phosphorus will have been released
- Experimental Design:
  - Measure temperature, dissolved oxygen, and total dissolved phosphorus throughout the water column at a deep site and a shallow control site
  - Deep site, Location 1 = 8.8 m
  - Shallow site, Location 2 = 3.8 m

Now I'll talk about the study that I did this summer.

I'll start with my hypotheses. Based on the fact that the Reservoir has a maximum depth of 9 m and the fact that stratification generally begins at 5 m to 7 m, I hypothesized that the Reservoir would be stratified at its deepest parts. I also expected that this thermal stratification would have caused hypolimnetic anoxia and that this anoxia would have mobilized phosphorus from the sediment.

To test these hypotheses, I took measurements of temperature, dissolved oxygen, and total dissolved phosphorus throughout the water column at a deeper site and a shallower site. I called the deeper site, which was 8.8 m in depth, Location 1 and the shallower site, which was 3.8 m in depth, Location 2. Location 2 was a control site that I expected was too shallow to stratify; its purpose was to prove that the observed trends in dissolved oxygen and phosphorus at Location 1 were caused by stratification and not proximity to bottom sediment or some other factor.

Here you can see the two sampling locations.

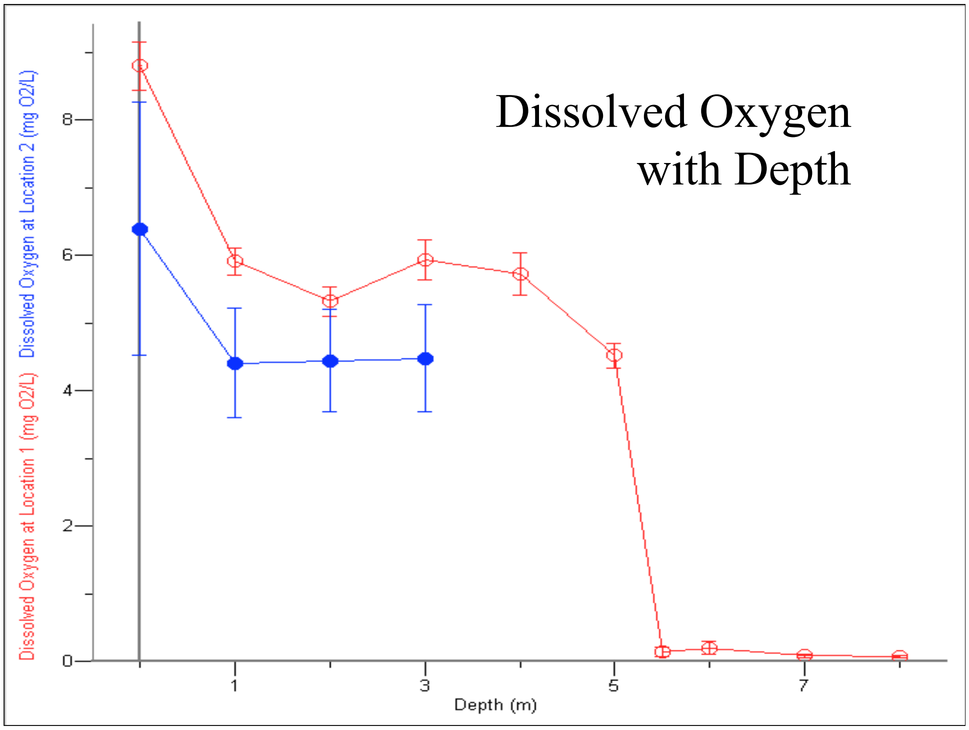


This graph shows my results for temperature with depth. The red lines are Location 1, and the blue lines are Location 2. The vertical bars are + and – one standard deviation from the mean.

Location 1 did appear to be stratified in agreement with the expected pattern. The epilimnion ranged from 0 m to 5 m, the metalimnion, from 5 m to 6 m, and the hypolimnion, from 6 m to the bottom.

Location 2 was, as expected, too shallow to stratify.

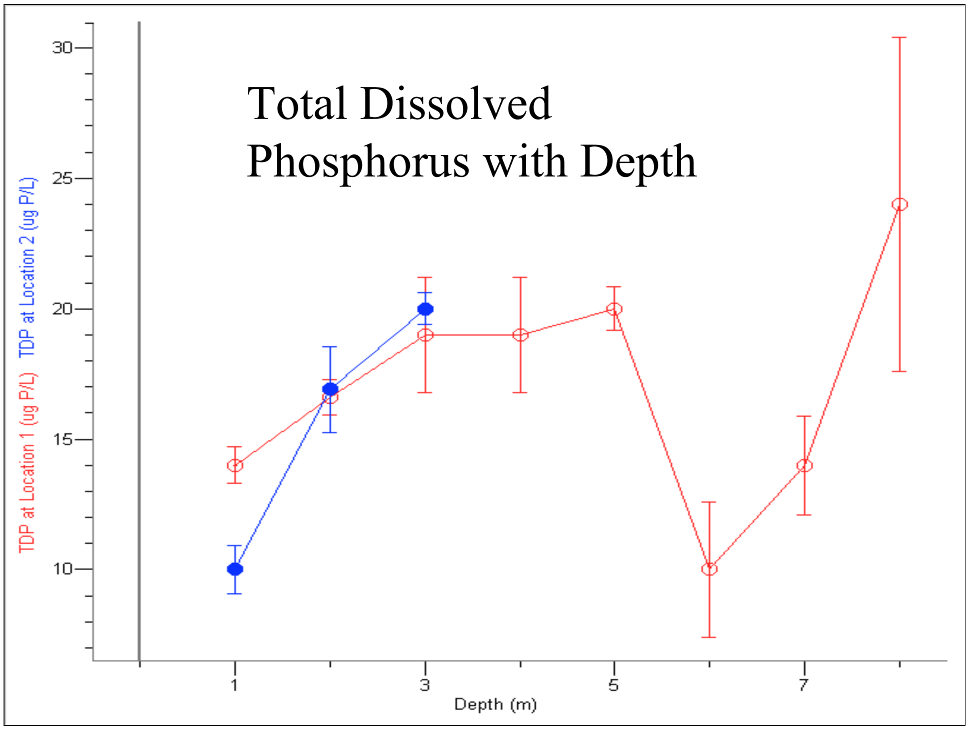
When I asked Scott Kishbaugh from the NYSDEC Division of Water to look at my results, he said that stratification of the Watervliet Reservoir is fairly weak in comparison to that of many other local lakes, which have much steeper thermal gradients.



Now, here is dissolved oxygen with depth.

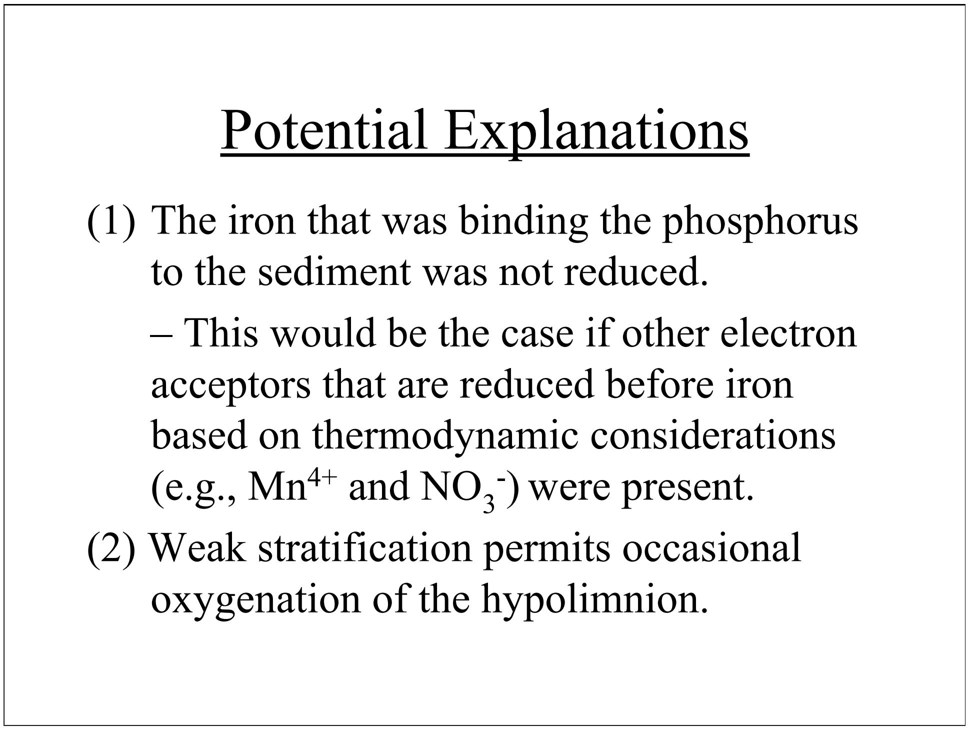
At Location 1, dissolved oxygen remained consistently above 4 ppm in the epilimnion. But beginning at the metalimnion and continuing throughout the hypolimnion, dissolved-oxygen levels fell close to zero. Location 2, which was not stratified, did not experience anoxia at its bottom.

Because dissolved-oxygen concentrations at the bottom of Location 1 well below the 1-ppm dissolved-oxygen threshold at which sediment-bound phosphorus typically begins to dissolve in earnest, I expected to see significant phosphorus mobilization.



Here are the actual results for total dissolved phosphorus with depth.

At Location 1, there was a statistically significant increase in total dissolved phosphorus from 1 m and 2 m to 8 m, but total dissolved phosphorus concentrations at 3 m, 4 m, and 5 m were statistically equivalent to those at 8 m. Scott Kishbaugh—the person at DEC whom I mentioned earlier—told me that lakes and reservoirs in which internal phosphorus release takes place typically have bottom-water phosphorus levels that are at least 5 to 10 times those at the surface. That is clearly not the case here, and therefore, it does not appear that sediment-bound phosphorus was released to any significant extent.



Here are some possible explanations for that.

(1) Phosphorus mobilization occurs when iron in the sediment is reduced as a result of anoxia. But sometimes there are other electron acceptors present in the water that are reduced before iron because they are more favored thermodynamically. These include manganese 4+ and nitrate. If these electron acceptors were present in the water, iron reduction—and the attendant liberation of phosphorus—should not have occurred. Unfortunately, I did not measure levels of either of these ions, so I can't say whether or not this explanation applies.

(2) Scott Kishbaugh proposed a second explanation: the weakness of thermal stratification in the Watervliet Reservoir might allow some mixing and, hence, some occasional oxygenation of the hypolimnion.

Warner's Lake, late August 2001

- Depth to bottom: 16 m
- Water Temperature
  - Surface: 25°C
  - Bottom: 6°C
- Bottom NO_3^- was depleted; Mn^{4+} was not measured
- Total Phosphorus
  - Surface: 8 ppb
  - Bottom: 80 ppb

As an illustration of what phosphorus release typically looks like, Scott Kishbaugh provided me with data collected on Warner's Lake in late August 2001.

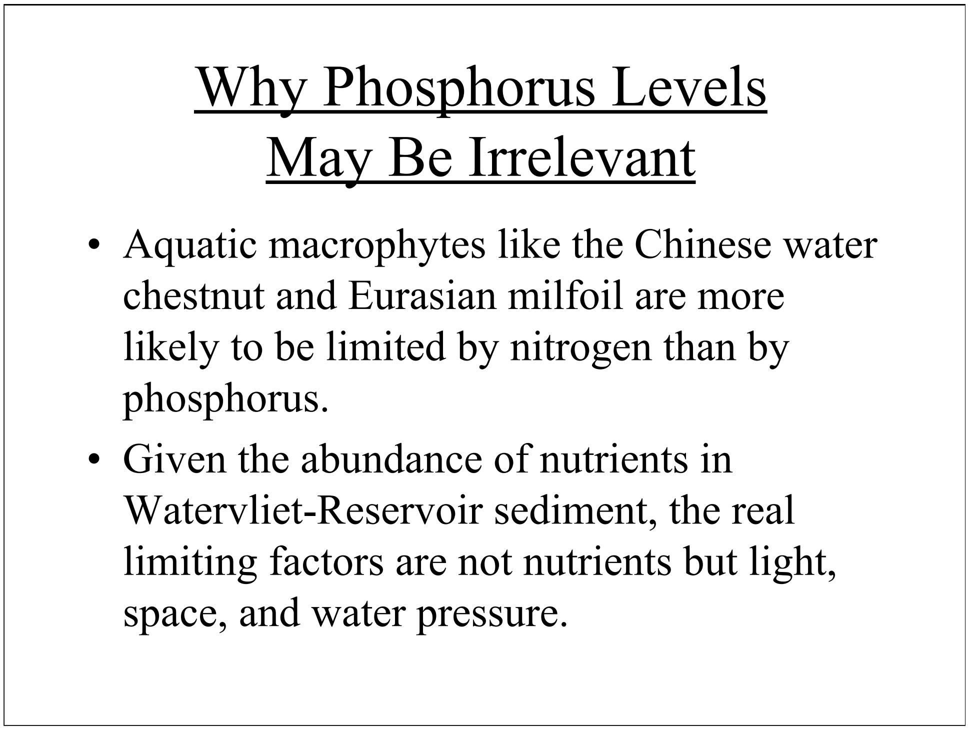
Notice how this lake was significantly stratified and how nitrate was depleted at its bottom. Both of these conditions are consistent with the substantial phosphorus release that occurred.

Future Study

- In order to definitively conclude that phosphorus is consistently not released, my study would have to be repeated over a series of years.
- Any subsequent studies should measure NO_x and Mn^{4+} in the hypolimnion.

My study does not rule out the possibility that phosphorus release could happen in future years. For example, stratification may have been unusually weak this year, or electron acceptors may have been in higher concentration than normal. In order to definitively conclude that phosphorus is consistently not released, my study would have to be repeated over a series of years.

Any subsequent studies should measure NO_x and Mn^{4+} in the hypolimnion, to determine whether or not the electron-acceptor explanation applies to the Watervliet Reservoir.



I'll end with perhaps the most important information of all. When I was discussing my results with Scott Kishbaugh, he told me that the Chinese water chestnut and Eurasian milfoil—which are the invasive macrophytes that blanket parts of the Watervliet Reservoir during the summer—tend to be limited more by nitrogen than by phosphorus. Furthermore, he said, because the sediments of the Watervliet Reservoir are probably rich in nutrients, these plants are likely not even limited by nitrogen. Instead, light, space, water pressure, et cetera are probably what really limit Chinese water chestnut and Eurasian milfoil growth.

Scott stated that "A substantial reduction in phosphorus or nitrogen in the water would not likely result in a decrease in macrophyte populations—in fact, if light is limiting, the resulting increase in water clarity (due to reduction of phytoplankton populations as a result of lower nutrient levels) might result in higher macrophyte densities."

In short, it appears that the goal of restricting macrophyte growth on the Watervliet Reservoir must be achieved by means other than the reduction of dissolved phosphorus concentrations.