Putting Nutrient Limitation Bioassays into a Bay-wide Context

Your class nutrient limitation bioassay results are a "snapshot" of what factor is limiting phytoplankton growth in a particular location (the mesohaline portion of the Patuxent River) and at a particular time of year. However, if the bioassay were repeated throughout the seasons of the year, your students' results are likely to vary.

Here are the results of many similar bioassays, conducted multiple times each year, for over a decade (Figure 1). These water samples were taken from a similar mesohaline site in the main stem of the Bay just east of the Calvert County shoreline. All of the results from N, P and N+P treatments are expressed as a percentage of the control.

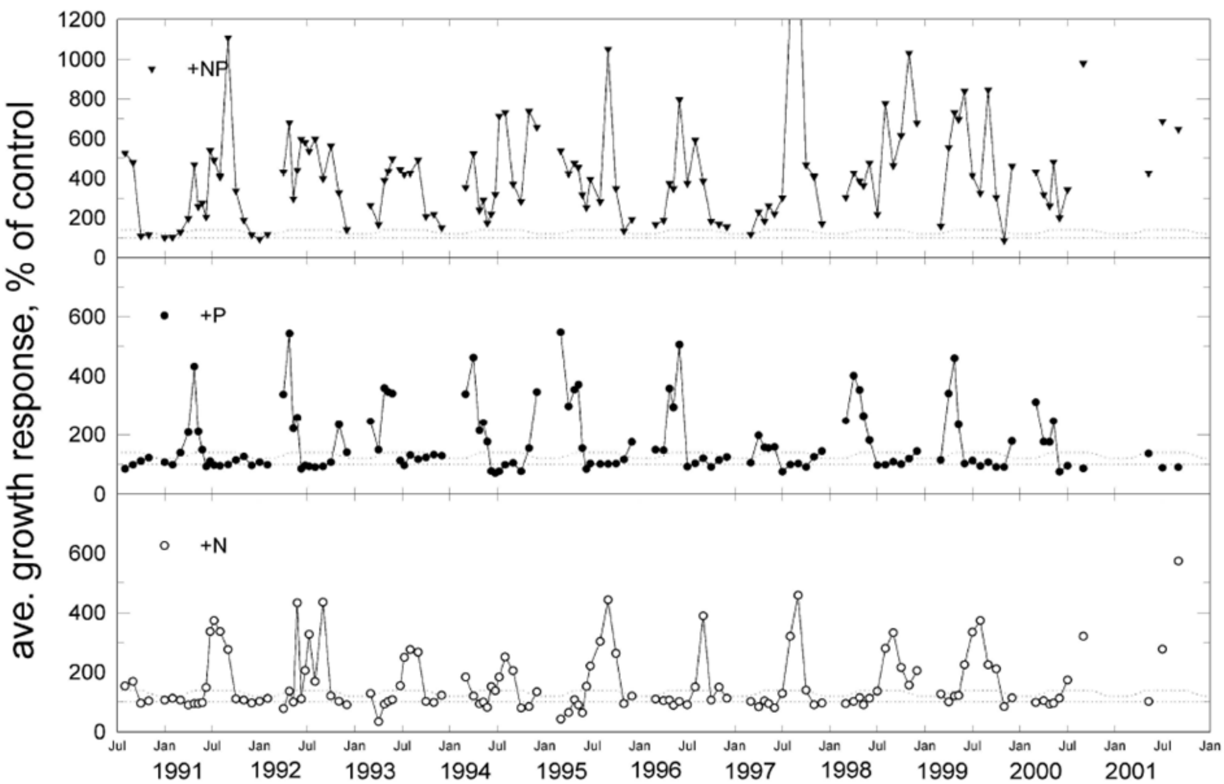

Figure 1. Results of nutrient limitation bioassays from water collected in the mesohaline main stem of the Chesapeake Bay. (Fisher and Gustafson, 2002).

Can you see a seasonal pattern in these bioassay results? What model outcomes do these responses suggest?

Generally, there is little growth in any of the treatments during the winter months indicating that light is the most prominent limiting factor in that season. During the spring bioassays, phytoplankton growth is elevated in both P and N+P treatments but not in the N treatments. This suggests phosphorus limitation. By mid to late summer the pattern changes again. Now N and N+P treatments exhibit increased growth, but P treatments generally are not responsive to nutrient additions. This signals nitrogen limitation for late summer and most of the fall.

Figure 2 below depicts similar monthly trends in light, phosphorus and nitrogen limitation. In this figure replicate bioassay results were used to express limitation as an Index Value that can range from 0 to 1. Zero represents no limitation, while 1 represents exclusive limitation by the factor under consideration. As indicated previously, light is weakly limiting during the winter months. Phosphorus is the primary controlling factor of phytoplankton growth in the spring. Nitrogen limitation dominates the system from July through October.

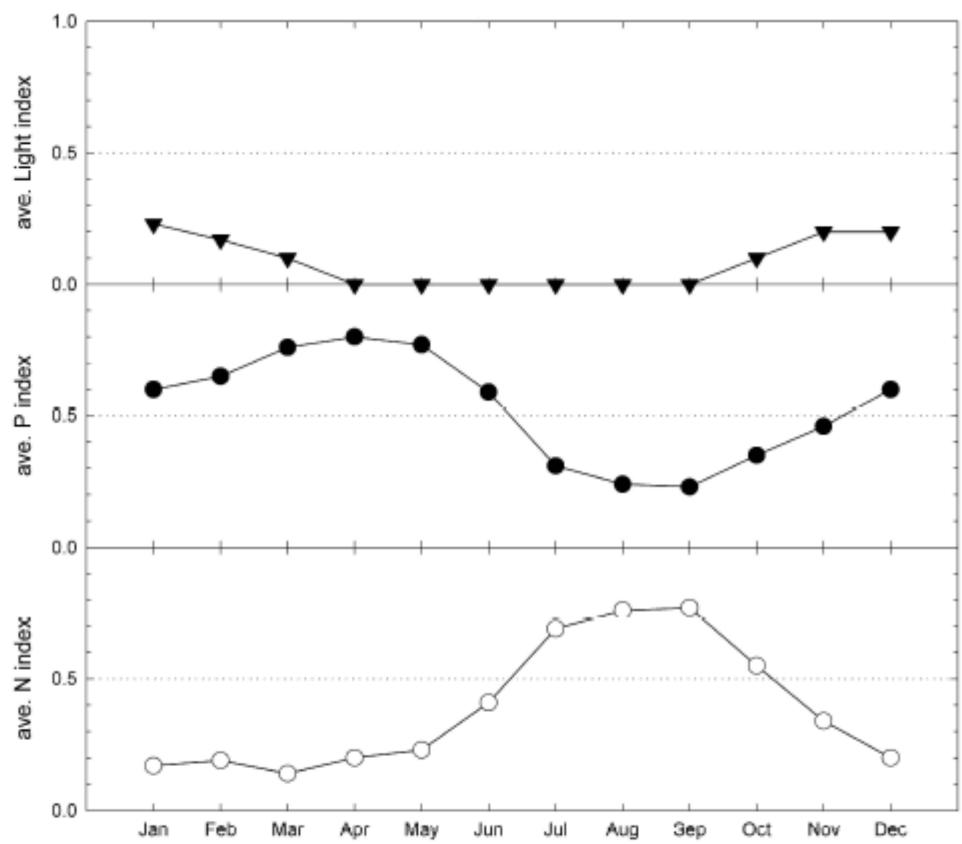

Figure 2. Nutrient limitation indices based on results of nutrient limitation bioassays from water collected in the mesohaline main stem of the Chesapeake Bay. (Fisher and Gustafson, 2002).

You should alert your students to the fact that these seasonal shifts in limitation are not necessarily seen throughout the estuary. For example, up-river from our sampling site on the Patuxent, the tidal freshwater portion of the river is light-limited most times of the year due to high turbidity and an excess of both nitrogen and phosphorus.

Why is there a seasonal shift in the limiting nutrient?

Nutrient inputs into the Bay are largely tied to the flow of freshwater runoff into the Bay. Wetter seasons and wetter years result in greater overall nutrient loadings. For example, Figure 3 shows that the input of nitrogen into the Bay is closely tied to the annual flow of water into the Bay. Certainly higher flow years will deliver more nutrients to the Bay, which will, in turn, cause greater growth of phytoplankton. Further, freshwater inflow is generally much richer in nitrogen than phosphorus. However, this variability in enrichment cannot completely explain which nutrient is limiting at any particular time.

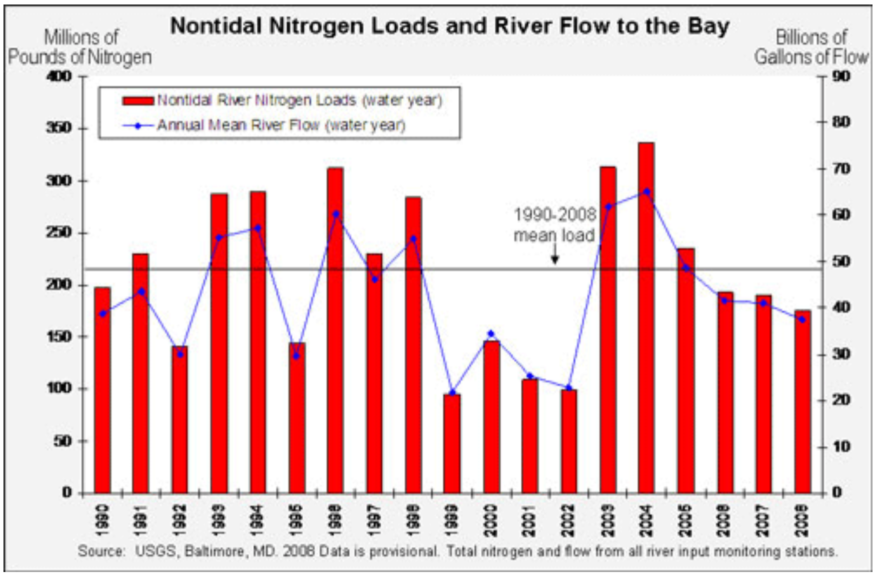

Figure 3. The variability in nitrogen inputs to the Bay is closely related to the amount of water flowing into the Bay. Source: http://www.chesapeakebay.net/status_nitrogenriverflow.aspx?menuitem=19798

The seasonal change in which nutrient controls phytoplankton growth in the Bay is actually tied to a different, but related, phenomenon – the seasonal depletion of oxygen (hypoxia and anoxia) in the bottom waters and sediments of the Bay (Figure 4).

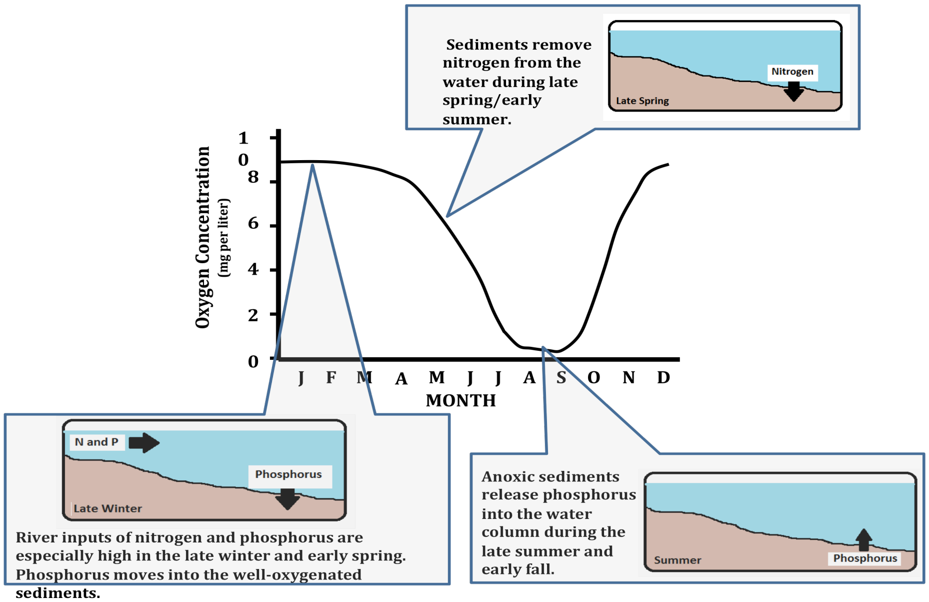

Figure 4. Oxygen concentration in water overlying the sediments influences the major seasonal net fluxes of nitrogen and phosphorus in the Patuxent River (redrawn from D'Elia, 1987)

Iron-rich sediments on the Bay bottom have the ability to bind and hold phosphate under oxygenated conditions. However, these same sediments will release this phosphorus back into the water during anoxic periods.

The binding of phosphorus to sediment particles readily takes place during the late winter and spring when the bottom waters are well-oxygenated. Sufficient P is removed from the water by this mechanism to cause phosphorus limitation of phytoplankton growth during this time of year.

As late spring and summer ensue, the water column stratifies as a result of warming temperatures and local increases in salinity. As the spring phytoplankton die, sink and decompose, the bacterial activity causes bottom waters to become depleted of oxygen. This oxygen cannot be restored by mixing with the surface waters due to stratification. By mid to late summer the bottom waters are anoxic.

During oxygen depletion of the late spring and early summer, biologically available nitrogen (nitrate) is also taken into the sediments and converted to nitrogen gas by the process of denitrification. In this gaseous form, nitrogen is largely unavailable to the phytoplankton community and can no longer contribute to algal growth.

Under anoxic conditions, sediments that once adsorbed phosphate now begin to release it into the water column by late summer. In fact, during this time of year, sediment release of P can exceed phosphorus input from all of the rivers in the watershed. Now that P is much more available, nitrogen becomes the nutrient limiting phytoplankton growth. This condition continues into the fall until cooler temperatures, increased winds, and autumn rains disrupt the stratified water column and oxygen can be restored to the bottom waters by mixing.

The Take-home Message:

Your class is already aware that nutrient enrichment is the root cause for many of the Bay's environmental problems – algal blooms, summer oxygen depletion in the deeper waters, and related losses of sea grasses and benthic communities. The solution to these problems lies in reducing the input of nutrients. But which nutrient is the most critical? The answer is: "It depends on the time of the year during which you want to reduce phytoplankton growth." However, **year-round reductions in phytoplankton will only be possible if inputs of both nitrogen and phosphorus are reduced**.

Nitrogen and phosphorus behave quite differently with regard to their biogeochemistry and cycling. Therefore, different approaches must be taken to target reductions in each nutrient. Generally, control of phosphorus inputs is more easily accomplished than for inputs of nitrogen. In fact during the early years of the Bay clean-up efforts, considerable phosphorus reductions were accomplished by simply banning the use of phosphate-containing detergents in the states within the watershed. However, as we have seen, controlling phosphorus alone does not solve the Bay's problems.

Reducing nitrogen inputs generally requires more complicated technologies and greater financial resources. For these reasons reductions in nitrogen inputs have always lagged behind those for phosphorus. This is still true today.

Each year the challenge of reducing nutrient inputs to the Bay becomes greater as the human population within watershed increases. However, technologies have been developed to successfully control both of the nutrients entering the Bay. **The primary issue now hampering the Bay's clean-up is summoning the political and social will of citizens within the watershed to finance the implementation of these nutrient control technologies.**

Citations:

D'Elia, C.F. 1987. Too much of a good thing: nutrient enrichment of the Chesapeake Bay. Environment 29(2):6-11,30-33.

Fisher, T.R. and A.B. Gustafson. 2002. Nutrient-Addition Bioassays in Chesapeake Bay to Assess Resources Limiting Algal Growth. Maryland DNR 2002 Report. Available at: http://www.dnr.state.md.us/bay/monitoring/limit/2002_level1_report.pdf