Too Much of Good Things

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The Old Professor

Question: Colorado's Water Quality Commission is studying water quality standards for nutrients, such as phosphorus and nitrogen. Wouldn't more nutrients in our lakes and streams lead to higher productivity, greater numbers of fish, and larger fish? Why limit the input of these nutrients?

The Old Professor replies: This question seems especially appropriate during the Holiday Season when many of us gorge ourselves with "extra nutrients." The simple answer is: just like humans, lakes and streams can take in too many nutrients…too much of good things. We get fat; lakes and streams get choked with excess vegetation and the whole structure of the aquatic ecosystems changes. However, like most things in aquatic ecology and resource management, many factors are involved and the exact effects differ from one water body to another.

The problem of too many nutrients in lakes, called eutrophication, has been the subject of thousands of studies and reports. Stream eutrophication is common, but, has not received as much publicity. In the rest of this article, I'll focus on the effects of excess nutrients in streams.

One of my first graduate students studied the water quality and ecosystem structure above and below nutrient-rich discharges to three streams in the Black Hills of South Dakota. Yes, total primary productivity (photosynthesis) was higher below the discharge points, but the numbers of fish desirable to anglers were far lower. The aquatic insect communities were greatly different, with mayflies and stoneflies completely absent. In addition, the amount of oxygen gas (called dissolved oxygen) in the water varied greatly from daytime to nighttime, often approaching zero by 4:00 AM. The oxygen that fish use to breathe is the dissolved form; not the form that is part of the compound, water. All of these changes were driven by large increases in the amount of slimy mats of filamentous algae, In comparison, areas above the discharge points were free of these slimy mats. Other forms of algae, called diatoms were dominant above the discharge points. Diatoms provide the base for the food web and also contribute far more dissolved oxygen than they use. The effects of the discharges were particularly striking in a soft water stream that originated in an area of igneous and metamorphic rocks.

The study of factors that control the productivity of ecosystems (called limiting factors) has been common throughout the history of ecology. Whatever needed factor is shortest in supply limits the production of the entire ecosystem. The most common limiting factor in lakes is the amount of phosphorus in the system; therefore, efforts to enhance lake productivity, or to limit the effects of excess nutrients, have focused on phosphorus. Stream productivity is often a different story. Carbon in the form of the carbonate-bicarbonate ions (inorganic carbon) frequently limits stream productivity. Hard water streams originating from or flowing over limestone formations are generally more productive than soft water streams because hard water is rich in carbonate-bicarbonate ions. Aquatic plants use the bicarbonate ions in photosynthesis and the entire system is higher in productivity when these ions are abundant.

Nitrogen is seldom a limiting factor in shallow, flowing waters. Nitrogen gas is readily available from the atmosphere, so it is seldom limiting in streams. Phosphorus can limit stream productivity, but additions of it seldom produce desirable results, probably because it usually is in forms that cause pollution rather than fertilization. Excess amounts of organic carbon, (ie; carbon from decomposing plants and animals, or animal wastes), have an entirely different set of effects. Excess organic carbon combined with nitrogen and/or phosphorus from these same sources, causes pollution. Remember, pollution is not limited to things that are directly toxic, such as metals and poisons.

Polluted waters, excessively enriched with organic carbon, nitrogen, and phosphorus are characterized by high "biochemical oxygen demand" (BOD). The decomposing plant and animal matter, plus the bacteria feasting on this material require extreme amounts of dissolved oxygen, which is the same oxygen that fish require for respiration. In effect, decomposing plant and animal matter rob fish of the oxygen they need to survive. In the absence of regulations to limit the amount of organic material dumped into streams, "dead zones" with no dissolved oxygen will develop.

Regulations controlling toxic pollution are generally easy to understand. If something is toxic and will kill fish, it should never be discharged into a stream, or lake. Regulations controlling organic carbon, phosphorus, and the various forms of nitrogen are harder to understand… and harder to design. The effects of too much organic carbon, too much nitrogen, or too much phosphorus vary with the characteristics of the water receiving these nutrients. Large, fast flowing rivers can "metabolize" or get rid more organic matter more quickly than small, slow flowing streams, or the standing water of a lake or stream.

Effective regulations consider not only the concentrations of polluting materials at a specific time and place, but also the total amount of material discharged over time, fluctuations in discharges over time, and the highest levels of pollutants discharged at any given point in time. Regulations often tend to look at average concentrations of pollutants – but averages can be meaningless. Discharges that contain lethal concentrations of any substance at any time cannot be tolerated, even for brief periods of time. Having conditions that sustain fish life 98 per cent of the time is not good enough. Trying to live in lethal environments two per cent of the time means being dead all of the time.

In summary, a little additional phosphorus, or nitrogen, or even organic carbon may produce a temporary, localized increase in productivity; but, in the long run allowing extra discharges of such nutrients is an invitation to disaster.

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