

Rethinking the Role of Nitrogen and Phosphorus in the Eutrophication of Aquatic Ecosystems¹

Karl Havens and Thomas Frazer²

For many years, environmental agencies have sought to improve the water quality of lakes and estuaries by reducing inputs of phosphorus. New research indicates that we must reduce both phosphorus and nitrogen to reverse eutrophication symptoms.

Nutrients are chemical elements that influence the productivity of all ecosystems. Nitrogen and phosphorus are two nutrients that are essential for the growth and survival of plants and animals, but often are present in short supply. Both nitrogen and phosphorus are applied regularly through fertilizer to increase the yield of crops needed to feed human populations. Fertilizers also are used widely for residential and commercial landscaping purposes.

Excess Nutrients and the Detrimental Effects of Eutrophication

Environmental concerns arise when nitrogen and phosphorus, originally applied to the land surface, are leached into the groundwater or delivered as runoff during rainfall events to streams, rivers, lakes and estuaries. **Excess nutrients in aquatic systems** can stimulate growth of plants and algae. In other words, these nutrients continue to serve as fertilizers once they reach the water. Increased nutrient delivery and the consequent proliferation of

plants and algae in aquatic systems is a process known as eutrophication.

Nutrient concentrations in lakes, rivers and estuaries vary widely and depend largely on the local geology and soil conditions. Low-nutrient waters with low amounts of algae are referred to as oligotrophic systems. High-nutrient waters with correspondingly high amounts of algae are referred to as eutrophic systems. Increased nutrient delivery to lakes and estuaries can cause a transition from an oligotrophic state to a eutrophic state.

In extreme cases of **eutrophication**, microscopic algae that grow in the water column reach densities so high that they reduce the light available to rooted plants living on the bottom. This shading effect may cause the plants to die, resulting in the loss of important habitat for fish and other organisms. Loss of plants can, in fact, compromise the ecological and economic integrity of lakes, rivers and estuaries. Greater production of algae may also lead to an increase in the frequency and duration of periods of low dissolved-oxygen concentration known as hypoxic events, which can cause further damage to the system.

Nutrient-enriched aquatic systems sometimes become dominated by noxious species of algae that form floating surface scums called blooms. Some of these algal species produce toxic substances that can negatively impact other plants and animals, including humans.

1. This document is SGEF190, one of a series of the Sea Grant Department, UF/IFAS Extension. Original publication date April 2012. Reviewed February 2018. Visit the EDIS website at <http://edis.ifas.ufl.edu>.

2. Karl Havens, director, Florida Sea Grant; and Thomas Frazer, professor, School of Forest Resources and Conservation; UF/IFAS Extension, Gainesville, FL 32611.

The Institute of Food and Agricultural Sciences (IFAS) is an Equal Opportunity Institution authorized to provide research, educational information and other services only to individuals and institutions that function with non-discrimination with respect to race, creed, color, religion, age, disability, sex, sexual orientation, marital status, national origin, political opinions or affiliations. For more information on obtaining other UF/IFAS Extension publications, contact your county's UF/IFAS Extension office.

U.S. Department of Agriculture, UF/IFAS Extension Service, University of Florida, IFAS, Florida A & M University Cooperative Extension Program, and Boards of County Commissioners Cooperating. Nick T. Place, dean for UF/IFAS Extension.



Figure 1. Aerial image of a blue-green algae bloom in Lake Okeechobee, FL.

Credits: South Florida Water Management District

Should One or Both Nutrients Be Controlled?

For many years, eutrophic conditions in inland freshwater systems have been attributed more to excessive inputs of phosphorus than nitrogen. New evidence is suggesting that both nitrogen and phosphorus are important (Conley et al., 2009; Lewis et al. 2011), and that improving water quality in certain lakes and estuaries that have experienced man-made eutrophication requires reducing inputs of both nutrients.

Why the historical focus on phosphorus? This conclusion was supported by a large body of research conducted in the 1970s, mostly in Canada and other temperate regions. Intense algal blooms were stimulated by experimental additions of large amounts of phosphorus to nutrient-poor Canadian lakes, whereas substantial additions of nitrogen had no such effect. Researchers also focused more on the role of phosphorus because it is much less available than nitrogen to plants and animals in the freshwater environment, and thus considered a more important factor that limits growth. In fact, certain algae, the blue-green algae also known as cyanobacteria, can obtain the nitrogen they require from its most abundant source, the atmosphere, through the chemical process of nitrogen fixation, thus theoretically creating a nearly limitless nitrogen source for these aquatic ecosystems.

We now know that the research from temperate lakes may not apply to subtropical and tropical lakes, or to estuaries and coastal waters. For example, subtropical lakes often have blooms of algae that cannot use atmospheric nitrogen. The growth of these algae is mainly stimulated by inputs

of nitrogen from inflowing rivers, streams and the land, including nutrients in fertilizer. One species that forms blooms, *Microcystis*, can produce potent chemical toxins that harm aquatic animals—and can potentially harm people if they drink water that has not been adequately treated. These algae have the interesting ability to start growing in lake-bottom sediments, which are rich in accumulated phosphorus. As they rise through the water column, these algae take up nitrogen and can attain bloom levels by the time they reach the surface. Just controlling external inputs of phosphorus may have a limited impact on *Microcystis* and its negative effects, depending on the ecosystem's internal reserves of phosphorus.



Figure 2. A surface bloom of *Microcystis* in the St. Lucie Estuary, FL.

Credits: Edward Philips, UF/IFAS

In many estuaries and coastal waters, nitrogen fixation occurs at low rates, or not at all because of the saline environment. Thus, the algae respond primarily to nitrogen delivered by runoff from the land. Blooms are often stimulated by excess nitrogen inputs related to human activities, such as fertilizer application and sewage runoff.

While there are some cases in temperate lakes where controlling phosphorus alone reversed the symptoms of eutrophication, there also are cases where the reduction of phosphorus upstream left high levels of nitrogen in the water, unused by the algae in the lake. When transported downstream, this nitrogen caused harmful blooms of algae in estuaries. In essence, the problem was transferred from the inland aquatic ecosystem to the coastal zone.

The current body of science suggests it is prudent to implement nutrient-control strategies that limit both nitrogen and phosphorus to effectively manage eutrophication of lakes and estuaries. This approach must be weighed carefully considering both the costs and benefits because control of nitrogen may be considerably more costly than control of phosphorus alone.

References

Conley, D.J., H.W. Paerl, R.W. Howarth, D.F. Boesch, S.P. Seitzinger, K.E. Havens, C. Lancelot, and G.E. Likens. 2009. Controlling eutrophication: nitrogen and phosphorus. *Science* 323: 1014–1015.

Lewis, W.M., Jr., W.A. Wurtsbaugh, and H.W. Paerl. 2011. Rationale for control of anthropogenic nitrogen and phosphorus to reduce eutrophication of inland waters. *Environmental Science and Technology* 45: 300–305.

Recommended Reading

Howarth, R., D. Anderson, J. Cloem, C. Elfring, C. Hopkinson, B. Lapointe, T. Malone, N. Marcus, K. McGlathery, A. Sharpley, and D. Walker. *Nutrient Pollution of Coastal Rivers, Bays, and Seas*. 2000. Vol. 7 of *Issues in Ecology*. Washington, D.C.: Ecological Society of America. Retrieved from http://www.esa.org/science_resources/issues/TextIssues/issue7.php

Acknowledgments

The authors are grateful to Professors Mark Brenner (UF Geology Department) and Edward Phlips (UF/IFAS School of Forest Resources and Conservation) for substantive and constructive comments and to Dorothy Zimmerman (Florida Sea Grant) for editorial work that greatly improved the clarity of the message presented in this document.