Nitrogen in Our Lakes and Rivers

John J. Peterka

The amount of nitrogen present in surface and in ground waters is often a reflection of man's activities on land. A nationwide analysis of watershed characteristics and stream nutrient runoff from 928 nonpoint-source type watersheds showed a positive correlation between general land use and nutrient concentrations in streams (Omernik 1977). That study found mean concentrations of both total nitrogen and total phosphorus to be nearly nine times greater in streams draining agricultural lands than in streams draining forested areas.

While such national surveys are useful in assessing general trends, if we are to determine how various activities in North Dakota influence substances entering our streams and lakes, we need rather detailed information on a watershed-by-watershed basis.

The problems are complex because most of the substances, including nitrogen, that enter our waters come, not from direct sources like sewage or industrial discharges, but from runoff and other diffuse sources that are difficult to identify or control.

The focus of this paper is not on the nonpoint sources of nitrogen themselves, but rather on what happens within the surface waters that receive these nutrients; we'll also briefly discuss some of the research underway in the state that pertains to these problems.

The Role of Nitrogen and Phosphorus in Surface Waters

Nitrogen and phosphorus are commonly applied to agricultural lands to increase crop production. Similarly, the addition of these chemicals to lakes and reservoirs increases aquatic plant production. While increased production is a desired result on agricultural land, added production in waters causes problems. When large quantities of nitrogen and phosphorus enter our surface waters, aquatic plants, primarily algae, use them to produce enormous blooms.

An easily-recognized clue to the presence of excessive nutrients in our lakes is the "pea-soup" blooms of algae that regularly discourage swimmers in mid- and late summer. These blooms eventually decompose, causing oxygen depletion and kills of fish. One of the most important problems facing fisheries management in our state is controlling these kinds of losses of fish.

Nitrogen and phosphorus are both key nutrients controlling the amounts of aquatic plant growth. Therefore, while our emphasis here is on nitrogen, we will necessarily consider both of these chemicals.

In many regions of the world, phosphorus is the most important nutrient in lakes limiting plant growth. In our region, however, it appears that nitrogen limits plant growth. (The term "limiting nutrient" is used when the supply of a certain chemical element that is required by plants in order to grow and reproduce is insufficient to meet the demand required by the plants. The element then "limits" plant growth.)

In laboratory tests on water samples from 12 of 14 North Dakota lakes sampled, nitrogen was the limiting nutrient for growth of algae at the time the samples were collected (EPA 1978). These tests indicate that phosphorus is present in ample amounts in North Dakota lakes and reservoirs tested so that additional plant growth will result when more nitrogen is added.

Other factors can also limit plant growth. In studies of Lake Ashtabula, for example, we concluded that nitrogen and phosphorus were present in such quantities that neither limited plant (algae) production for the growing season (Peterka and Reid 1968). Rather, some physical factor such as temperature or light was limiting. Lake Ashtabula is a very productive lake, even for North Dakota.

Why North Dakota Lakes Are Fertile

Most North Dakota lakes and reservoirs are already, by nature, very fertile, making the addition of man-caused nutrients even more critical than might otherwise be the case. This high natural fertility is due largely to factors which cause high concentrations of nutrients and make those nutrients available to aquatic plants throughout the growing season.

The first of these factors is that our soils are naturally rich in nutrients. These soils and their nutrients are picked up by runoff waters which then enter streams, rivers, lakes and reservoirs. A second factor is that in North Dakota the annual evaporation rate exceeds the amount of precipitation; this helps to concentrate the nutrients once they enter the lakes. The third factor is water depth. In deep lakes, complete mixing of the water does not occur, and nutrients tend to settle out into the bottom waters. Most North Dakota lakes, however, are shallow enough that strong winds constantly mix their waters, making a continuous supply of nutrients available to the aquatic plants. Finally, long days during the growing season provide the energy for prolific plant growth.

An often overlooked, but potentially important source of nutrients in surface waters is precipitation. Atmospheric contributions are proportionately greater in lakes that are naturally nutrient-poor than in those that are nutrient-rich.

Dr. Peterka is professor, Department of Zoology.

For example, in Lake Metigoshe, low in nutrients, we estimated that about 50% of the total nitrogen and total phosphorus that entered the lake during the ice-free season was in rain falling on the lake surface (Downing 1974). On the other hand, in Lake Ashtabula, a nutrient-rich lake, we estimated that about 10% of the annual input of nitrogen was in precipitation (Peterka 1970). We need to examine atmospheric sources of nitrogen and phosphorus and their contributions to surface waters in North Dakota, particularly as industrial development and agricultural practices intensify.

The Role of Wetlands

Wetlands are a unique and important feature of our state. They occur in a wide band from the northwest to the southeast corners of North Dakota and encompass an area of about 36,000 square miles, or about 52% of the state's total area (Stewart and Kantrud 1974).

We mentioned above that the runoff from fertile soils contributes nitrogen and other nutrients to North Dakota's surface waters. Recently we have been involved in studies to assess the relationships of wetlands to lake and reservoir water quality. We have begun to study whether or not wetlands act as possible "traps" for such nutrients, and we are also looking at the amounts of nutrient losses from drained wetlands.

Preliminary results of our studies have shown that four shallow wetland marshes in Arrowwood National Wildlife Refuge in central North Dakota discharge about as much phosphorus and nitrogen as enters them (Peterka and Hanson 1978). Although there was no net retention of nutrients, the refuge marshes did influence the water quality in an important way. They changed the soluble forms of nitrogen and phosphorus that came into the marshes into combined forms in the water discharged into Jamestown Reservoir. This is significant because, while soluble forms of nitrogen and phosphorus are readily available for use by plants, combined forms are not. These results indicate that wetlands may indeed play a role in water quality of lakes by influencing the kinds of nutrients that enter them; additional studies, however, are necessary before the question of marshes as nutrient traps is resolved.

We have also looked at the amounts of nutrients carried in surface runoff wastes from drained wetlands. In a study of the Devils Lake Basin (DeGroot 1978), we found high concentrations of nitrate nitrogen in runoff from a wetland basin for only the first year after it was drained. Concentrations of other nitrogen and phosphorus substances were similar to those measured in runoff from sites drained for periods of 4, 9 and 17 years (Fig. 1). Apparently much of the soluble salt is lost from wetland basins soon after they are drained.

Concentrations of nitrate nitrogen in Starkweather Coulee, the major drain from Starkweather Watershed in the Devils Lake Basin, were highest at times of peak water discharge when they reached about 3 mg/l (3 milligrams per liter), a high concentration for nitrate in streams. (By contrast, the highest concentration of nitrate nitrogen we found in the James River, also at maximum stream discharge, was 0.7 mg/l.) The high concentrations of nitrate nitrogen in Starkweather Coulee come mostly from contributions from the soil, as most of the water in the Coulee is from melted snow which we found to be low in nitrogen: about 0.2 mg/l for nitrate nitrogen, 0.25 mg/l for ammonia nitrogen, and about 1.0 mg/l in total Kjeldahl nitrogen.

Concentrations of nitrate nitrogen and total Kjeldahl nitrogen in runoff from a prairie site in the Devils Lake Basin were less than those from agricultural sites (Fig. 1); it is likely that the high concentrations of nitrate nitrogen in runoff waters in the basin are related to intensive agricultural practices and not to natural causes.

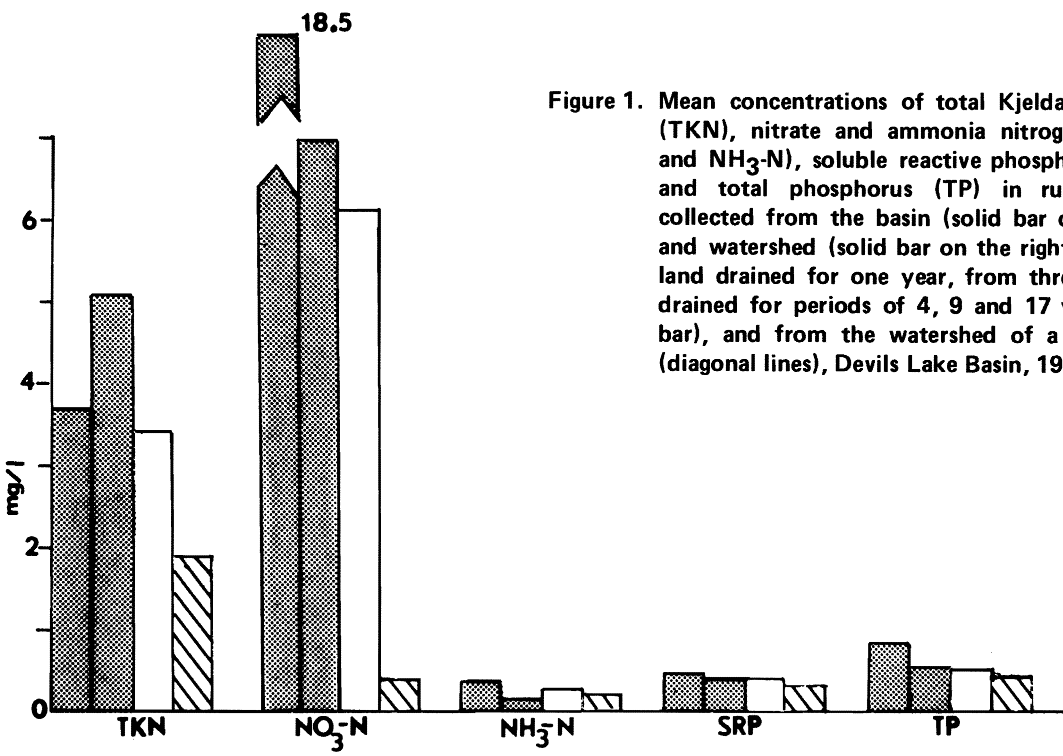

Figure 1. Mean concentrations of total Kjeldahl nitrogen (TKN), nitrate and ammonia nitrogen (NO_3-N and NH_3-N), soluble reactive phosphorus (SRP) and total phosphorus (TP) in runoff water collected from the basin (solid bar on the left) and watershed (solid bar on the right) of a wetland drained for one year, from three wetlands drained for periods of 4, 9 and 17 years (open bar), and from the watershed of a prairie site (diagonal lines), Devils Lake Basin, 1978.

There is much yet to be learned about the functioning of wetland marshes, about the roles played by various sizes of marshes, and about how to control the amounts and timing of water flows through them to produce the desired productivity in lakes receiving their discharges. We need to broaden our studies beyond the original wetland sites we looked at in order to determine relative contributions of substances contributed by wetlands, agricultural lands, and natural causes to the general runoff from the basin. These data can best be gained at a site where we can control such variables as crop cover, tillage, fertilization, and drainage. Meanwhile, about 45% of the original area of North Dakota wetlands has been drained since the mid-1920s, and about 15-20,000 acres of wetlands are drained annually (Kantrud 1979).

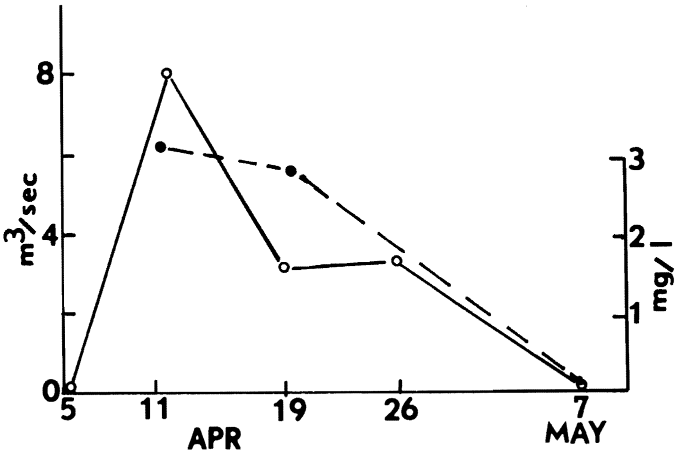

Figure 2. Water discharge (m^3/sec) and concentrations of nitrate nitrogen (broken line) in the lower reaches of Starkweather Coulee, spring 1978.

Summary

The addition of nitrogen from man-caused sources to North Dakota's already fertile lakes and reservoirs contributes to algae production and, ultimately, to oxygen depletion and fish kills.

Researchers are looking at ways to control such negative effects through identification of nutrient sources – both man-caused and natural, through better understanding of the biological effects of nutrients in lakes, and by studying ways in which natural land features such as wetlands can be used to control nutrient levels in lakes.

REFERENCES

1. De Groot, E. W. 1979. **Water quality of drained wetland runoff vs. agricultural runoff in the Devils Lake Basin, North Dakota.** M.S. thesis. Zoology Department, NDSU, Fargo. 45 pp.

2. Downing, J. A. 1975. **Hydrophytes, plankton, and water chemistry related to recreational development at Lake Metigoshe, North Dakota.** M.S. thesis. Zoology Department, NDSU, Fargo. 60 pp.

3. Environmental Protection Agency. 1978. **A compendium of lake and reservoir data collected by the national eutrophication survey in the central United States.** Working Paper No. 476. Corvallis, Oregon. 199 pp.

4. Kantrud, H. A. 1979. **Wetlands remain in jeopardy.** North Dakota Outdoors. 41(8):7-11.

5. Omernik, J. M. 1977. **Nonpoint source – stream nutrient level relationships: A nationwide study.** Environmental Protection Agency. Ecological Research Series. EPA-600/3-77-105. 151 pp.

6. Peterka, J. J. 1970. **Productivity of phytoplankton and quantities of zooplankton and bottom fauna in relation to water quality of Lake Ashtabula Reservoir, North Dakota.** Research Project Technical Completion Report. North Dakota Water Resources Research Institute. W1-221-008-70. 79 pp.

7. Peterka, J., and D. A. Hanson. 1978. **Jamestown study looks at marshes as nutrient traps.** North Dakota Outdoors. 40(9):8-9.

8. Peterka, J. J., and L. A. Reid. 1968. **Primary production and chemical and physical characteristics of Lake Ashtabula Reservoir, North Dakota.** Proceed. N. D. Acad. Sci. 22:138-156.

9. Stewart, R. E., and H. A. Kantrud. 1974. **Breeding waterfowl populations in the prairie pothole region of North Dakota.** Condor. 76(1):70-79.