Ammonium ions and acid lakes

The thin chemical consommé that falls as acid rain contains more than just traces of sulfuric and nitric acid. Each raindrop carries a mixture of compounds and ions, some of which may also contribute to making a lake more acid. Now, a few researchers are beginning to look at what happens to ammonium ions after they fall into lakes. New experimental data seem to indicate that these ions, under the right conditions, can help to acidify lakes.

The key factor, says ecologist David W. Schindler of the Freshwater Institute in Winnipeg, Manitoba, is biological activity within the lake. When microscopic aquatic plants like phytoplankton consume ammonium ions, the net result is an increase in the lake's acidity.

"The focus has been too much on the input and not enough on addressing what conversions might happen in the lake," says Schindler. "There is certainly more to it than just what strong acids enter the system."

One reason for the interest in ammonium ions, says Schindler, is that "on this continent, we've had a pretty marked increase in ammonium in precipitation." Ammonium is now typically the second most common positively charged ion present in snow and rainfall, according to reports from the U.S. National Atmospheric Deposition Program. Some scientists are concerned that increasing amounts of ammonium compounds, especially from feedlots and heavily fertilized fields, are entering the atmosphere.

To try to understand what happens to ammonium ions in a lake, Schindler and his colleagues analyzed data from an experiment conducted several years ago. For four years in the mid 1970s, the researchers dumped ammonium chloride directly into a small, rocky lake in northwestern Ontario. As reported in this month's BIOGEOCHEMISTRY, they found that the addition of ammonium chloride caused the lake to acidify, especially when small amounts of phosphate were also added to encourage the growth of phytoplankton. The acidity was the direct result of the biological conversion of ammonium ions into nitrogen compounds within the plants and the consequent production of hydrogen ions.

In general, ammonium oxidation is a secondary effect, says James N. Galloway of the University of Virginia in Charlottesville. "A lot of the ammonium is taken up by the soil even before it gets to the lake," he says. "The main cause of acidification of surface waters is sulfuric acid." Galloway was a member of a National Academy of Sciences panel that last year identified the principal factors causing lake acidification (SN: 3/17/84, p. 164).

Although there is no clear evidence yet that any lakes have been acidified because of ammonium inputs, "it shows what can happen," says Schindler. A few scientists fear that at some time in the future in some locations, the soils through which the water-carried ammonium ions run may become saturated. Then, excess ammonium ions could end up in lakes.

"People generally have thought that biological uptake is not a problem," says Schindler. However, a few signs are beginning to appear that ammonium and even nitrate ions can overload soil ecosystems. "We really need to worry about the efficiency of how ecosystems react to the input," he says, "to see whether, as deposition increases, we get a decrease in the efficiency of the biological processes that convert the inputs."

Schindler's group is now adding nitric acid directly to a lake to study what happens over an extended period of time. They hope to do a similar study using ammonium compounds. Other studies are starting to focus on ammonium and nitrate ions in forest soils. "But that's such a complex picture," says Galloway, "that I suspect it would be a decade before we have as good an understanding of the impact of acid deposition on terrestrial systems as we now do on aquatic systems."

—I. Peterson

Scarlet gilia: Flowering chameleon

Chances are, you thought only lizards and people could be chameleons. Not so. Two biologists at Northern Arizona University in Flagstaff have shown that scarlet gilia plants are experts at the change game also.

Flowers of scarlet gilia, *Ipomopsis aggregata,* change from red to varying shades of pink and white during their flowering season from July to early September. Such color shifting lets the plants keep up with the different color preferences of pollinators, depending on which pollinators are present at different times of the season, say biologists Ken Paige and Thomas Whitham.

Paige and Whitham studied color shifts in scarlet gilia during the summers of 1981 through 1983 on Fern Mountain near Flagstaff. Although scarlet gilia is known for its bright red flowers at sea level, the plants on Fern Mountain and other high elevations show an array of flower colors from red to pink to white. The biologists showed that flowers on the mountain change color to cater to the different color preferences of a changing population of pollinators, while plants at lower elevations stay red because the pollinator population does not change.

Scarlet gilia relies mainly on hummingbirds and hawkmoths to transfer pollen between plants. Hummingbirds are attracted to the plant's bright red flowers, which they duly reward with gifts of pollen. Hawkmoths, on the other hand, prefer to forage at night, when lighter flowers are easier to see. They selectively pollinate light pink and white flowers, bypassing the darker reds.

At elevations where hummingbirds stay all summer, plants stay red all summer, the biologists found. But at higher elevations, from which hummingbirds emigrate during August, plants shift to progressively lighter colors.

Paige and Whitham found that hummingbird emigration coincides with the color shifts of scarlet gilia. Early-flowering plants on Fern Mountain produce mainly red flowers, reflecting the abundance of hummingbirds available to pollinate them. Late-flowering plants produce lighter-colored flowers, reflecting the declining population of hummingbirds and increased reliance on hawkmoths for pollination.

The biologists covered some plants during the day and others at night to expose them selectively to hummingbird or hawkmoth pollinators. In plants exposed only to hummingbirds, they found that red flowers are twice as likely to produce fruit as white flowers, showing that red flowers had been pollinated more than white flowers. But in plants exposed only to hawkmoths, lighter-colored flowers are about twice as likely to produce fruit as red flowers.

Color shifting occurs not only among the population of scarlet gilia plants but also within individual plants (see cover photo). Paige and Whitham found that late-flowering plants are more likely to change colors than those that flower early. Shifting colors from dark to light allows late-flowering plants to adapt to the transition from hummingbird/hawkmoth pollinators to solely hawkmoth pollinators.

The biologists also found that plants that shift colors produce more fruit than those that stay the same color. A shift to only one shade lighter increased fruit production by as much as 22 percent, according to their report in the Jan. 18 SCIENCE. Thus plants that shift colors have enhanced reproductive success because of higher frequencies of pollination and greater fruit production.

What's the upshot of color shifting in scarlet gilia? It shows that plants are very flexible and cannot be considered passive, Paige says. "Perhaps the most important thing is that biologists have long ignored any kind of variation in a plant as something that's environmental noise [a nonadaptive change that occurs for no real reason]. But every individual, plant or animal, that varies does so for an important reason." *—D. D. Bennett*