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Fish Story: The Great Acid Rain Flimflam

Edward C. Krug

The following is a slightly edited version of an article by the same title appearing in the Heritage Foundation's Spring 1990 POLICY REVIEW (Volume 52, pp. 44-48). It is presented with permission.

For more than a dozen years, the conventional wisdom among scientists, environmentalists, and politicians has blamed acid rain for the depletion of game fisheries in the Adirondacks and Nova Scotia and for substantial damage to forests from Vermont to North Carolina. The government of Canada certainly takes this view, and regards acid rain clouds from the Midwest as one of its principal sources of tension with the United States. President Carter endorsed a report by his Council on Environmental Quality calling acid rain one of the two most serious environmental problems of the century. It is largely to reduce the acid in rain that President Bush's Clean Air legislation calls for a 50 percent reduction in sulfur dioxide emissions (10 million tons) by the year 2000, at an estimated cost of $4 billion to $7 billion per year.

The concerns that acid rain legislation is intended to address are legitimate and understandable. A number of rivers in Nova Scotia have lost most of their salmon over the past 40 years as they have become more acidic. Red spruce are dying on top of Camel's Hump in Vermont and Mount Mitchell in North Carolina. And there is no doubt that some Adirondack fisheries are in a bad way. From the turn of the century until the 1950s, for instance, Lake Colden was one of the best trout fly fishing lakes in the eastern U.S. Teddy Roosevelt fished there often; he was vacationing at Lake Colden when President McKinley was shot. Today, Lake Colden is highly acidic (pH 5.0) and nearly fishless. It is held up as the classic case of acid rain's destructiveness.

Recent research, however, suggests that acid rain has little or nothing to do with these problems. Surveys of lakes in New England and New York show much less acidity than anticipated, while other studies show that acid rain has very little effect on surface water acidity. Perhaps most intriguing, fossil records in lake sediments reveal that many lakes that are acidic today have been highly acidic for centuries, except for several decades in the late 19th and early 20th centuries when they were unnaturally alkaline.

Memories of trout and salmon in now fishless lakes and streams apparently date from a period of ecological aberration. A number of lakes in the Adirondacks and Nova Scotia that are naturally acidic became more alkaline for several decades in the late 19th and early 20th centuries,

ORER News

Brueckner Edits JUE

University of Illinois Economics Professor and ORER Research Associate Jan Brueckner has been named Editor of the *Journal of Urban Economics*. The prestigious *Journal* is one of the leading publications in urban economics. Brueckner has served for many years as a member of the publication's editorial advisory board.

Go East, Young Man

On October 18, ORER Director Peter Colwell presented the results of his study, "The Value of Agricultural Land," to a seminar of faculty members at the University of Connecticut. On October 30 he presented the same paper at a seminar sponsored by the Center for Real Estate Development at the Massachusetts Institute of Technology. The MIT presentation was part of a series of seminars on real estate and urban economics conducted by the Center. Colwell had earlier presented his findings to a faculty audience at the U of I.

Alumni Luncheon

The tenth luncheon for University of Illinois alumni working in the real estate field was held on November 2 at the Chicago Yacht Club. More than 90 attendees heard Peter Morris of VMS Realty Partners share his "Reflections on the Current State of the Real Estate Industry." Thanks again to Gene Stunard for arranging for use of the Yacht Club's facilities.

The luncheon series has been very successful in bringing alumni together and providing a forum for timely and, at times, controversial speakers who volunteer to address those in attendance. Costs of food and facilities

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when massive cutting of trees and burning of stumps by lumberers reduced the acidity of the forest floor, and soil runoff made it possible for species such as trout and salmon to survive. After lumbering and burning came to an end, forests grew back, and the soil runoff, and hence the waters, returned to their natural acidity. These changes in land use often dwarf in importance the impact of acid rain.

There is similarly no evidence of widespread forest decline related to acid rain. Indeed, Forest Service statistics indicate Northeastern forests to be the most robust in the country. The principal concern is that acid rain may have damaged red spruce in high-altitude spruce/fir forests. But these forests make up only a fraction of 1 percent of Eastern forests, and even here, the influence of acid rain is uncertain. The EPA's National Acid Precipitation Assessment Project (NAPAP) has determined that other stress factors (killing winters and severe droughts over the past 40 years, such as occurred at Camel's Hump and other mountains) have been more important. Also, many species of trees and bushes–among them red and black spruce, oak, balsam fir, eastern hemlock, rhododendron, and blueberry–depend on acidic soil for survival.

Control Soot, Emit Acid

There is no question that the rain and snow over the Appalachians, New England, and Nova Scotia are more acidic than normal. Rain over the Ohio Valley and Adirondacks has a pH of 4.2, while that over Nova Scotia has a pH of 4.6 to 4.8–compared with a pH of 5.0 for normal rainfall over forested areas. (Chemists use the measure pH to describe the concentration of hydrogen ion released into water by an acid. It is a negative log scale, so the smaller the number the greater the acidity; thus pH 4.0 water is 10 times more acidic than pH 5.0 water. Lemon juice has a pH of 2.0 and our stomach juices are pH 1.0. Apples have a pH of 3.0, meaning they are 16 times as acidic as Adirondack rain.)

Nor is there any question about the source of acid rain. It results from the combustion of fossil fuels, especially in the Midwest, and ironically it has been aggravated by environmental policies designed to reduce air pollution problems, especially soot, in areas such as Pittsburgh and Cleveland. Acid rain is created by burning fossil biomass. Carbon, nitrogen, and sulfur (present in all biological material) are converted to gases upon oxidation (burning). These gases combine with atmospheric water to form carbonic, nitric, and sulfuric acids.

When tall smokestacks were built to spread emissions from the vicinity of Midwestern factories, winds carried the acidic clouds to the northeast. Emissions also became more acidic as advances such as particle precipitators and cleaner burning fuels reduced soot. (Soot contains alkaline substances that neutralize acid.) Efforts to alleviate local soot problems thus led to regional acid rain.

Sulfur Trouble

Widespread acid rain probably began by the 1940s in the Northeast. It peaked around 1973, when national sulfur dioxide emissions measured 31 million tons. But the emissions had fallen to 23 million tons by 1985, partly as a result of pollution controls and conservation, and replacement of older, more heavily polluting factories and power plants by state-of-the-art facilities as mandated under the Clean Air Act of 1970.

The major concern over acid rain has to do with sulfuric rather than nitric acid, because forest growth in eastern North America is limited by the availability of nitrogen. Essentially all nitric acid in acid rain is absorbed as a nutrient by trees; little reaches lakes and streams. However, deposition of sulfuric acid exceeds the nutritional requirements of the forests and much, but not all, of the sulfate finds its way into lakes and streams.

Even the normal rainfall in forested areas, with pH 5.0, is too acidic for most species of sport fish to survive. Fish and many other species can survive the rainwater only because acids are naturally buffered by lime-like substances in rocks and mineral soils of lake and river drainage systems. Acid in watershed runoff is consumed by reaction with the alkalinity of lime-like substances found in many types of rocks and mineral soils that underlie watersheds and the bottoms of lakes and streams. Acidity of lakes in the Adirondacks and Nova Scotia results not from acid rain but from the absence of this natural buffering.

For Peat's Sake

Most lakes in the Northeast are not highly acidic, even though acid precipitation falls on the entire area. In 1980, before it had studied the situation, the EPA asserted that the acidity of Northeastern lakes had increased 100-fold (a decrease of two pH units) as a result of acid rain. But a 1984 lake survey by NAPAP found only 240 of New England's and New York's 7,000 lakes to be "acid-dead" (pH of 5.0 or lower). The survey found that in the whole eastern United States there are only 630 acid lakes, representing 35,000 of the approximately 200 million acres of water in the East, or less than one fiftieth of 1 percent of the water. Over half the acid lake capacity, 20,000 acres, is in Florida, which does not receive high rates of acid rain.

Further studies by NAPAP in 1988 and 1989 suggest that since 1850 there has been no increase in acidity in lakes with a pH above 5.5; these lakes have granite and gravel bottoms with sufficient lime to neutralize the acid in rain. For Adirondack lakes with a pH under 5.5, NAPAP concluded that there has been some acidification, but on average by less than half a pH unit. Attention on acid rain now focuses primarily on the Adirondacks rather than on the entire Northeast, because studies show 10 percent of Adirondack lakes (or 24 percent, depending on what is included as a lake) to have pH of 5.0 or lower.

There are much more important reasons than acid rain, however, to explain their acidity. The Adirondack lakes in question are in poorly buffered and, therefore, naturally acidic watersheds. Their rocks are poor in lime-like substances; their watersheds are mantled by highly acidic, very thick peaty forest floors, and leaching of water through the soil produces a low-nutrient environment where acid-producing trees and plants, such as sphagnum mosses, are common. In fact, a recently completed multimillion dollar biological and chemical survey of over 1,400 Adirondack lakes and ponds observed a striking correlation between biology and acidity: sphagnum mosses are associated with acid lakes. Oak Ridge National Laboratory determined that acid Adirondack lakes tend to be concentrated in watersheds having coniferous forests and the most acidic soils.

Bark Eaters

Perhaps NAPAP's most important Adirondack studies have involved *paleolimnology*–examinations of fossil organisms and chemicals buried in lake sediment. The pH balances of earlier periods can be determined with considerable precision by examining algae fossils in conjunction with radioisotope dating, because different species of algae are present with different pH levels. These studies reveal that high-altitude Adirondack lakes, including Lake Colden and Woods Lake, have been fishless for most of their history. However, the lakes temporarily lost some natural acidity during the mid-to-late 19th and early 20th centuries, and during this period were filled with fish. Woods Lake, for instance, was acid-dead in 1850, long before there was acid rain. Beginning in the 1860s, the lake became gradually more alkaline, peaking at a 5.7 pH in 1910. It has since reacidified, and now has a pH of 4.8.

These findings are consistent with what we know from history. Indians never lived in the Adirondacks. The Iroquois word "Adirondack" means "bark eater;" the food supply, including fish, was never plentiful. Most Adirondack waters have always been cold and unproductive; the few excellent fisheries were generally confined to the few large lowland lakes and rivers. Initial European settlement and activity damaged what fisheries there were. For example, Atlantic salmon were eliminated from Lake Champlain by the 1830s, and lake trout have disappeared from the lake since 1880.

Since the 1800s, the Adirondacks have been well known for their massive stocking failures. Tens of millions of fish have been put into waters where they promptly died. Great Lakes whitefish were introduced as food for trout. But these whitefish grew too large for trout to eat. Competition from whitefish, along with fishermen's preference to catch trout, reduced or eliminated trout populations. Introduction of bass and yellow perch outcompeted and eliminated trout fisheries from many ponds and streams.

> *After lumbering and burning came to an end, forests grew back, and the soil runoff, and hence the waters, returned to their natural acidity. These changes in land use often dwarf in importance the impact of acid rain.*

Devastated Land, Fish in the Lakes

However, there were successful stockings of brown and brook trout in the mid-to-late 19th century, when the Adirondacks became a major center for lumbering and paper pulp–and also for the destructive slash-and-burn methods that until recently were typical of logging. Cutting was invariably followed by fires. Fuel was plentiful; left-over cuttings, and the luxuriant mosses and thick peaty forest floor, exposed to sun and air, became dry and highly flammable. In 1903, in a two-month conflagration rivaling Yellowstone's 1988 fires, Adirondack fires literally burned in their own updraft, like chimney fires sweeping up mountainsides. Witnesses compared the burning mountains to "smoldering volcanoes." The sun became orange; stars were blocked out at night.

The cumulative devastation was horrible. According to an official history published by the Adirondack Museum, "Logging and fires changed the Adirondacks more drastically and rapidly than any factors since these mountains first rose above the sea." The landscape was denuded, and severe erosion washed away the thin and rocky mineral soils.

Runoff from the land became much more alkaline. Forests gone, spongy and water-absorbent mosses and the acidic peaty forest floor were burned off and replaced by alkaline ash. The ironic result, though, was that sport fish could survive in lakes previously uninhabitable.

Unprecedented disturbance in the Adirondacks was then followed by unprecedented protection. Plans for the "Forever Wild" Adirondack Park and Forest Preserve were established in 1892, and the state of New York gradually acquired park land, much of it purchased literally at fire-sale prices from lumber and paper companies that were abandoning their devastated forests. Since about 1915, laws against cutting and burning have been seriously enforced. Forest fires are now put out quickly. As a result, the forests, acid peaty soils, and acid-requiring and acid-producing trees and mosses are coming back. And lakes that historically have been highly acidic are nearing their natural pH balances.

To add to the pressure on fisheries from natural acidification, the beauty of the mountains and improved public transportation resulted in a massive increase in the number of fishermen. Registration in Adirondack public campgrounds rose from 37,000 in 1927 to 950,000 in 1970. In addition, these campers were very uncomfortable with insects, particularly blackflies. DDT was mixed into cement bricks and deposited into the waters to slowly release DDT over the years to kill flies. Elimination of flies contributed to the disappearance of the trout that relied on them for food.

The Key to Lox

The experience in Nova Scotia is similar to that of the Adirondacks. Nova Scotia has more acid lakes and streams than any other area of North America; indeed nearly half its lakes have a pH lower than 4.7. Salmon have been disappearing as lakes and streams have become more acidic, and fingers are pointing to acid rain as the culprit. The concern is perfectly understandable, but the rain over Nova Scotia is only one third as acidic as that over the Adirondacks.

As in the Adirondacks, Nova Scotia has a history of slash-and-burn lumbering followed by reforestation, and a long history of fishery problems. A 1986 study of Nova Scotian fisheries by Environment Canada (the Canadian version of our EPA) noted the severe burning of forests in the province at the turn of the century, with 90 percent of southwestern Nova Scotia (where salmon depletion is most pronounced) then being mapped as treeless barrens.

Environmentalists who are concerned with preserving natural acidic aquatic ecosystems will be at odds with those who want to lime lakes and streams in order to go fishing.

The soils–little more than peaty forest floor and moss–were literally burned down to the underlying granite bedrock, leaving behind alkaline ash. By 1954, however, about half of the land was forested, and in 1970, 70 percent was forested. Effects on lakes were the same as in the Adirondacks: forest runoff, which had become more alkaline, returned to its natural acidic state. The process is confirmed in sediment studies, which again, as in the Adirondacks case, reveal that lakes are acidifying after a period when they were unnaturally alkaline.

Kejimkujik Lake, 10 square miles of water in the acid lake and river district of southwestern Nova Scotia, had a pH of 4.0 in 1850. In the decades thereafter, lake pH rose to about 5.0 with cutting and burning of the watershed. With forest recovery, the lake has reacidified slightly to pH 4.8. While the sediment record shows that Kejimkujik Lake has become somewhat more acidic over the past 30 years, it is still not as acidic as it was before cutting and burning.

Rivers of Hunger

Experience in Norway is also comparable. Acid rain clouds from Britain and Germany have been blamed for the recent depletion of trout in lakes in southern Norway. But this is not the first time these lakes had lost their fish. Viking legend is filled with stories of fishing lakes and streams that went barren as a result of "sinful" behavior. The medieval Norwegians even had a word for lakes without fish, "fiskelostjern." Sediment analyses of Lake Langtjern, the most studied acid lake in the country, show that it was more acidic 800 years ago (pH 4.3) than it is today (pH 4.7). Studies of two other Norwegian lakes show a sharp increase in acidity (from pH 5.5 to pH 4.5) between 1350 and 1500, when forests grew back because the plague of 1349 killed two thirds of Norway's population. Of the 12 Norwegian lakes with published sediment records, 11 were acidic prior to the industrial era.

Between 1850 and 1900, long before tall smokestacks and particle precipitators, there was a sharp increase in the acidity of many Norwegian lakes and streams, and a corresponding decline in fisheries. Geologist Ivan Rosenqvist developed the theory of changing land use to explain the phenomenon. After 1850 an exodus of population to the New World, combined with modern agricultural and forestry practices, put an end to traditional slash-and-burn methods that had been used to burn off acid soils and acid-producing vegetation. Marginal rocky and mountainous lands were abandoned and afterward were covered by lichens, moss, heath, and forest. Acidic peaty soils and acid-producing vegetation increasingly covered the landscape. According to Rosenqvist, it was these watershed changes that most affected the pH balance of surface waters.

The notion that acid rain is responsible for acidity in lakes and streams is also contradicted by the existence of highly acidic surface waters in regions without acid precipitation. Fraser Island, Cooloola National Park, and Tasmania in Australia, and the Westland area of New Zealand have no acid rain, yet are filled with highly acidic lakes and streams. Indeed, the magnitude of acidic surface waters in areas without acid rain dwarfs that of areas supposedly "devastated" by acid rain. In the Amazon basin, a river system the size of the Mississippi, the Rio Negro, is naturally acidic and fishless. The naturalist and explorer Alexander von Humboldt wrote of these "rivers of hunger" nearly 200 years ago, definitely predating industrial activity in this region.

Clear as Acid

The return to natural acidity in the lakes and streams of Nova Scotia and the Adirondacks is obviously a disappointment to sport fishermen. It is not clear, though, why acidification should otherwise be considered an environmental problem. Acidity frequently contributes to beauty, particularly the crystal clarity of acidic waters with little living in them. And swimmers do not face nuisances such as slimy green algae or leeches. Lake Colden and the other fishless High Peak lakes are the Adirondack Park's most visited. Similarly, the clear acidic lakes of the Cape Cod National Seashore (an area with almost as many acid lakes as the Adirondacks) are so popular that the National Park Service has deliberately underdeveloped swimming and hiking access to them to prevent overuse.

If, however, the loss of fish is considered a problem, then multibillion dollar controls on sulfur dioxide emissions are not the solution. Since lake acidification results much more from the absence of natural buffering than from acid rain, reductions in the sources of acid rain will not restore fisheries. According to NAPAP projections, a 30 percent reduction in rain acidity over 20 years would deacidify only 26 Northeastern lakes.

A much less expensive and more effective solution is to do what farmers and gardeners do with acid soil: add lime. Lime dropped by helicopter buffers acids in watersheds the same way that cutting and burning, or limestone in rocks and gravel, does. A NAPAP study estimates that all Adirondack lakes and ponds more acidic than pH 5.7 can be limed for $170,000 per year. Extrapolating to the entire Northeast, all acid lakes in New England and New York could be limed for under $500,000 per year.

Over the past several years, scientists have added lime to Woods Lake. But, as in most acidic headwater lakes, lime placed directly into the lake gets flushed out too quickly to be very useful. Therefore, in the fall of 1989, scientists limed the acidic soils surrounding Woods Lake so that the lime will slowly dissolve over time to wash alkalinity into the lake. It's a simple answer that is much less expensive than emission controls and has the advantage of working.

Similarly, the overall health of high-altitude red spruce forests can be improved by low-cost, low-rate application of a balanced neutral nutrient salt mix, as is being done in Europe. Liming is not appropriate in these forests because it can reduce acidity, thereby adversely affecting varieties of trees requiring acidity. Improved nutrient status enables forests to better resist all types of stress, from climate and disease to air pollution.

Of course, environmentalists who are concerned with preserving natural acidic aquatic ecosystems will be at odds with those who want to lime lakes and streams in order to go fishing. This conflict has come to a head in Cape Cod, where the National Park Service cites its mandate to "protect the natural ecosystems of its parks" in resisting pressure to "improve" acid lakes by liming. Liming would kill the sphagnum mosses that grow deep in the bottoms of these lakes. The question is whether we want sphagnum mosses or fish; we usually can't have both.

The response among most American and Canadian voters is almost certainly to be fish. If so, the central question for acid rain policy is this: Do we want to spend billions of dollars a year on emissions controls that won't put back fish in lakes and streams that used to have them? Or do we want to spend hundreds of thousands of dollars a year on a simple policy that will?

Edward C. Krug is a writer and consultant in Winona, Minnesota. He is currently completing a book on the acid rain issue. At the time the original article was written, Dr. Krug was a soil scientist with the Illinois State Water Survey.

Acid Rain Update: Watershed Liming Presents A New Alternative

There are new solutions to high acidity in streams and lakes. In the past, fish in many upstate New York lakes were lost after the water became too acidic. While some still argue whether this rise in acidity is due to changes in surrounding land use (reforestation) or to the impact of acid rain, most scientists are committed to counteracting its destructive effects.

The traditional method of reducing acidity is to treat the water itself by applying a limestone slurry. This method, however, has met with limited success. Spring rain and melting snow drain into restocked lakes, and acidity returns to its previous high levels, killing fish and their eggs.

Cornell biologist Carl Schofield approaches acidity from a different angle. By dropping limestone pellets throughout the watershed, Schofield attacks high acidity at a level one step closer to the problem's source.

Schofield drew his ideas from previous experiments in Great Britain and Scandinavia. Watershed liming provides an extended period during which the alkaline pellets gradually dissolve, allowing for greater longevity of treatment. His New York experiment, which includes Woods Lake, marks the introduction of this method of treatment to the U.S. If the results are consistent with those of previous experiments, the benefits of watershed liming may last five or more years. Since the effects of direct liming last about a year, watershed liming may well be more economical.

Critics argue that liming creates its own set of ecological problems. Increased levels of toxins and sediment have been demonstrated, as well as more frequent abnormalities in fish. In an argument not designed to appeal to fishermen, critics claim that liming destroys forms of life that thrive in more acidic environments. Artificial means of reducing acidity, however, could be replaced by a more active lumber industry. Perhaps this alteration of surrounding land use, although not necessarily politically palatable, presents the most direct solution to high acidity.