LINSLEY POND AS A LABORATORY LAKE

It has been some time -- some fifteen thousand years, in fact -- since caribou grazed over the Branford tundra and a glacier stood at the head of Linsley Pond. Lake trout and salmon may have been caught there in Connecticut's Stone Age, but if so, the last ones were caught, or suffocated, in the seventh millennium B.C. As a tourist attraction the pond may never again rival Lake Louise, though even today, after three suburban centuries, Linsley has more of the charm of Thoreau's Walden than Walden Pond has. A full-page portrait of the lake has been published in Scientific American; not satisfied with this, the world's experts on lakes-- a busload of them on one occasion -- have sought it out to photograph it for themselves. What draws them may be the fifty-nine separate references to Linsley Pond in the most recent and authoritative treatise on lakes; its author, and other connoisseurs, place Linsley in the select group (the Hausseen or laboratory lakes) that includes Lago Maggiore, Windermere, and the Lake of Geneva.

In 1936, when all this was started by G. Evelyn Hutchinson and two of his students, Linsley's chief attraction was its nearness to New Haven; the investigators were driving a 1929 Buick roadster at the time. Now, after more experience with other lakes, they find Linsley nearly unique in one respect: its small size. All lakes are smaller than the ocean, and their usefulness to science as miniaturized oceans is never far from the thoughts of limnologists. Most lakes that are deep enough to be stratified as the ocean is, though, are very much bigger than Linsley. Some elementary geometry will show that larger lakes have a little more bottom in contact with a great deal more water. If one is interested in a lake as a metabolizing system -- more complex than a rat, say, and somewhere between a fishbowl and an ocean in size -- what happens on and in the bottom is just as important as what happens in the water; but the influence of the bottom is harder to detect in a larger lake. So, being forbidden to scale down Windermere, the limnologist chooses a smaller model. What Linsley has that Lago Maggiore lacks is relatively more mud.

This mud, mainly made of dead plankton and tree leaves, accumulates so fast in Linsley that the lake has lost half its volume in 15,000 years. As pollen grains and other useful fossils are still buried where they fell, and can be recovered in borings, the historical record that results, stretched out to one millimeter per year, is rich in detail -- about a thousand times richer than the one in the deep ocean. Natural radiocarbon, produced by cosmic rays and built into vegetable matter, tells the dates; it does so by disappearing from fossil carbon at such a rate that half is gone every 5730 years.

But isotopes, being tagged atoms, are used to trace other properties than time. For instance, the air over Linsley (and everywhere

else in the Northern Hemisphere) contains about 25 percent more radiocarbon than it did before there were H-bombs, and water-lily leaves, breathing air, are as radioactive as tree leaves -- not dangerously, but detectably. The lake and its pondweeds have acquired almost none of this, however, because a small amount of groundwater, charged with radiocarbon-free carbon dioxide by contact with ancient limestone, trickles into the lake. In the competition between "hot" carbon in the air and old carbon from the ground, the old carbon wins, and keeps the lake less radioactive than the air.

In a lake as small as Linsley the deep water runs out of oxygen for most of every summer. Before isotopes, this annual shortness of breath was the main measure of a lake's metabolism. Mud does not accumulate so fast in a large, deep lake because more of it is oxidized before it reaches bottom. Carbon-13, a stable isotope that makes up about one percent of natural carbon (Carbon-14, radiocarbon, makes up only a trillionth) has been used to show how much of the mud that settles is oxidized at once, and how much is fermented in the depths to methane and carbon dioxide, and so restored to circulation. Though the fermentation proves to be appreciable, the net loss of organic carbon to the mud still amounts to about a quarter of the amount made annually by the plants. (The rest, after being recycled several times by animals and bacteria in the upper water, is exported to Branford River.)

The material lost is mostly carbohydrate (cellulose), but it contains some nitrogen, phosphorus, and sulfur (and a little copper, as Riley found several years ago). In other words, the buried mud is a sink for these important elements, as the ocean floor is for manganese and many others. Nitrogen has not been studied lately; some is known to be fixed in the lake by algae, as it is by bacteria on the roots of clover. Phosphorus, the scarcest of the essential nutrients, was studied by Hutchinson in 1943. Although some escapes from the mud (by becoming soluble as ferrous phosphate) when the deep water runs out of oxygen, the main fate of incoming phosphorus is to be quickly taken up by algae and then to settle out for good. This conclusion, based on several years' analyses, was confirmed in 1950, when an isotopic tracer (Phosphorus-32) was added to the surface water and all went to the bottom in a few weeks. Attempts had been made in several countries to fertilize lakes with superphosphate; these were given up as useless when Hutchinson's findings were published.

Recent evidence that much of the world's sulfur passes annually through the bodies of sulfur bacteria, as the carbon passes through green plants, has focused attention on the sulfur in Linsley Pond. A stable isotope, Sulfur-34, making about 4 percent of natural sulfur, has been a useful tracer. Again, it proves the mud to be a sink for incoming sulfur, but the process is not a simple settling out, as for phosphorus and copper. Instead, it appears that a major portion of the lake-water

sulfate is metabolized (reduced to hydrogen sulfide) by bacteria in the mud, but where some iron is present, as it is in Linsley, the sulfide is precipitated chemically as ferrous sulfide, accounting for the mud's black color. In other lakes the hydrogen sulfide may possibly escape to the atmosphere, as it evidently does from the sea (where it is known as "the smell of the salt"). A year's study of the income and outgo of sulfate in Linsley has been completed and artificial Sulfur-35, a more efficient tracer than Sulfur-34, is to be added to clinch the argument in the spring of 1963.

Linsley's animals and plants have been and will be examined in more conventional ways, as by identifying and counting them. The isotopic clues to their total metabolism have been emphasized because they are new, and add a new dimension to Linsley Pond's uniqueness. More could be said, too, about those fifteen thousand years of history, in which new kinds of fossils -- biochemical compounds such as sugars and pigments, that prove to outlive the organisms that made them -- are coming to be used. What began somewhat casually in 1936, in the deepest natural lake that happened to lie near New Haven, has become an intellectual investment that continues to grow at compound interest. Other lakes are under study for a variety of reasons, but comparison, the limnologist's substitute for the experimental method, has constantly to be made between them and Linsley Pond. And as new discoveries, like that of isotopic labelling, generate new ideas, Linsley is increasingly likely to be chosen as the model lake in which to test them. This is the reason why Yale's limnologists are now more interested than ever in its continued use as a laboratory lake.

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