Profile of David W. Schindler

All great stories require a little embellishment, and such is the case for an event illustrating the tremendous work ethic of limnologist David W. Schindler, the Killam Memorial Professor of Ecology at the University of Alberta (Edmonton, AB, Canada). In the summer of 1974, a series of forest fires sprung up around the lakes Schindler and his team were studying in western Ontario. One day, one of the firefighters informed Schindler that a helicopter water bucket had accidentally dropped into a lake. "He knew that I scuba-dived and asked if I would be willing to dive for it," says Schindler. "I said I would need half an hour to get my tank and gear together, and they sent a plane for me."

Everything started out well enough, but then, amidst the smoke and surrounding air traffic water-bombing the fires, Schindler's pilot misjudged the landing and crashed into a rock face, injuring them both. "I had at least a crack, I think, in every bone in my body," says Schindler. Yet, despite all that, Schindler returned to the lakes the next day, ready to resume his research. "People made a big thing out of the fact that I went back to work the next day," says Schindler, "but it was really just to get out of that hospital. It was a horrible place in a pulp-mill town, and the air quality was awful."

Still, no one can dispute the passion Schindler has for his research and the environment, which began when he was growing up in the 1950s in Minnesota lake country. Since 1968, he has used innovative whole-lake experiments to study the effects of eutrophication, acid rain, climate change, ultraviolet radiation, and nonnative species on lake ecosystems. Schindler's work has influenced ecology management policy in the United States, Canada, and Europe, and he has been recognized with some of the highest honors in his field, including the first annual Stockholm Water Prize in 1991 and the Volvo International Environment Prize in 1998. He is a member of multiple scientific societies, including the National Academy of Sciences, to which he was elected in 2004.

A great deal of Schindler's dedication comes from his personal stake in the lakes he studies and their surrounding boreal habitats. An outdoorsman, he enjoys fishing, hiking, and dog sledding—until a few years ago, he and his wife raised over 70 dogs at their rural Alberta home. Schindler knows the precarious state of the natural habitats that support these activities that

David W. Schindler. Image courtesy of Creative Services, University of Alberta, Edmonton, AB, Canada.

he and countless others enjoy. Throughout western Canada, for example, the quantity and quality of fresh water is gradually declining, potentially creating a water crisis in the near future unless measures are taken. Schindler and coauthor William F. Donahue address this important issue in Schindler's Inaugural Article in this issue of PNAS (1).

Three Books and a Calorimeter

Schindler's path toward lake science began with a peculiar twist. He excelled in science in high school, but his advisors recommended that he shy away from biology. "They said there are no careers in biology, all you could really be is a high school teacher," he says, "and, of course, that was anathema to a high school student in those days." After graduating from high school in 1958, Schindler went to the University of Minnesota (Minneapolis) to study engineering and physics. But a fortuitous visit to North Dakota State University (Fargo) set Schindler back on the biology track. Schindler met a limnology professor, Gabriel Comita, who wanted to set up a bomb calorimeter to do some experiments. "This was back when determining the energy content of organisms was all the rage," says Schindler, but Comita had no idea how to go about it.

Fortunately, Schindler had plenty of calorimetry experience from his physics laboratory classes, and he was hired to help set up Comita's experiments over the summer. "I thought it was a really good deal because I could live at home, save a lot of money, and be around my beloved lakes," he says. That summer, Schindler went out into the field and collected various aquatic invertebrates to run in the calorimeter. "But, this being the preelectronic age, on these calorimeter runs, I'd have to sit and take a temperature reading every few minutes. In between, I'd pick things off of [Comita's] bookshelf" to read, says Schindler. The first book he read was Charles S. Elton's *Ecology of Invasions by Animals and Plants* (2), and he subsequently read part of Hutchinson's and Edmondson's *A Treatise on Limnology* (3) and part of Niko Tinbergen's *Animal Behavior* (4).

Comita's bookshelf truly inspired the young scientist. "Having read all these books, I was a convert. From then on, I knew exactly what I wanted to do," Schindler says. He transferred to North Dakota State, switched to zoology, and continued his research with Comita. "And to this day, I can't figure out why Elton's *Ecology of Invasions* is so little known outside of scientific circles and Rachel Carson's *Silent Spring* (5) is so well known. Elton's book is better written, and it treats a much more important problem," says Schindler.

Those three books by Elton, Hutchinson and Edmondson, and Tinbergen would return to Schindler's life a couple of years later. "One day I was sitting in Comita's office talking about graduate school," he says, "and I mentioned that it must be really fun to study with people like Elton or Tinbergen. And then he said, 'Well, maybe you could.'" Comita rummaged through one of his drawers and handed Schindler an application for a Rhodes Scholarship. "At that time I had never heard of a Rhodes Scholar, but I thought I would give it a try, and I succeeded," Schindler says. After receiving his bachelor's degree in zoology from North Dakota State in 1962, he traveled to Oxford University (Oxford) to meet the people whose written words had greatly influenced him.

At Oxford, Schindler initially began working under Tinbergen, whom he says was a marvelous individual. Schindler, however, wanted to work in the field, but Tinbergen's behavioral studies of fish were all laboratory-based. Schindler then joined Elton's group at Oxford, the Bureau of Animal Populations, where Schindler undertook an ecosystems approach to lakes. After developing some laboratory models, he spent a year in Minnesota trying to apply them to

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This is a Profile of a recently elected member of the National Academy of Sciences to accompany the member's Inaugural Article on page 7210.

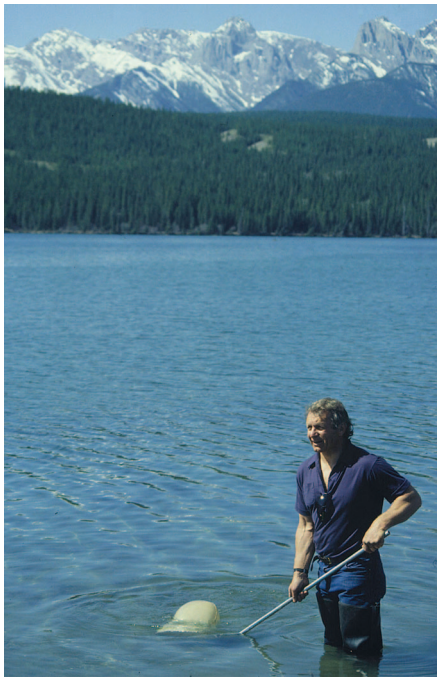
Severson Lake, a small lake that Comita had studied. "Unfortunately, there were all sorts of things happening to that lake while I was studying it to make my models not work. I think the lesson I learned is that it was much more important to study lakes and try and figure out how they worked than to apply fancy mathematical models to them," Schindler says.

The Experimental Lakes Project

The summer before his final year at Oxford, Schindler traveled back to the United States to look for postdoctoral or assistant professor positions. He found leads at both the University of Michigan (Ann Arbor) and Yale University (New Haven, CT), but he noted that "those big urban areas were just a bit much for a hillbilly from Minnesota," says Schindler. He found a position at Trent University, a small university that had just opened in Peterborough, ON, in Canada. The location was perfect for Schindler. "It was a very, very rural setting with a huge variety of lakes, many of them in untouched basins, and a huge variety of geological and physiographic settings as well," he says.

Just after joining Trent University, the Fisheries Research Board of Canada opened a laboratory in Winnipeg, MB, called the Freshwater Institute. Schindler was intrigued by the eutrophication studies that were going to be a point of major emphasis for the institute. However, the first time Schindler interviewed, he felt that the station was not quite well developed enough to join, and he did not feel like returning to the same kind of terrain that he had grown up around most of his life. When Schindler reinterviewed in 1968, though, he was invited to head an experimental lakes project to be based in a wilderness area in northwestern Ontario. Schindler could not pass up the chance to undertake large-scale, whole-lake experiments, something never done before. "By that time, they had also put together a stellar staff of senior scientists," he recalls. The Eutrophication Section was headed by well known ecologist Jack Vallentyne, who had recruited a group of about 15 senior scientists from around the world. "I was one of the two or three youngest members of the group, and it was just a terrific environment for a young scientist to be in."

Over the next two decades, Schindler and his team conducted a continually evolving series of experiments on the 46 test lakes that made up the Experimental Lakes Area (ELA) in western Ontario. The initial research focus was on eutrophication, and within a few years Schindler had revealed phosphorous,



Schindler sampling in Talbot Lake, Jasper National Park, Jasper, AB, Canada.

which can originate from detergents and sewage treatment plants, as the major culprit of this process. Schindler and his colleagues demonstrated that excess phosphorous and nitrogen stimulated the algal communities of lakes to take in vast amounts of carbon dioxide from the atmosphere, and likewise cyanobacteria could shift to fix more atmospheric nitrogen if ionic nitrogen was in short supply (6). "Basically, the lakes were capable of evolving communities that allowed them to have enough carbon dioxide and nitrogen to balance the added phosphorous, whereas the reverse

"[The public] ought to see what science yielded. . . ."

was not true. There were no biogeochemical mechanisms by which lakes could pull in atmospheric sources or phosphorous to correct any deficiencies," he says.

The most convincing result came from a double-basin experiment in 1973 in which Schindler essentially separated a lake, dubbed Lake 226, with a giant shower curtain and treated one half with carbon, nitrogen, and phosphorous and the other half with carbon and nitrogen only (7). Aerial photographs captured the dramatic results: the phosphorous-treated half of the lake had become green and murky because of algal blooms, whereas the other half of the lake remained clear. Pictures can speak a thousand words, and the stark contrast of the two sides of Lake 226 caught the public's eye and policymakers' collective ear.

Little did Schindler realize that he would become a spokesperson for the Fisheries Research Board. Initially, Jack Vallentyne handled the public relations duties; however, in 1970, the Fisheries Board evolved to become a civil service organization under Fisheries and Environment Canada, and Vallentyne decided that he could not manage within that system. "One day he just came in and announced that he was leaving and told me, 'This public interaction stuff is important, but you have to do it now,'" says Schindler. He admits that he was not particularly inclined to take over the public relations side of things. "I'm really a pretty introverted person," says Schindler. But he felt that somebody had to do it. "I've always believed that the public puts up the funds for science, and they ought to see what science yielded that was relevant to them," he says.

When Schindler took over speaking about lakes and their management, the battles over eutrophication had already begun to go through the legislatures in both Canada and the United States. Schindler began testifying often at legislative hearings. Fortunately, although he may not have had the desire for public relations, Schindler's rural roots gave him the necessary talents to speak effectively, with his direct, almost brusque conversational style and ability to avoid scientific jargon. "Of course, the pictures of whole-lake experiments were very convincing and cut through a lot of the propaganda," he says. The ELA experiments helped to pass laws in Canada and the United States to limit the use of phosphorous in detergents and required phosphorous removal in large sewage treatment plants.

Troubles from Above

Despite the ELA project's successes, however, Schindler was somewhat horrified to hear talk from legislators about possibly shutting the ELA down. "So we decided it was time to find a new mandate if we wanted to keep whole-lake experiments going. That new mandate turned out to be acid rain," he says. Schindler perceived that a major gap in the acidification research up to that point was due to the fact that almost all of the work on organisms was focused on individual species rather than on food-chain interactions. Beginning in the

late 1970s, Schindler designed a set of landmark experiments to show that some food chains were so sensitive that eliminating one or two species could disrupt the whole pathway supporting organisms that the fisheries considered important (8). Once again, dramatic results and dramatic pictures of starving fish helped bring about public attention and legislation aimed at stricter air quality standards.

The ELA continued working on acidification and eutrophication research throughout the 1980s. The ELA also expanded to other areas such as the effects of heavy metals and forest fires on lake ecology, the latter being the consequence of the various wildfires damaging some untreated reference basins (9). More important than these damage studies, however, were the positive results seen in the recovery experiments, a requirement under the ELA lease agreement. In the case of eutrophication, lakes began recovering as soon as nutrient input stopped, and they eventually returned to normal within 1–2 years (10). The acidification recovery has been slower but is still progressing better than expected. "The biogeochemists of the day were saying that once lakes were acidified they could never be recovered," says Schindler, "and, while they were correct that some of the geological mechanisms buffering lakes from acidifying were destroyed, we showed that there were microbial mechanisms that people had not thought about that would allow at least partial recovery of the lakes (11, 12)."

But although the science went fairly smoothly, the public policy side had a far bumpier road. Invariably, a politician or bureaucrat was at odds with Schindler or his research. "Canadian bureaucrats didn't like what I had to say about acid rain," he cites as an example. Regarding acceptable target levels proposed by governments for aquatic sulfate deposition, he says, "Our experiments indicated that the target wasn't good enough, and a review that I wrote for *Science* in 1988 (13) also indicated that it was not good enough." After this event, Schindler remembers having trouble receiving permission to travel to hearings in the United States, and Canadian External Affairs demanded to screen any document that he planned to use in his talks. "I finally took this to a lawyer who advised me not to become a Canadian citizen, [saying] 'just continue on your U.S. citizenship. Take a day's holiday when you're going down to the U.S.A. to testify, and they can't touch you,'" says Schindler.

By 1989, these governmental efforts to muzzle his criticisms and continual efforts by fisheries management to cut funding had left Schindler jaded. Then, the University of Alberta offered both Schindler and his wife, Suzanne Bayley, a wetlands scientist, academic positions. The move allowed Schindler to leave civil service and provided stability for his wife, who had been working without a salary on "soft money" for the past 10 years. Moving closer to the Rocky Mountains also gave Schindler an opportunity to shift his research toward alpine lakes, an ecosystem he had been fascinated with for a long time.

Dry Canada

One of the first projects Schindler started in Alberta would have made his former advisor, Charles Elton, proud. Nonnative fish species had been stocked into many alpine lakes for recreational purposes, and Schindler found that they wreaked havoc on the food chain. He proposed to conduct whole-lake experiments to examine whether he could remove these fish stocks and restore the natural communities (14, 15). He also began studying pesticides and other chlorinated compounds in sub-Arctic and alpine settings. "Some of these compounds are deposited in greater quantities at high elevations (16). They were also stored away in glaciers in the '50s and '60s, when things like DDT and PCBs were in widespread use. And now, with climate warming, those deposits are beginning to melt out into alpine lakes and rivers (17)," Schindler says.

More recently, he has returned to eutrophication, which has experienced a resurgence in Alberta. While eutrophication legislation in the 1970s focused on the threat of detergents and municipal sewage to the Great Lakes in Canada and the United States, increased phosphorous use for agricultural purposes in the west was going largely unchecked. "No one thought to regulate it, and, of course, with the rapid development in livestock and rapid land clearing and conversion to cropland in the west, eutrophication is alive and well. The center of concern has just shifted," he says.

Concern might be an understatement, as Schindler believes that decreases in the quality and quantity of Canada's freshwater supply might be the largest crisis facing that nation in the upcoming century. In his PNAS Inaugural Article (1), Schindler and Donahue examined historical flow records for many rivers in the prairie provinces, as well as climate change and its effects in the northern regions. "I think we were shocked by how extreme the changes in river flows had been," says Schindler. "In the best cases we examined, there was a decline in summer flow by 30% during the 20th century, while the worst case had a decline of 85%." Schindler notes that some of the areas most affected by this decline are some of the fastest growing municipalities in Canada.

Although he is not required to put his work into the public eye, Schindler does his best to get his research and messages out to the general public. Every year, he gives as many public talks as scientific talks, and he tries to write as many popular articles as scientific ones, including pieces in major newspapers. He admits he still does not particularly like public speaking and dealing with the controversies but says, "What drives me to do this stuff is seeing all of this good environmental science lying around on shelves in ivory towers that nobody puts into practice."

Nick Zagorski, *Science Writer*

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