BIOGRAPHICAL MEMOIRS

David W. Schindler

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A Biographical Memoir by Stephen R. Carpenter, James J. Elser, and Daniel E. Schindler

David "Dave" W. Schindler contributed fundamental knowledge about causes and consequences of lake eutrophication and acidification using whole-lake experiments. The clarity of the experiments and power of the evidence motivated policymakers to address important environmental problems. His work transformed our knowledge of inland waters and changed the careers of generations of students.

Figure 1 David W. Schindler at the University of Alberta. *Photo by John Ulan. Courtesy of the University of Alberta.*

Early Life and Education

David William Schindler was born on August 3, 1940, in Fargo, North Dakota, across the Red River from Barnesville, Minnesota, where he was raised in a farming family. His father, Edward Schindler, was the mechanic and accountant for a potato and sunflower farm and warehouse he owned with his two brothers. Dave's mother, Angeline, was a music teacher who preferred the comforts of living in town to the rigors on the family farm. Dave's disdain for the "big city" (Barnesville's population was about 1,000 at that time) motivated him to escape to the farm to live with his grandmother, Mary (Koenig) Schindler, who nurtured his independence and encouraged him to read widely when he wasn't rambling outside.

Childhood life on a farm was filled with recurrent physical and practical challenges, all of which helped develop Dave's sense of confidence that most problems could be resolved through parsimonious disassembly and some trial and error. Dave was a restless child with insatiable energy and curiosity. In his leisure time, he played school sports, excelling in wrestling and football and competing in both at college. He tolerated school attendance just enough to maintain his standing, which was hard to deny because of his excellent grades. Farm activities provided legitimate excuses for cutting school, and Dave found any reason he could to spend time with the itinerant farm workers who camped under the local railroad bridges and caught fish from nearby streams and ponds. Routine adventures included hopping trains to neighboring towns to scout for new places to fish and hunt, years before he was old enough to possess a driver's license. A family cabin in northeastern Minnesota offered additional opportunities to pursue his early fascinations with lakes and

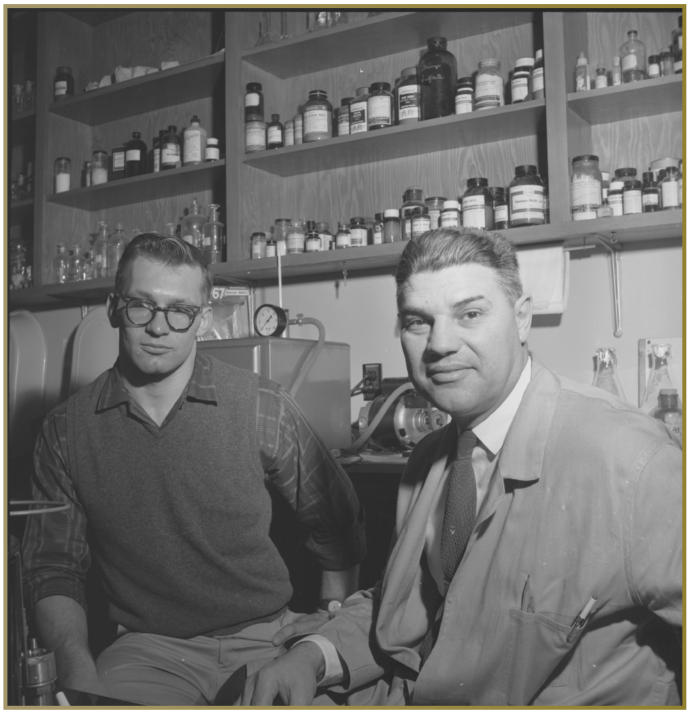

Figure 2 David Schindler and Gabriel Comita at North Dakota State University in about 1960. *Photo courtesy of North Dakota State University Historical Archives.*

solitude. Prophetically, a month-long fishing trip during high school (with a German farmhand who was sent by Dave's grandmother as the chaperone) to the Canadian Shield in northwestern Ontario captured Dave's imagination and kindled his lifelong passion for protecting the boreal forest.

A football scholarship to the University of Minnesota took Dave to Minneapolis, an unfathomable place to live for a farm boy. A year of boredom with the rigid structure of an engineering degree and his longing for the wide-open landscapes of home convinced Dave to transfer to North Dakota State University (NDSU) to pursue a degree in biology. He was back in his comfort zone (even as a middle-aged adult, Dave never understood why the Coen brothers' movie *Fargo* is hilarious!). A serendipitous encounter with professor Gabriel Comita provided Dave's first research opportunity in ecology, exploring the energetics of lake food webs (Figure 2). Comita recognized Dave's academic potential and encouraged him to apply for a Rhodes Scholarship to pursue a doctorate at Oxford University, which he was awarded in 1962 in recognition of his excellence in academics, wrestling, and football. Dave's younger brother, James, was also awarded a Rhodes Scholarship a few years later, making them one of the few U.S. families to earn this double recognition.

At Oxford, Dave convinced Charles Elton, arguably the most influential ecologist of that era, to accept him into his research group. Despite the rigid social norms of Oxford, Dave flourished and thrived in the intellectual environment it provided. His doctoral research took him back to northern Minnesota for the summer field seasons, during which he studied the ecological energetics of zooplankton in the ponds and lakes that had provided those childhood fishing experiences. During a summer field season back in Minnesota, Dave met Käthe Dietrich, a visiting language instructor at NDSU. They married soon after and would have three children together: Eva, Daniel, and Rachel.

Dave began his first academic job at Trent University in Peterborough, Ontario, in 1966. The "lake country" of southern Ontario and displeasure with the American politics of the time attracted him to Canada, and he lived there for the rest of his life. Though he served on the faculty for only two years, Trent established an endowed professorship in Dave's honor several decades later. Dave was lured away from Trent by a job offer from Jack Vallentyne and Wally Johnson, then with the Fisheries Research Board of Canada, a Canadian federal government agency. The vision of Vallentyne and Johnson was to establish a field station in northwestern Ontario, as far away from human influence as was practical, to use entire lakes as experimental units to study how they responded to and recovered from human perturbations, particularly pollution.[1] This approach to whole-ecosystem experimentation was pioneered by Arthur D. Hasler, Johnson's graduate advisor at the University of Wisconsin-Madison where Johnson personally observed the power of whole-ecosystem experiments to provide policy-relevant information.[2] At about the same time another distinguished student of Hasler's, Gene E. Likens, was inspired to establish the Hubbard Brook Experimental Forest research program for whole-watershed experiments.[3]

Soon after his appointment to the Experimental Lakes Area (ELA), Dave was invited to lead an experiment to determine the cause of eutrophication, a topic of some considerable controversy at the time and a focal point of much research today. It is perhaps the issue to which Dave made his largest contributions to ecology and environmental policy. The role of key nutrients in structuring ecological systems remains of fundamental interest while, to this day, nutrient oversupply remains the most pervasive driver of degraded water quality in the world. In the 1960s and 1970s, persistent blooms of cyanobacteria plagued the lakes and coastal waters of North America, Europe, and beyond. Attention turned to the role of pollution from sewage, bringing organic matter as well as nitrogen and phosphorus. Identifying the culprit was a high priority but the waters of debate were cloudy. Many scientists argued for phosphorus as the key driver, due to its well-known role in fertilizers supporting abundant plant growth. However, phosphorus (as phosphate) was also a key ingredient in laundry and dish detergents to "make your whites whiter than white" by softening hard water to make detergents more effective. Industry representatives argued that algal blooms were driven by the nitrogen that is abundant in sewage, with P playing a secondary role.[4] While algal abundance was well-known at the time to be most closely correlated with lake P concentrations and Dave made the argument that algal photosynthesis could draw on a vast reserve of atmospheric CO_2 to replenish C if it were lacking while N-fixing cyanobacteria could do likewise for nitrogen, no amount of dueling testimony based on correlational studies, small-scale "bottle" experiments, or derived from logic alone resolved the issue.[5] An experiment to separate the effects of P from those of organic C and N at the ecosystem scale was needed.

Dave set to work and identified Lake 226 as suitable for its convenient dumbbell shape, allowing it to be separated into two basins with the installation of an impermeable curtain. One side received inputs of inorganic nitrogen and of organic carbon (as sucrose) at levels mimicking those in sewage pollution. The other side received identical inputs but also phosphorus (as phosphate) in appropriate proportion. The results were spectacular (Figure 3).[6] Following the release of what one of us (JJE) called "the single most powerful picture in the history of limnology," the ramifications were almost immediate and far reaching.[7] The lower basin clearly shows the bright green algal bloom produced by the addition of phosphate. Starting in Canada, bans on phosphate detergents and mandates for advanced wastewater treatment targeting phosphate removal were implemented throughout the world, starting first in the Great Lakes Basin after a recommendation from the International Joint Commission. In subsequent years, many lakes experienced improvements in water quality, a prime example being Lake Erie, where cyanobacteria blooms that had become pervasive in the 1960s and 1970s waned during the 1980s and 1990s. In presenting the 2008 Killam Annual Lecture, Dave highlighted the eutrophication work as one of the biggest success stories in environmental science and policy. Of course, the world is complex and so is science. Lake Erie once again produces cyanobacteria blooms; nutrient pollution persists because the predominant source of nutrients has shifted from easily controlled point sources such as sewage outfalls to nonpoint sources such as agricultural runoff.[8] Furthermore, the aquatic sciences remain robustly engaged in a renewed technical debate about the relative roles of phosphorus and nitrogen in driving eutrophication, focusing on inherent constraints on nitrogen-fixation or on the impacts of denitrification.[9,10] As would be expected, Dave engaged actively and forcefully in these discussions, which are ongoing.[11,12]

Figure 3 "The single most powerful picture in the history of limnology." This aerial view of dumbbell-shaped Lake 226 (Experimental Lakes Areas, Canada) to which organic carbon and inorganic nitrogen were added to both sides of the divided basin, with phosphorus added only to the lower basin and producing the bright green algal bloom. *Photo credit: E. DuBruyn, Canada Department of Fisheries and Oceans. Courtesy of IISD Experimental Lakes Area.*

By the 1970s, it was clear that acidic precipitation was an extensive environmental problem in the United States and northern Europe.[13] In 1973, Schindler began a series of whole-lake experiments to study early effects of acidification on biogeochemistry and food chains. The research showed that crucial animals in the food chain, the opossum shrimp (*Mysis relicta*) and the fathead minnow (*Pimephales promelas*), stopped reproducing at pH 6. As a result, lake trout (*Salvelinus namaycush*) began to starve well above the pH threshold of 5.1 for direct toxicity.[14] Thus, acid precipitation posed a severe threat to a crucial fishery. These whole-lake experiments demonstrated that ecosystem responses to pollution were often propagated through the tangle of indirect interactions that characterize communities—interactions that are notoriously elusive to understand when studied at constrained experimental scales.[15,16] Like the eutrophication experiments highlighting the importance of gas exchange between lakes and the atmosphere for understanding how lakes respond to nutrient pollution, the acidification experiments emphasized the importance of biogeochemical exchanges between the water column and lake sediments for enabling recovery from perturbation.[17] Whole-lake experiments revealed the embeddedness of aquatic ecosystems in the atmosphere and the landscape. The ELA acidification experiments, combined with research in the United States and western Europe, led to policies for regulating acid emissions into the atmosphere.[18]

ELA was a special place not only because of Dave's leadership but because the project members took a truly interdisciplinary approach to tackling ecosystem science problems. As many as a dozen Ph.D.-level scientists were involved in all the big experiments. Many of them were highly specialized disciplinarians. Dave was the synthesist who held these groups together and inspired them to collaborate to find the answers to the big questions. The long time series of high-quality observations provided new insights of global change[19] and a series of innovative experiments that continues as we write in 2025.[20]

In 1989, Dave and his second wife Suzanne Bayley (a wetland ecologist) packed up their kennel of over 100 racing sled dogs and left ELA to join the faculty at the University of Alberta, where he served as the Killam Memorial Chair and Professor of Ecology. There he advocated for ecosystem research at realistic space and time scales that were relevant for environmental policy.[21] In Alberta, Dave focused his work on the major regional threats to aquatic ecosystems, including strengthening environmental impact assessments of the pulp and paper industry, industrial development of the oil sands,[22] the developing water scarcity and climate crisis in Canada,[23,24] and non-native species in Canada's mountain parks. Much of these efforts involved deep collaboration with the Indigenous communities who, given their subsistence livelihoods, are particularly vulnerable to industrial contamination of aquatic resources. Dave disdained the distinction of "pure vs. applied" research; he believed that fundamental discoveries could be made studying problems with direct application to policy, particularly in collaboration with the people who were most affected by threats to ecosystems.

Dave was an effective communicator of scientific research, with more than 300 scientific publications and countless interviews and commentaries in the public media. He was deeply motivated to engage with decision makers and the public to amplify the social impact of his science. He received more than 100 prestigious awards, including the inaugural Stockholm Water Prize, and was named an Officer of the Order of Canada. He was a fierce advocate for Canada's Indigenous people, whose treaty lands and freshwater resources were affected by the actions of others. Dave was a giant of environmental science whose legacy endures in our science and in our public policies. We are fortunate to have known him as a collaborator, mentor, and friend, and for D.E.S., as a father and role model. Also fortunate are all who enjoy the many benefits of clean and healthy lakes and rivers that his research enabled.

Acknowledgments

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