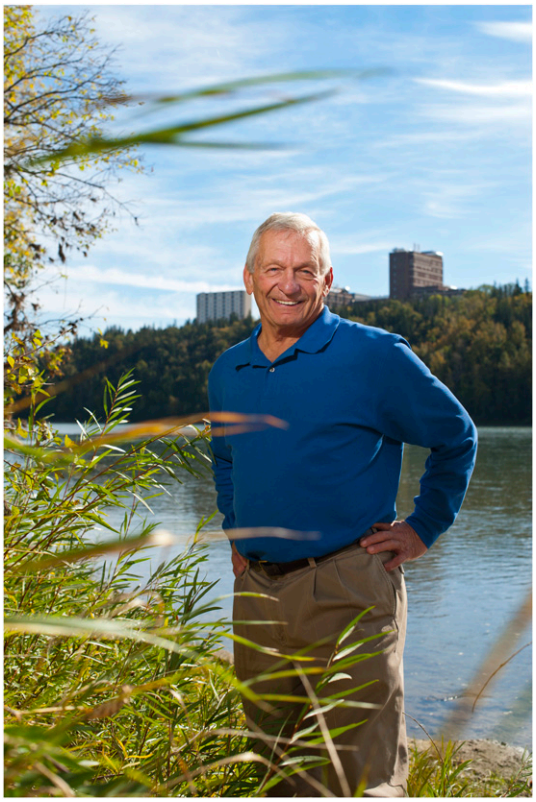
David W. Schindler (1940–2021): Trailblazing scientist and advocate for the environment

Karen A. Kidd[a,1], William F. Donahue[b], Erin N. Kelly[c], Peter R. Leavitt[d], and Heidi Swanson[c]

On March 4th, 2021, the global aquatic sciences community lost one of its most influential scientists, David W. Schindler. Dave's landmark research that led to better protection of fresh waters around the world, his uncanny ability to identify, raise the profile of, and address key crises in aquatic sciences, and his tireless education of the public and decision makers on environmental issues have left an unmatched legacy.

Throughout his monumental career, Dave's research shone a light on the ecological crises unfolding in freshwater ecosystems. His trailblazing approach included listening to those who were closest to the environment or a problem he was working on, particularly the wisdom of Indigenous knowledge holders, applying science in a way that was respectful of Indigenous ways of knowing, and using research findings and his own reputation to amplify their voices and effect more holistic stewardship. Much to the chagrin of some politicians and industries, Dave's remarkable scientific acumen was matched by his tireless commitment and formidable ability to raise public awareness of environmental issues. For him, fresh waters had to be protected, and to do so, science had to be communicated: it was this moral conscience and *modus operandi* that underpinned Dave's decades of effecting real-world change. For many years, he was the most quoted Canadian academic in the media, a measure of his unwavering commitment to putting science in the public eye and one that was recognized with the Royal Canadian Institute's Sandford Fleming Medal for communication of science. Dave "always believed that a scientist can be an advocate," and he practiced what he preached.

Dave grew up on a farm in northern Minnesota, spending his formative years working with his hands and stomping around the forests and lakes, while also excelling at school and in sports. A fateful fishing trip as a teenager with the hired farmhand to northwestern Ontario's Lake of the Woods region inspired a lifelong attraction to that part of the world. Dave's excellence in academics and athletics led him to initially enroll in an undergraduate engineering–physics program, while competing in varsity football and wrestling. But a summer undergrad job and a happenstance reading of Charles Elton's *The Ecology of Invasions by Animals and Plants* (1) inspired him to switch to ecology.



David W. Schindler. Image credit: John Ulan (University of Alberta, Edmonton, AB, Canada).

Dave's path took him to Oxford on a Rhodes Scholarship, where he received his Doctor of Philosophy in 1966 with Charles Elton, then to Canada to spend 2 years as a professor at Trent University. From there, Jack Vallentyne recruited Dave in 1968 to be the founding director of the Experimental Lakes Area (ELA) research station, then part of the Fisheries Research Board of Canada. After a nationwide hunt for a suitable location,

[a]Department of Biology, School of Earth, Environment, and Society, McMaster University, Hamilton, ON L8S 4K1, Canada; [b]WFD Consulting, Nanaimo, BC V9T 5L6, Canada; [c]Department of Biology, University of Waterloo, Waterloo, ON N2L 3G1, Canada; and [d]Limnology Laboratory, University of Regina, Regina, SK S4S 0A2, Canada

Author contributions: K.A.K., W.F.D., E.N.K., P.R.L., and H.S. wrote the paper.

[1]To whom correspondence may be addressed. Email: karenkidd@mcmaster.ca.

Published May 20, 2021.

they returned to the site of Dave's childhood fishing trip and established the ELA in northwestern Ontario. With the mandate to create an unparalleled experimental facility, Dave selected the initial 46 lakes and watersheds from hundreds surveyed, coalesced a blue-ribbon scientific team, and embarked on transformative, whole-ecosystem experiments to address issues of global concern, starting with eutrophication and soon following with acidification.

In 1989, frustrated by increasing bureaucratic interference in ELA operations and science, Dave and his wife, wetland ecologist Suzanne Bayley, accepted faculty positions at the University of Alberta, where Dave became the Killam Memorial Chair and Professor of Ecology (1989–2013). He retained a lifelong personal and scientific connection to the ELA and reminded us many times that "you'll learn a lot more from studying one lake than you ever will studying 20 jars on a windowsill."

Dave's reputation as a visionary in limnology was cemented by his four greatest contributions: the critical role of phosphorus in causing eutrophication of lakes, the sensitivity of lake food webs to acid rain, the role of climate change on freshwater ecosystems, and the environmental effects of oil sands development. These achievements were driven by his unwavering belief that environmental scientists have a responsibility to focus on the considerable real-world problems that society faces. During a time when there was considerable debate about the merits of "applied" research, Dave always believed that basic discoveries could be made by working on policy-relevant problems.

In the 1970s, when algal blooms were choking Lake Erie, controversy erupted about the nutrient responsible for lake eutrophication. This debate, and industry's insistence that carbon was the culprit and not its phosphorus-laden detergents, fueled Dave to conduct several whole-lake studies. The most impactful study was the fertilization of Lake 226, a narrow system that Dave and his team divided into two basins using a vinyl curtain. For several years, one basin received carbon and nitrogen, while the other additionally received phosphorus. The aerial image of the algal bloom only in the phosphorus-enriched half is undoubtedly the most impactful in the aquatic sciences (2). This photo, as well as Dave's countless hours in congressional hearings and public meetings, convinced decision makers worldwide to reduce phosphates in detergents and municipal wastewaters. This success was driven by Dave's dogged determination and unmatched ability to communicate complex studies in a way that made sense to nonexperts. One of Dave's many mantras was: "If you can't explain it simply, you don't understand it well enough."

Acid rain was the next major issue that Dave tackled, again through whole-ecosystem experiments mainly in the 1980s. Here, Dave and the ELA team showed that the acidification of lake water slowly removed key members of the aquatic food web, changed paths of energy flow, and starved iconic lake trout (3). These results unequivocally showed that damage from acid rain can occur at a much higher pH than previously believed based on laboratory studies. Dave was again indefatigable in conveying these results, using plain language and striking photographs when he presented to legislative assemblies, despite organized opposition from the power industry. His actions changed environmental legislation in several countries, including the US 1990 Clean Air Act that reduced emissions of acidifying substances from smokestacks and acid rain (4), and the Air Quality Agreement between Canada and the United States in 1991.

Dave's focus on climate change was literally sparked from protecting the ELA camp from rogue forest fires, which seemed to be increasing in frequency, intensity, and scale in the 1980s. By initiating meteorological monitoring and regular measures of water quality and food webs in ELA's reference lakes, Dave lay the foundation for what became an unparalleled documentation of the multidecadal effects of climate change on boreal aquatic ecosystems. He and his ELA colleagues showed how changes in precipitation and runoff altered the fundamental chemistry and biota of small lakes. Ultimately, his concerns about climate change, combined with his passion for water protection, culminated in a synthesis publication of the interactive threats of climate change and unsustainable water use and management to water supplies and aquatic ecosystem health in west-central Canada (5).

Dave did not shy away from controversy or highly politicized issues, and in the 2000s he turned his attention to oil sands mining upstream of the Peace-Athabasca Delta, a UNESCO World Heritage Site and a vital ecosystem for Indigenous communities. Results from the early science-based regional monitoring program indicated oil sands developments were not affecting the Athabasca River system. However, traditional knowledge holders downstream were experiencing changes to their environment. Dave listened closely to communities, reviewed the monitoring data, and then conducted studies that demonstrated increasing concentrations of some metals and polycyclic aromatic hydrocarbons in the Athabasca River and its watershed, a finding initially denied by companies and government (6, 7). His actions resulted in oil sands monitoring programs being overhauled to better understand downstream and downwind effects. These hard-won changes arose from Dave communicating the results of his research to the public, while simultaneously advocating that the people who live on the land and water know it best. He was an incredible ally and advocate for Indigenous communities, and was far ahead of his time in valuing, respecting, and linking their knowledge to science to support real and meaningful policy changes.

Dave was widely recognized and praised for his groundbreaking science, devotion to science in the public interest, and commitment to environmental conservation. International recognitions included the inaugural Stockholm Water Prize and the Volvo Environment Prize. Top recognitions in Canada included the Gerhard Herzberg Gold Medal, awarded to Canada's top scientist, and his appointment to the Order of Canada, the country's highest civilian honor. Some of his other accolades included the first Frank Rigler Award from the Canadian Society of Limnologists, the inaugural

Romanowski Medal from the Royal Society of Canada, the Canadian Nature Federation's Douglas Pimlott Award for Conservation, a Lifetime Achievement Award from the Canadian Institute for Environmental Law and Policy, the Outstanding Achievement Award of the American Institute of Fisheries Research Biologists, the G. E. Hutchinson Medal from the American Society of Limnology and Oceanography, and the Rachel Carson Award from the Society of Environmental Toxicology and Chemistry. He was also recognized with memberships to national academies of Canada, the United States, United Kingdom, and Sweden, and a baker's dozen of honorary degrees.

Dave's intensity, intellect, and athletic prowess made him an intimidating figure, a fact he often used to his advantage. Indeed, he has been described as a "smoldering volcano" and "fearless crusader," with boundless energy for life and his passions. Equally important was his sense of humor, shoulder-shaking chuckles, love of telling jokes, and cuttingly funny one-liners muttered in a clearly heard stage-whisper. Dave would giggle about keeping the heat turned down to near freezing levels in his office to drive out unwanted guests, and was renowned for his introductory seminar at the ELA, which he described as an ecosystem with him as its apex predator! And that was Dave: an exceptional "force of nature" who loved to laugh.

We first met Dave in the 1990s and 2000s as graduate students and postdoctorates at the University of Alberta. By then he was already a scientific giant, having published hundreds of papers and received many awards. He was a champion for transformative experiments and environmental monitoring that uncovered ecological problems and the solutions to fix them. His effective communication and fearless advocacy informed and inspired many to take action on environmental issues, and Dave's contributions to the protection and restoration of aquatic ecosystems cannot be overstated. He was an inspirational, lifelong mentor to each of us. The life of Dave W. Schindler will be celebrated for years to come, including by his many friends, family, students, and colleagues who will carry on his legacy.

Acknowledgments

This article was written on behalf of Dave's many students and postdoctoral fellows.

1 C. Elton, *The Ecology of Invasions by Animals and Plants* (Methuen & Co./Chapman & Hall, Kluwer Academic Publishers BV, Chicago, 1958).
2 D. W. Schindler, Eutrophication and recovery in experimental lakes: implications for lake management. *Science* **184**, 897–899 (1974).
3 D. W. Schindler *et al.*, Long-term ecosystem stress: The effects of years of experimental acidification on a small lake. *Science* **228**, 1395–1401 (1985).
4 R. A. Kerr, Acid rain control: Success on the cheap. *Science* **282**, 1024–1027 (1998).
5 D. W. Schindler, W. F. Donahue, An impending water crisis in Canada's western prairie provinces. *Proc. Natl. Acad. Sci. U.S.A.* **103**, 7210–7216 (2006).
6 E. N. Kelly *et al.*, Oil sands development contributes elements toxic at low concentrations to the Athabasca River and its tributaries. *Proc. Natl. Acad. Sci. U.S.A.* **107**, 16178–16183 (2010).
7 E. N. Kelly *et al.*, Oil sands development contributes polycyclic aromatic compounds to the Athabasca River and its tributaries. *Proc. Natl. Acad. Sci. U.S.A.* **106**, 22346–22351 (2009).