

Profile of Stephen R. Carpenter

Whether you are a fisherman, a kayaker, or just a lover of the outdoors, the sight—and smell—of a scummy, algae-covered lake may not be particularly appealing. For Stephen R. Carpenter, who is all of the above as well as a renowned lake ecologist, the problems associated with this algae buildup, or eutrophication, go far deeper than simple aesthetics. “Eutrophication is a significant environmental problem that can impact humans on a recreational, economic, and even public health level,” says Carpenter, “and it’s likely to intensify in the coming decades due to increases in human population, demand for more food, land conversion, and fertilizer use.”

Carpenter, the S. A. Forbes Professor of Zoology and Halverson Professor of Limnology at the University of Wisconsin–Madison (Madison, WI), has studied freshwater ecology for over 30 years. His multitude of research interests include eutrophication, aquatic food webs, nutrient cycling, and ecological economics. Beyond his research and teaching, Carpenter also has, among other activities, served on numerous National Science Foundation (NSF) advisory panels, been President of the Ecological Society of America (2001–2002), and served as the Chair of the Beijer Institute of Ecological Economics Board of Directors (2003–2005). In addition, he works on the editorial board of multiple scientific journals, including PNAS. Carpenter was elected to the National Academy of Sciences in 2001.

Recently, Carpenter has become interested in the capabilities and limits of ecosystem forecasting. In his Inaugural Article published in this issue of PNAS (1), he forecasts the long-term impact of the primary human contributor to lake eutrophication: nonpoint phosphorus pollution. Using Wisconsin’s Lake Mendota as a model, Carpenter projects the phosphorus concentrations in the water, sediment, and surrounding soils over the course of a millennium. The scenarios predict a need for dramatic change because moderate reductions in agricultural phosphorus will only delay, and not prevent, eutrophication. The results also demonstrate the persistence of eutrophication. “In theory, eutrophication is reversible,” says Carpenter, “but from the perspective of a human lifetime, once you push a lake over that threshold, eutrophication is a one-way trip.”

From Streams to Lakes

Born in Kansas City, MO, in 1952, Carpenter was immersed in science and the



Stephen R. Carpenter and algae on Lake Mendota, WI.

outdoors at an early age. Carpenter spent most of his youth in Bethesda, MD. “It was a much smaller place back then,” he says. “Bethesda was at the urban fringe of DC. Everything beyond that was rural.” His father, Richard, was a chemist, so there was always a lot of science discussion in the household. After his father became a staff member on the National Academies’ Board on Environmental Studies and Toxicology, ecology and the environment became a regular part of their conversations.

Growing up, Carpenter spent many summers on his grandfather’s farm in Missouri. In between helping with the farm work, he and his cousins found time to enjoy the nearby wilderness, whether fishing, camping, or just frolicking: “Boys who are roaming free in a farm environment find all kinds of interesting things to do.” Carpenter thinks his transition to an ecologist just stemmed naturally from his youth. “Hiking, camping, fishing, and hunting all come together in ecology,” he says. “I was really excited when I discovered there was a way to get paid for being a scientist outdoors.”

Carpenter’s interest in ecology blossomed during his undergraduate education at Amherst College (Amherst, MA), where he met a pair of dynamic teachers: Stuart Fisher and Lincoln Brower. “Fisher and Brower . . . were very influential and made me think ecology was just a great thing to do,” says Carpenter. “Fisher, in particular,

was an aquatic systems ecologist, and that field really captured my imagination.”

Carpenter performed undergraduate research for Fisher, who specialized in stream ecology, and Carpenter published his first paper on the primary production of macrophytes (rooted aquatic plants) in the Fort River of Massachusetts (2). Carpenter’s work in Fisher’s laboratory convinced him to further his ecological research in graduate school, and after receiving his B.A. in biology in 1974, Carpenter entered the graduate programs in Botany and Oceanography & Limnology at the University of Wisconsin–Madison. He joined Michael Adams’ laboratory to study the role of macrophytes in the phosphorus cycle of lakes.

Graduate research gave Carpenter his first exposure to the three fields he would continue to study over the course of his career: lake science, phosphorus cycling, and the emerging field of ecosystems ecology. “My project was part of the follow-on grants to the International Biological Program,” says Carpenter. “The [International Biological Program] was, I think it’s fair to say, the first big ecosystem research program funded in the United States.”

Graduate school also proved to be personally rewarding for Carpenter. He met fellow student Susan Moths, whom

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driven over a threshold," he explains. "This could take as long as 150 years, but once the lake is driven over the threshold, water quality is substantially worse and persistently so."

In his article, Carpenter also explores a second, more dramatic policy shift for effectively stopping phosphorus imports. "Under that more severe scenario [of stopping agricultural import]," says Carpenter, "the lake gets no worse and begins to make a smooth recovery, although it does take a long time."

Carpenter adds that his simulations only considered agricultural phosphorus input. In practice, humans could take other measures, such as installing buffer strips to absorb phosphorus or erecting structures to retard erosion, which could speed up the recovery process. Although he does not know how many of these measures are feasible, he says that at a minimum some change is needed: "We can't simply continue with the status quo. That basically writes off water quality."

A Call for Change

Although his Inaugural Article and other recent projects focus on Lake Mendota, Carpenter believes his models are applicable to lakes around the world: "I became quite active in studying eutrophication globally, and that sparked my interest in global phosphorus cycles and the ways that large-scale management of phosphorus is affecting lakes." In 1995, he had an opportunity to pursue this interest when he received a Pew Fellowship in Conservation and the Environment. "That fellowship allowed me to look very broadly at lake degradation and causes of environmental problems," he says, "and it was a real switch point in my career."

In the past decade since receiving the Pew Fellowship, Carpenter has lent his voice as a lake expert to bring attention to various ecological issues. In 2001, he helped author a viewpoint paper, along with James Clark of Duke University and other prominent scientists, addressing the role of ecological forecasting in the decision-making process (9). The same year, he and other international scientists coauthored another paper highlighting the dangerous losses of resilience that make ecosystems vulnerable to rapid and severe degradation (10). Carpenter points out that lakes often do not undergo a steady progression from clear to eutrophic, and instead they can exist in two stable states, clear or turbid, separated by an unstable intermediate. Currently, many lakes are stressed to levels near the unstable point. "A big runoff event, like an extremely wet summer or a big thunderstorm, could come along and quickly tip the balance," he says "It's essentially an accident waiting to happen."

In June 2001, Carpenter undertook his largest ecological forecasting project by taking part in the Millennium Ecosystem Assessment, an international, multipartner-funded program launched by the United Nations. "The goal of this program was to understand globally the status, trends, and plausible futures of ecosystem services," he says. Carpenter served as cochair for the Scenarios Working Group: "We were charged with looking up to 50 years in the future and projecting what the situation for ecosystem services might be under various assumptions about changes in global policy, demographics, [and] global governance."

After 5 years of information gathering and research, the Scenarios team pro-

duced a mixed bag of results; although they concluded that the environment on Earth was deteriorating, it was still treatable (11). "There are a number of policies that could improve ecosystem services," says Carpenter, "and all of them are being practiced somewhere at a large enough scale that you can tell that they work. Unfortunately none of the policies are being practiced at the scale needed to improve global ecosystem services by 2050."

Carpenter plans to do what he can to help implement some of those policies, and he also plans to remain active in ecosystem forecasting and ecosystem management. "I think that ecologists have a tremendous role in understanding change," he says. "We are on the brink of some very big changes in the way ecosystems function and in the way people relate to ecosystems." He notes that findings from the Millennium Ecosystem Assessment showed that recent environmental changes influenced by humans are some of the fastest seen in history, and future changes might be faster still. "While some of these changes may be beneficial, many others can be potentially threatening."

"We simply have to change the way we do business in managing ecosystems," he adds, "and in that regard ecosystem ecologists have an opportunity and responsibility to work with policymakers and scientists from other disciplines to make those changes as constructive as possible. We're either going to make changes on our own or get some hard ones forced on us by nature, and the former is much more preferable, in my opinion."

Nick Zagorski, *Science Writer*

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