BIOGRAPHICAL MEMOIRS

Jonathan J. Cole

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A Biographical Memoir by Gene E. Likens, Stephen R. Carpenter, and Michael L. Pace

Jonathan (Jon) J. Cole fundamentally changed the understanding of the carbon cycle in lakes, rivers, and the ocean. With colleagues, he clarified the role of freshwater ecosystems as sinks or sources of atmospheric carbon dioxide. Utilizing whole-lake manipulations, they discovered the contribution of terrestrial carbon to animal production in lakes. Cole did this pioneering limnological research by explaining the factors controlling the amount and flux of carbon in the aquatic carbon cycle in diverse aquatic ecosystems. His work on dissolved inorganic carbon (CO_2) in freshwater ecosystems was innovative, brilliant, and illuminating.

Cole was born on January 14, 1953, in New York City to parents Leonard and Selma (Greenblatt) Cole. He attended the prestigious High School of Music & Art in New York City. Jon attended Amherst College, where he was awarded the O. E. Schotte Scholarship and graduated *magna cum laude* in 1976. He earned a Ph.D. from Cornell University in 1982 (with Gene E. Likens). He held a postdoctoral appointment with Susumu Honjo at the Woods Hole Oceanographic Institute from 1981 to 1982 and was a Noyes Postdoctoral Fellow at the Ecosystems Center at the Marine Biological Laboratory with John Hobbie from 1982 to 1983. He participated on several research cruises while at the Woods Hole Oceanographic Institute, including deep (3,900 meters) dives on the submersible ALVIN. In 1983, he was hired as an assistant scientist at the newly formed Institute of Ecosystem Studies in Millbrook, New York, where he eventually rose to the rank of Distinguished Senior Scientist in 2010.

Figure 1 Jonathan J. Cole.

Cole married fellow scientist Nina F. Caraco in 1980. They shared research interests and many hobbies, including dogs, cooking and enjoying good food, kayaking, wind surfing, and kite boarding. His playful sense of humor and quick wit were hallmarks and endearments to all who knew Jon.

Cole's Ph.D. dissertation research was done at Mirror Lake in the White Mountains of New Hampshire. He studied the production of dissolved organic matter by bacterial mineralization of phytoplanktonic detritus.[1] Later work by him and Caraco focused on the phosphorus budget of Mirror Lake.[2] Mirror Lake was part of the larger Hubbard Brook Ecosystem Study.[3] Jon served as the executive director of the Hubbard Brook Scientific Advisory Committee from 1983 to 1997.

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Figure 2 Transporting sampling equipment to Mirror Lake from Pleasant View farmhouse in a little red wagon, circa 1980.

Research on the complete phosphorus budget for Mirror Lake included several novel components, such as measurement of atmospheric inputs, groundwater inputs and losses, urination input by swimmers, and evaluation of atmospheric sulfur deposition on the phosphorus cycle. Jon and Nina evaluated the input of phosphorus to the lake from pets by enticing their dog to swim in a children's plastic wading pool filled with distilled water and then measuring the phosphorus content of the water.

Cole also was one of the leaders of the Cary Institute of Ecosystem Studies (institutional name change in 2007) team that investigated the invasion of zebra mussels (*Dreissena polymorpha*) into the Hudson River. One outcome of that long-term study was a detailed analysis of the impacts of invasive bivalves on an ecosystem with the unusual benefit of detailed data gathered before and after the invasion.[4] Over the course of this work, Cole, Caraco, and other collaborators also documented that the Hudson and similar rivers and estuaries worldwide emit considerable CO_2 into the atmosphere[5] and that some of the organic carbon coursing down the river is ancient.[6] Consequently, a sixty-day-old fish might acquire through its food some 5,000-year-old carbon.[7] This "old carbon made new" is a unique feature of some aquatic ecosystems in which organic matter from ancient soils and sediments becomes mobilized and re-enters organic matter cycling after a long senescence. Moreover, Cole and Caraco developed strong evidence that the invasive zebra mussels reduced phytoplankton biomass in the Hudson River by more than 80 percent.[8]

Cole also was a creative co-leader of whole-lake experiments with a team of investigators, including two of the authors (SRC and MLP), for more than twenty-five years to investigate the effects of nutrient enrichment on trophic cascades, carbon sources to aquatic consumers, and early warnings of regime shifts by ecosystems. The ideas for these studies were generated on the porch of a small cabin above Tenderfoot Lake at the University of Notre Dame Environmental Research Center (UNDERC), often following a delicious meal prepared by Jon.

Measurements of ecosystem production, respiration, and carbon cycling depended on Cole's knowledge of gas exchange and isotopic fractionation between lakes and the atmosphere.[9,10] Isotopic enrichment of lakes with inorganic ^{13}C showed that terrestrial primary production contributed a large share of the carbon flow to aquatic consumers.[11] These isotopic studies also revealed that top predators influence whether a lake is a source to the atmosphere of CO_2 or a sink.[12]

Jon was a highly competent, diligent, and much sought-after reviewer and contributor to scientific publishing. For the journal *Limnology and Oceanography,* he served on the editorial board (1982–90), as associate editor (1998–2001) and as reviews editor (2009–13); for *Ecosystems* as associate editor (2003–09); for *Aquatic Biology* as associate editor (2006); and for *Freshwater Reviews* as associate editor (2007).

Although the Cary Institute of Ecosystem Studies is not a degree-granting institution, Jon mentored numerous students, postdoctoral associates, and visiting colleagues. We all profited and learned from his wide-ranging intellect and interests. Never shy about offering an opinion or engaging in a discussion about people and culture, Jon was a popular colleague. Graduate students often commented that he made science fun. He frequently said to students, "the purpose of graduate school is to learn to drink coffee with scientists." By this phrase he meant joining the research community through sharing knowledge and ideas, which nicely encompasses what one hopes for in graduate education. In the Cary Institute of Ecosystem Studies lunchroom and in the cabin at the UNDERC field station, Jon engaged in this training. At the latter location, he had a jalopy-like espresso machine that

Figure 3 Cole collecting an oxygen and temperature sensing sonde from a dense bed of *Trapa sp*. in the Hudson River. *Photo by Nina Caraco.*

Figure 4 Cole with northern pike caught along the Swedish shore of the Baltic Sea. Pike comprised terrestrial carbon, likely fixed thousands of years previously. *Photo by Mats Janssen*.

only he could operate. After considerable hissing (from the machine) and possibly some swearing, he would produce a fresh, hot brew. Lively conversation would follow.

Jon received many awards for his scholarship including election to the International Water Academy in 2000, the National Academy of Sciences in 2014, and the American Academy of Arts and Sciences (AAA&S) in 2010. He was named a Fellow of the American Geophysical Union in 2011 and AAA&S in 2001. Jon was a member at large of the Association for the Society of Limnology and Oceanography (formerly, American Society of Limnology and Oceanography) (ASLO) from 1994–97 and served as its president from 2004–06. In 2016, he was honored with the organization's Martin Award for "Carbon Dioxide Supersaturation in the Surface Waters of Lakes."[13] He also was awarded the ECI Prize from the International Ecology Institute in 2003, for which he wrote and published the book, *Freshwater Ecosystems and the Carbon Cycle* in the organization's Excellence in Ecology series.[14] Jon served as the G. E. Hutchinson Chair in Ecology at the Cary Institute of Ecosystem Studies from 2008–13.

We will greatly miss his rare intellect and unique sense of humor. He was an outstanding scientist, exemplary idea generator, wonderful friend, and colleague. He died peacefully on July 25, 2023, of cancer.

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