Coaxing lakes to conduct experiments: palaeolimnology and the acid rain debate

Richard W Battarbee
Environmental Change Research Centre, University College London, UK

In the 1960s the occurrence of unusual algal blooms on large lakes throughout the world alerted limnologists to the new phenomenon of cultural eutrophication. Unfortunately at that time the young strand of limnology we call "palaeolimnology" was not ready to make a meaningful contribution to the debate that followed when the "when" and "why" questions were posed by worried drinking-water supply companies and other lake-water users. However, a decade or so later when surface water acidification problems were detected in low alkalinity lakes the situation had changed; palaeolimnology had come of age. Most crucially with the emergence of ^{210}Pb dating it was possible to date recently accumulated sediments in lake basins enabling diatom analysis in particular to become a powerful diagnostic technique. And by comparing the palaeoecological records of lakes of different kinds, with different bedrock geology, different catchment land-cover and different acid deposition inventories it was also possible in the words of Ed Deevey "to coax history to conduct experiments" (Deevey, 1969). This approach was apposite as the primary hypotheses put forward to explain the loss of salmonid fish populations in highly acidic surface waters in the UK and Scandinavia (i.e. acid deposition, land-use change and natural leaching) all demanded a demonstration, if not an understanding, of processes playing out over long time-scales, well beyond the reach of the observational record. For instance, acid deposition became an important driver of change in upland lakes in the UK already by the mid-nineteenth century, land-use change in Norway that led to the regrowth of spruce forest began to occur in the later decades of the 19th century and a test of the natural leaching hypothesis required centennial to millennial scale evidence.

Following a series of large, multi-institutional and multi-national palaeolimnology projects during the 1980s in Europe and North America the primacy of the acid deposition hypothesis was established (e.g. Battarbee, 1990; Charles, 1990). Subsequent measures to reduce the emissions of acidic gases from the combustion of fossil fuels have led to a marked reduction in acid deposition and, judging from long-term monitoring data, the gradual recovery of acidified lakes and streams is now taking place (Curtis et al., 2014). However, when today's diatom assemblages are compared to those found in early 19th century sediments that pre-date the acidification phase it is clear that the recovery process has a long way to go (Battarbee et al., 2014). And as climate change now threatens to exert increasing pressure on ecosystem processes the path back to good ecological status may well be further confounded. A new experiment is unfolding in which the lake sediment record continues to perform a historical benchmarking role as potentially new ecosystems are being created. How such ecosystems should be managed is an open question (cf. Murcia et al., 2014).

Battarbee RW. (1990) The causes of lake acidification, with special reference to the role of acid deposition. *Philosophical Transactions of the Royal Society of London* B 327: 339-345.

Battarbee RW, Simpson GL, Shilland EM, et al. (2014) Recovery of UK lakes from acidification: An assessment using combined palaeoecological and contemporary diatom assemblage data. *Ecological Indicators* 37: 365-380.

Charles DF. (1990) Effects of Acidic Deposition on North American Lakes: Palaeolimnological Evidence from Diatoms and Chrysophytes. *Philosophical Transactions of the Royal Society of London. Series B, Biological Sciences* 327: 403-412.

Curtis CJ, Battarbee RW, Monteith DT, et al. (2014) The future of upland water ecosystems of the UK in the 21st century: A synthesis. *Ecological Indicators* 37: 412-430.
Deevey E. (1969) Coaxing history to conduct experiments. *Bioscience* 19: 40-43.
Murcia C, Aronson J, Kattan G, et al. (2014) A critique of the 'novel ecosystem' concept. *Trends in Ecology and Evolution* 29: 548-553.