BLICKWINKEL/ALAMY

European spruce forest — grounds for experiment[2].

across much of a forest's growing season. Deep within the soil profile, concentrations of N_2O were orders of magnitude greater than atmospheric levels. During drought, soil N_2O concentrations near the surface declined to sub-atmospheric levels, promoting the diffusion of N_2O from the atmosphere into the soil. With rewetting, soils quickly resumed their role as a net source of N_2O to the atmosphere. Both net uptake and production rates of N_2O were small — within the range that other investigators have viewed as unreliably close to zero[4]. However, net N_2O consumption during the drought was sufficient in both magnitude and duration for the soil profile to require almost four months for cumulative fluxes to reflect net N_2O production again.

To help identify the processes governing these N_2O fluxes, Goldberg and Gebauer[2] quantified the rare, stable isotopes ^{15}N and ^{18}O in the N_2O within the profile. Because these isotopes are relatively heavy, microbial processing of them tends to be slower than that of the more common, lighter ^{14}N and ^{16}O. As a result, quantifying $^{15}N_2O$ and $N_2{}^{18}O$ can provide clues about the processes governing N_2O production and consumption[8–10].

Trends in $N_2{}^{18}O$ were possibly confounded by the exchange of oxygen with soil water, but the $^{15}N_2O$ data are revealing. Near-surface soil N_2O exhibited high amounts of $^{15}N_2O$ relative to deeper values. This is consistent with microbial consumption of N_2O dominating N_2O dynamics throughout the profile, because microorganisms preferentially consume $^{14}N_2O$, leaving remaining N_2O relatively enriched in ^{15}N. Importantly, soil drought increased the relative abundance of $^{15}N_2O$ throughout the profile. The authors[2] suggest that the source strength of N_2O within the profile declined with drought, whereas rates of N_2O transformation into N_2 remained constant.

Goldberg and Gebauer's study[2] is an example of the kind of research required to understand the global N_2O budget — measurement of N_2O fluxes and soil-profile concentrations, combined with isotopic analyses — but they do not elaborate on the mechanisms governing the isotopic shifts they observed. If, as they suggest, N_2O sources declined and consumption was maintained with drought, the dominant microbial source must have shifted to one that generates greater relative amounts of $^{15}N_2O$. This could explain increasing $^{15}N_2O$ throughout the profile with drought, because different microbial pathways can generate N_2O exhibiting distinct abundances of ^{15}N. Alternatively, rates of consumption of N_2O could have increased while the N_2O source strength and path were maintained; such a change would result in a shifting 'front' of $^{15}N_2O$ with drought, similar to that observed.

Studies such as this are essential for predicting Earth's future climate. Atmospheric concentrations of N_2O are low compared with those of carbon dioxide — 319 parts per billion compared with 379 parts per million (figures as of 2005)[3]. On a 100-year timescale, however, each molecule of N_2O has some 300 times the radiative forcing power of CO_2 (ref. 11), making it an important driver of Earth's climate.

Future research must clarify the mechanisms that generate net soil N_2O uptake in different soil types under varying environmental conditions. Research will particularly need to focus on the influence of soil moisture on N_2O dynamics, given the predicted increase in drought frequency and rainfall variability in many regions. Advances[8,12] in quantifying the relative abundances of two types of $^{15}N_2O$ ($^{15}N^{14}NO$ and $^{14}N^{15}NO$) promise to help in distinguishing between the paths by which N_2O is produced. Such work will help us further constrain the global N_2O budget and, ultimately, understand critical features of the two-way feedbacks between climate and N_2O. ■

Sharon A. Billings is in the Department of Ecology and Evolutionary Biology, and the Kansas Biological Survey, University of Kansas, 2101 Constant Avenue, Lawrence, Kansas 66047, USA.
e-mail: sharonb@ku.edu

1. Galloway, J. N. *et al. Science* **320,** 889–892 (2008).
2. Goldberg, S. D. & Gebauer, G. *Global Change Biol.* doi:10.1111/j.1365-2486.2008.01752.x (2008).
3. Intergovernmental Panel on Climate Change *Climate Change 2007: The Physical Science Basis* (eds Solomon, S. D. *et al.*) (Cambridge Univ. Press, 2007).
4. Chapuis-Lardy, L., Wrage, N., Metay A., Chotte, J.-L. & Bernoux, M. *Global Change Biol.* **13,** 1–17 (2007).
5. Wrage, N., Velthof, G. L., van Beusichem, M. L. & Oenema, O. *Soil Biol. Biochem.* **33,** 1723–1732 (2001).
6. Vieten, B., Conen, F., Seth, B. & Alewell, C. *Biogeosciences* **5,** 129–132 (2008).
7. Davidson, E. A., Ishida, F. Y. & Nepstad, D. C. *Global Change Biol.* **10,** 718–730 (2004).
8. Bol, R. *et al. Rapid Commun. Mass Spectrosc.* **17,** 2550–2556 (2003).
9. Holtgrieve, G. W., Jewett, P. K. & Matson, P. A. *Oecologia* **146,** 584–594 (2006).
10. Baggs, E. M. *Rapid Commun. Mass Spectrosc.* **22,** 1664–1672 (2008).
11. Rodhe, H. *Science* **248,** 1217–1219 (1990).
12. Sutka, R. L., Ostrom, N. E., Ostrom, P. H., Gandhi, H. & Breznak, J. A. *Rapid Commun. Mass Spectrosc.* **17,** 738–745 (2003).

Ralph Lewin (1921–2008)

Ralph Lewin, who died on 30 November aged 87, was a marine biologist specializing in algae, and a poet. Here is an example of his verse:

Toxic Blooms

Toxic blooms, toxic blooms
Vie with smog and sonic booms.
Bigger, thicker, redder tides
Taint the seas with plankticides.
Toll the tocsins! Tides of doom!
Woe to us the bloody bloom!

Neurotoxicants attack
Herrings in the Skagerrak,
Decimating fishes that
Used to throng the Kattegat,
Dooming them to dismal fates:
Death by dinoflagellates.

His poems had a range of topic and tone, but they typically had a thread of gentle humour that also characterized his communications with this journal over editorial standards. Lewin spent most of his long career at the Scripps Institution of Oceanography, California, and — science and poetry apart — will also be remembered as co-translator of A. A. Milne's *Winnie-the-Pooh* into Esperanto. More can be found at http://tinyurl.com/5kkyyx and http://tinyurl.com/58r4le.