Stable Isotopes as Ecological Tracers
By Geoff Wilson

You are probably familiar with some of the fascinating observations that biologists have made by putting radio or satellite transmitters on wild animals and then following their movements. The whereabouts of bat roosting sites, the wintering locations of loons, and they way marten move through their territories are just a few regional examples of information obtained by tracking animals this way.

But individual animal behavior is only a small part of understanding how nature works. While in some cases knowledge of a single species may be all we need to achieve a management goal (for example, identifying and preserving winter deer yards is largely sufficient to insure deer survival over winter), in most cases, knowledge of the interactions between multiple factors within an ecosystem is required before effective environmental policy can be created.

Sometimes these factors are too small to be seen, let alone tagged with a radio transmitter. Take nitrogen, for example, the most common element in the atmosphere. Naturally occurring nitrogen gas is relatively inert, while the nitrogen compounds we humans emit (mainly by burning fossil fuels) can be reactive with plants and other compounds. How can you track nitrogen as it moves through an ecosystem and still keep track of where it came from?

Many elements, including nitrogen, come in two or more variations, and scientists have turned these variants to their advantage. Elements are composed of protons, neutrons, and electrons. The number of protons defines the element: hydrogen has one proton, helium two, nitrogen seven, and so on. Add or remove a proton and you have a different element.

Add or remove a neutron, however, and you don't have a different element, just a heavier or lighter version of the same element. These variations by weight are called isotopes. Some are radioactive and decay over time, but many are stable, long lasting, and easy to work with. Both can be used to "spike" a sample by adding an unusually high amount of a less common isotope. As this sample interacts with the ecosystem, scientists can look for the isotopic "spike" and follow the movement of that element. This involves collecting a sample of the material in question and analyzing it on a device called a mass-spectrometer, which sorts the elements that make up the sample by their weight.

In the case of nitrogen, there are two stable isotopes. Ninety nine percent of the nitrogen in the environment occurs as N-14, an isotope with 7 neutrons and 7 protons. The remaining trace occurs as N-15, an isotope with 8 neutrons and 7 protons. By releasing compounds formed with an extra amount of this much-rarer N-15 into an ecosystem, scientists can track the movement of these compounds by seeing where the N-15 isotope goes.

Scientists recently did just that at the Hubbard Brook Experimental Forest in Woodstock, New Hampshire. They were interested in tracking the progress of nitrogen that was deposited on the forest during the winter months. During winter, nitrogen deposition falls in snow rather than rain, meaning that it accumulates in the snow-pack all winter before entering the forest ecosystem in large amounts over the short period of snowmelt. Because snowmelt occurs before the start of the main growing season, plant life is unable to make immediate use of this nitrogen. Some of it, therefore, enters the streams as runoff.

To investigate the situation, Dr. John Campbell, a U.S. Forest Service scientist, spiked the snowpack with an N-15 tracer. This involved purchasing a specially-prepared compound of nitrogen from a chemical supply company. The compound was otherwise identical to the form of nitrogen that typically falls on the forest, only made with more N-15. The compound was diluted in water and sprayed on the snow with a spray-bottle. The fate of the nitrogen compound was then traced by collecting snowmelt from two locations: one below the snow but above the soil, and a second in the ground below the soil.

Virtually all of the N-15 tracer in the snowmelt collected above the soil was recovered, meaning that very little happens to nitrogen compounds as they wait for spring within the snowpack.

In contrast, only about half of the N-15 turned up in the samples located down below the soil, representing soil water headed for the streams. This showed that, even when plants are relatively inactive in spring, roughly half of the nitrogen that fell over the course of the winter was retained in soil.

Though nitrogen is the most common element in the atmosphere, humans have greatly increased the amount of reactive nitrogen in the environment. On forests this is mainly through fossil fuel combustion; in water bodies, fertilizers use and human waste-water are large contributors. In all cases, the extra nitrogen can cause a cascade of sometimes contradictory effects on the ecosystem: it can act as a fertilizer, as an acidifier, as a water pollutant, or as a contributor to ground-level ozone (which can reduce tree growth). Water quality, air quality, and healthy plant growth – all of which we depend upon the natural world around us to provide for free – can be adversely affected.

Stable isotopes like N-15 provide a useful tool as society strives to understand the relationships between the services it receives from ecosystems, the stresses it puts on them, and the dynamic systems themselves.

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