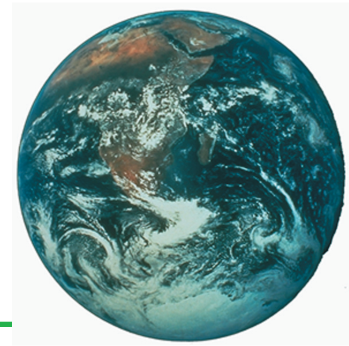
Stable Isotopes: Providing the Answers to Tough Questions



"Many advances in science occur at the interface between the traditional disciplines." -Beatrice Van Horne

Scientists at the U.S.Geological Survey have an amazing tool in their hands. This tool, a mass spectrometer, measures the relative amounts of the different isotopic forms of an element that occur in a sample. But why would scientists want to do that?

Geologists have used mass spectrometers for decades to examine rock samples from the Earth, Moon, and meteorites. Based on the isotopes in these samples, they have determined

Stable isotope analysis of various tissue types from walrus in Alaska has enabled researchers to study walrus nutrition.

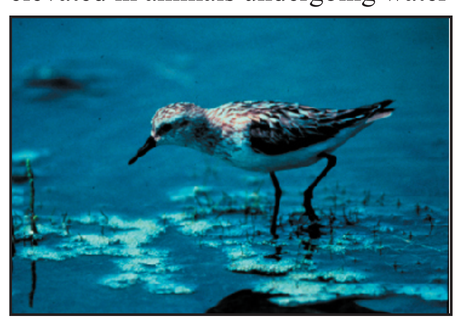
that the solar system formed 4.5 billion years ago. In more practical applications, they have used isotope analyses to determine how often a volcano erupts or landslides occur in a specific area. The USGS now has a world-class stable isotope laboratory in Denver. Only recently, however, have biologists gotten into the act by using this technology in inventive ways.

What is Stable Isotope Analysis?

The different isotopes of an element have different numbers of neutrons (and therefore a different atomic mass). Many of the isotopic forms do not decay through time; hence the term 'stable isotope.' Biologists are able to capitalize on two important traits of stable isotopes. First, the isotopic ratios of a subject's tissues reflects isotopic ratios from things it ingests. Second, the local isotopic ratios vary spatially across the face of the earth. Combining knowledge about these two traits, biologists are able to make inferences about nutritional relationships and the migration of birds, mammals, and fish.

To understand the approach, let's look at hydrogen. Hydrogen occurs in two stable isotopes: hydrogen-1, and hydrogen-2 (deuterium). Both forms, when combined with oxygen, create water. But water created from hydrogen-2 is heavier and condenses to form rain faster than water created from hydrogen-1. Because there is more precipitation near the equator, and less near the poles, ratios of the hydrogen isotopes vary by latitude. In general, the further away from the equator, the less hydrogen-2 is found in the precipitation. When rain falls in an area, the plants absorb the rainfall, and the plants, as well as higher levels of the food chain, reflect the isotopic ratio of the precipitation. In this way, scientists can determine the geographic origin of a plant, or of an insect or bird that may have eaten the plant, based on the ratio of hydrogen-2 in the organism, combined with knowledge of the underlying spatial pattern of hydrogen-2 in precipitation.

By measuring a variety of stable there is a latitudinal gradient in C isotope ratios. Nitrogen-15 values are elevated in animals undergoing water



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or nutritional stress; hence, it may be possible to use isotope measurements to compare the quality of different habitats. Carbon and nitrogen isotopes are also more enriched in marine than in inland environments, thus providing

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the potential to discriminate between coastal and inland populations.

Biologists Get into the Act

The use of isotopic analysis for biological studies is in its infancy. USGS scientists using this technique have already shown amazing results from preliminary studies.

Identifying the linkages between seasonal habitats of migratory species has been difficult. Biologists typically use markers such as leg bands and rely on recaptures of marked individuals as a means of establishing links between seasonal habitats. But these methods are ineffective for non-game species, including the more than 100 North American bird species that winter in the Neotropics, because there are virtually no recaptures.

However, migratory individuals already carry natural geographic markers – the stable isotopes contained in their body tissues. Making use of these natural markers is a matter of deciding what tissue(s) to sample, which in turn depends on the study objectives.

Flight feathers are used to study bird migration because feathers contain isotopic signatures of the habitat where the feathers were grown, typically the winter habitat for many long-distance migrants. USGS scientists have recently shown that flight feathers collected from shorebirds wintering in two different sites in Argentina have significantly different carbon and nitrogen isotope ratios, thus demonstrating the potential of isotopes to identify winter locations.

Diet studies are difficult to do without observing feeding behavior or sacrificing the animal being studied. Often neither approach is possible. It has long been believed that cutthroat trout are a crucial food resource for grizzly bears in the Yellowstone ecosystem. However, cutthroat trout populations are threatened by competition from lake trout in Yellowstone Lake, and biologists are concerned about the potential effects on grizzly bear populations. If cutthroat trout decline, will grizzly bears learn to add other food sources to their diet? USGS scientists have determined that ratios of sulfur, carbon, and nitrogen isotopes differ among potential grizzly food sources, and are using this information, combined with samples of bear hair to monitor changes in grizzly diet through time.

In another study, biologists are comparing the historic and current diet of the white-tailed kite to determine if a long-term change in population status was due to a change in diet. The feathers of museum specimens are being used to infer the historic diet; something that simply could not be accomplished with traditional methods.

Stable isotope analysis of various tissue types from walrus in Alaska has enabled researchers to study walrus nutrition and have provided the first-ever look at walrus feeding ecology. Initial information indicates that walrus have very specialized food sources. Any disturbance to these food sources would likely put a stress on the walrus population, in turn affecting indigenous people who use walrus in their diet.

What's Next?

While this pioneering work has shown startling results, there is enormous potential for this technology. Studies of ecosystem processes, food webs, diets of organisms, migratory paths, energy reserves, reproductive strategies, and predator-prey relations lead to better wildlife and ecosystem management decisions. From sea lions, walrus, bears and shorebirds, to photosynthesis, insect life cycles, and water pollution from confined animal feeding operations, critically needed new research can now be accomplished. The collaborative efforts of geologists and biologists to work at the life science/earth science interface bring new insights and different perspectives to more vexing questions, and enables revolutionary (and more efficient) methods of studying the earth and its inhabitants.

Information:

Central Region
Biological Science Coordinator
Frank D'Erchia
303-236-2730 x246
frank_derchia@usgs.gov

USGS Home Page
http://www.usgs.gov

Central Region Home Page:
http://biology.usgs.gov/cro

Biologist contact:
Adrian Farmer
970-226-9410
adrian_farmer@usgs.gov

Geologist contact:
Gary Landis
202-236-5406
g_landis@usgs.gov