CONSERVATION AT A DISTANCE

There's more to ecology than ringing birds, and in this special section *Nature* explores how the molecular sciences are transforming the field. In 'Atomic detectives', **Sharon Levy** explores how atoms in feathers can reveal the secrets of rare warblers. And **Carina Dennis** unveils a technique that aims to make killing whales for science a thing of the past in 'A gentle way to age'.

Atomic detectives

In a scrubby jack-pine thicket in Michigan, Peter Marra and his colleagues set up a net, bait it with a plastic lemon, and play the song of one of the planet's rarest birds, the Kirtland's warbler. Soon after, a male warbler, resplendent in his bright yellow and grey breeding plumage, comes bombing into the net, mistaking the plastic lemon for a competitor on his turf. To reach this place, the tiny bird may have flown 2,400 kilometres from the island of Eleuthera in the Bahamas.

The Kirtland's warbler *Dendroica kirtlandii*, (pictured below and right) belongs to a family of small, colourful birds that nest in the forests of the United States and Canada, and winter far to the south. In the 1970s and 80s, destruction of its breeding habitat brought the species to the brink of extinction. During this period, observers found fewer than 200 singing males in Michigan. Intensive management of their breeding habitat — replanting jack pines and removing cowbirds, which parasitize warbler nests — has helped the Kirtland's population rebound to more than 4,000 birds.

But events in their largely unknown wintering grounds may still be harming warblers. Marra, a biologist at the Smithsonian Migratory Bird Center in Washington DC, is among a pioneering group that is trying to identify threats to warblers and other vulnerable creatures[1] — using not just bird nets and binoculars, but also mass spectrometers.

The tool relies on the fact that elements such as carbon, hydrogen and nitrogen have more than one isotope. The isotopes differ in their mass, so a mass spectrometer can reveal how much of each isotope a sample contains. Because different foods have different isotopic make-ups, the ratios of carbon and nitrogen isotopes in the tissues of animals can reveal what they have been eating, and suggest the type of area they've inhabited. And thanks to the fact that some elements, such as hydrogen, have isotope ratios that vary over the globe, researchers can also see where an animal has been, by tracing its path across the isotopic landscape, or 'isoscape' (see 'Written in the elements').


C. I. BOCETTI

Where to? Peter Marra is using isotopes to work out where the Kirtland's warbler (below) spends winter.

Such studies are allowing researchers to reconstruct the behaviour of many endangered species, yielding information that could prove invaluable to efforts to conserve them.

Many songbirds that make long annual migrations between northern latitudes and the tropics have been declining for decades. The reasons have confounded researchers, who until recently have not been able to connect breeding populations in the north with specific wintering populations in the south. "The links between breeding and wintering grounds represent a huge hole in our knowledge," says Marra. "It doesn't matter how much conservation work we do in the United States. We need to protect animals year-round, in both breeding and wintering areas."


P. DORAN

Some migrants are at risk in their winter habitat.

Marra's earlier study[2] of the American redstart (*Setophaga ruticilla*), a common warbler, was the first to show that habitat conditions in distant tropical wintering grounds could influence the birds' reproductive success in US forests. He exploited the fact that plants in cool, moist habitats tend to use a different form of photosynthesis from that used by most dryland plants. This means that plants in damp habitats have lower levels of heavy carbon (carbon-13) in their tissues. The different carbon ratios transfer up the food chain to the insects on which the redstarts feed.

Using the ratio of carbon-13 to carbon-12 in the birds' blood, Marra inferred that the healthiest males arriving at his study site in New Hampshire had wintered in damp mangrove forests, where they had fattened up on abundant insects. Because these birds had become fit to take their long journey north sooner than birds wintering in the drier scrublands of Jamaica and elsewhere in the Caribbean, they arrived first on their northern breeding grounds, laid claim to the choicest nesting territories, and fledged more chicks.

Another ground-breaking study[3] used isotopes to reveal the wintering grounds of the black-throated blue warblers (*Dendroica caerulescens*). These warblers breed in forests throughout the eastern United States and Canada, but over the past 30 years or so the population in southern states has dwindled while numbers in the north have held steady. Dustin Rubenstein of Cornell University in Ithaca, New York, and his colleagues analysed hydrogen isotope ratios, which vary predictably in rainfall at different latitudes. They showed that birds breeding in the southern United States wintered on the island of Hispaniola, which includes Haiti, a country that has suffered drastic deforestation. Those breeding farther north wintered in more intact habitats in Jamaica and Cuba.

What counts

"In North America, we're very good at running around counting birds, and knowing whether populations are going up or down," says Keith Hobson, a research biologist for the Canadian Wildlife Service who is based in Saskatchewan. "The problem is we don't often know why these changes are happening. So the insights that stable-isotope studies give us into causes are priceless."

The stable-isotope technique itself is not new; archaeologists have long used isotope ratios in bone to reconstruct the diets of ancient peoples. Forensic scientists are catching on to their use too (see 'Written in the elements'). But the high cost and relatively low efficiency of mass spectrometers meant that wildlife biologists were slow to take up the tool. This all started to change in the 1990s, when improved equipment became available. "There's been a great improvement in the speed with which samples can be run," says Hobson. "People can suddenly afford it, and the throughput of samples has become huge with continuous-flow isotope mass spectrometry."

> **"The exciting thing is that the isotope approach can be entirely non-destructive."** — Keith Hobson

Recent work reveals the changes that can reverberate throughout whole ecosystems when an animal population is decimated. In Monterey Bay, California, numbers of sardines and anchovies began to crash in the 1940s — possibly reflecting a natural oscillation exacerbated by decades of overfishing. This year, Ben Becker of the Point Reyes National Seashore in California and Steven Beissinger of the University of California, Berkeley, published a study in which they compared isotope ratios in the feathers of endangered modern marbled murrelets (*Brachyramphus marmoratus*) to those from museum specimens collected before the sardine crash[4]. Because the heavier isotope of nitrogen, nitrogen-15, concentrates in organisms' tissues as it moves up food chains, the isotope ratio offers a guide to what position the animal occupies in the chain. Becker and Beissinger found that today's seabirds are forced to feed lower on the food chain than their ancestors, surviving on krill rather than more nutritious small fish. This may explain why, in some years, as little as 10% of local marbled murrelets attempt to nest.

In at the krill

Steven Emslie of the University of North Carolina in Wilmington and Bill Patterson of the University of Saskatchewan in Saskatoon are also using isotopes to look at krill. They are asking whether penguins shifted to eating krill after whalers wiped out most of the Southern Ocean whales — major consumers of the crustaceans — some 200 years ago.

Hobson first applied isotope techniques to wildlife in the 1980s, when he used nitrogen isotope ratios to gather information on the feeding patterns of seabirds, including the long-extinct great auk (*Pinguinus impennis*)[5]. He now thinks the technique has most potential as a probe into the mysteries of migration. He and his colleagues are using carbon and hydrogen isotopes to reveal the surprising long-distance travels of dragonflies and bats, and to probe the fates of some once-abundant North American migratory waterfowl. The technique could even help answer the long-standing puzzle

WRITTEN IN THE ELEMENTS

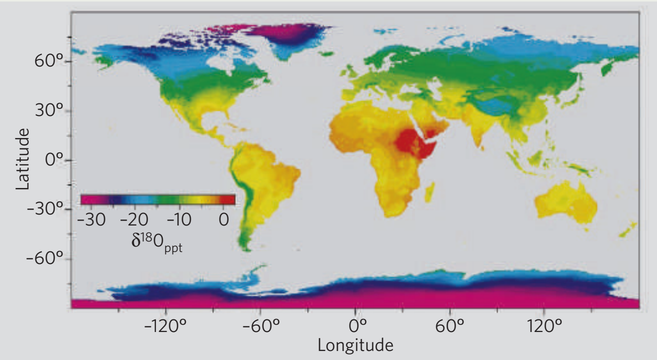
The dead speak, as any forensics expert will tell you. Even the very atoms from which a body is made can have something to say about where the dead person was from, how old he or she was, or even where the person had recently travelled.

The technique, called stable-isotope analysis, relies on the fact that many elements come in heavier and lighter forms, or isotopes. The ratios of these isotopes varies in space and time, and this helps scientists to coax information from corpses, as well as from bioterror microbes and drug hauls.

Wolfram Meier-Augenstein, for example, a chemist at Queen's University in Belfast, UK, has assisted in six murder investigations, determining a body's area of origin from its isotope ratios. The amount of oxygen-18, for example, varies in water sources across the globe[7] (see map). And sugar in the United States is more likely to be made from maize, which has more carbon-13 than other sources used in Europe, such as sugar beets. "Quite literally, you are what you eat and drink," says Meier-Augenstein.

At the Lawrence Livermore National Laboratory in California, Bruce Buchholz can tell the birth date of a person to within a year and a half from a single tooth by taking advantage of the spike in carbon-14 that occurred on Earth in the late 1950s due to atmospheric testing of nuclear weapons[8]. The technique was used to help identify some victims of the December 2004 Sumatran tsunami.

Drug dealers and bioterrorists are also a target. Jim Ehleringer at the University of Utah in Salt Lake City has used isotope-ratio signatures to determine the origin of cocaine. Bolivian coke, for example, has less nitrogen-15 than coke from Peru[9]. He and Helen Kreuzer-Martin, now at the Pacific Northwest National



SOURCE: REF. 7

Laboratory in Richland, Washington, have been gathering the data needed to assign geographical origins to dangerous microbes, such as anthrax or salmonella, and their spores[10]. Stable-isotope analysis is ready to go mainstream, says Kreuzer. "My guess is that we will have it in the courtroom in the next few years or so."

"The technique is probably in wider use than is generally known," says Meier-Augenstein, who adds that law enforcers would prefer to keep it under their hats, so criminals are at a disadvantage. The FBI has its own expanding stable-isotope lab, and some commercial labs exist.

Meanwhile, Meier-Augenstein is looking at parts of the body that record isotope ratios on relatively recent timescales. "It is very good for verifying a person's movements," he says. "I have people knocking on my door from anti-terrorist forces asking what I can do for them."

Emma Marris

T. DAVIES/CORBIS

of how new travel routes evolve.

Stuart Bearhop of Queen's University in Belfast, UK, studied hydrogen isotope ratios in the claws of a community of European blackcaps (*Sylvia atricapilla*). All European blackcaps breed in Germany and Austria, but this population diverged from its parent population, which winters in Spain and Portugal, and began wintering in Britain a few decades ago[6]. Birds that winter in Iberia have significantly higher levels of hydrogen-2, allowing researchers to tell the two groups apart even though they mix on their breeding grounds. Blackcap males from Britain arrive at the nesting grounds earlier, tend to mate with females who have also come from the United Kingdom, and produce more chicks than birds that come from the south.

The mechanics

The competitive advantage of British blackcaps almost certainly arises from a change in the timing of their travel to the nesting grounds. "Migratory behaviour in this species is triggered by changes in day length, and the critical day length is reached in Britain about ten days earlier than it is in Spain and Portugal," says Bearhop. The altered timing gives males the first choice of breeding territories, and helps ensure that UK-wintering birds find like-minded mates. Although there is as yet no evidence that the two populations are speciating, isotope ratios have made clear what Bearhop calls "a nice mechanism by which two populations could become reproductively isolated."

Even the hidden physiologies of animals can be revealed by isotope analysis. The heavier isotope of nitrogen occurs in much higher concentrations in marine than in terrestrial or freshwater food webs. Hobson is exploiting this pattern to study birds that winter on the ocean but fly far inland to breed. "The dogma has been that large-bodied, high-latitude breeding birds carry all their nutrients with them when they fly inland, that they use marine nutrients stored in fat to make their eggs," he says. This idea led to concerns that the chicks of many waterfowl species that breed in the high Arctic were suffering from heavy loads of contaminants, such as mercury and selenium, that pollute nearshore waters where the adult birds forage in winter.

But Hobson's studies of the feathers of newborn birds show that most marine ducks and geese create their eggs with nutrients from food they find on their nesting grounds. That finding relieves some concerns over marine contaminants, but also points out potential problems. "If these birds rely on local conditions to favour reproductive success," says Hobson, "then climate change in the north may have a much greater influence on them than expected."

Although they face the important challenge of improving and updating hydrogen-isotope maps — across latitudes and elevations — stable-isotope techniques have opened up a world of possibilities for wildlife researchers. Isotope ratios in different types of tissue offer a way to analyse food sources over varying periods of time: ratios in faeces or blood plasma reflect food eaten over a day or two; those in cellular blood cover diet over about a month. And the feathers or claws formed on breeding grounds retain the same isotope signature many weeks later when birds arrive to winter in an entirely different part of the globe.

J. P. BLAIR/NATL GEOGR. IMAGE COLLECTION

Species across the globe, from penguins to marbled murrelets, could benefit from isotope tracking.

All this represents a huge improvement on traditional methods: hoping that birds banded near their nests will be sighted on distant, unknown wintering turf, or killing a research subject to get a snapshot of its stomach contents. The ultimate beauty of stable-isotope studies is that they allow information on whole populations of animals to be collected without injuring a single individual. "The exciting thing is that the isotope approach can be entirely non-destructive," says Hobson. ■

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