Using ground beetles to track Kenai Peninsula climate change

by Ed Berg

When I see a beetle crawling along the ground, I see a walking thermometer. A beetle thermometer doesn't tell you an exact temperature, but it can tell you a temperature range, as a climate indicator. There are warm climate beetles and cold climate beetles, just as there are warm and cold climate plants (and people!).

All insects, being cold-blooded, have their preferred temperature ranges. But beetles—and especially ground beetles (carabids)—are abundant and conspicuous in Alaska. You probably noticed these long dark beetles scurrying along the forest floor, especially if you turn over a log. They are most active at night, when they are catching other insects. Alaska ground beetles typically range from about a quarter to three-quarters of an inch long. Their head and shoulders stick out in front, giving them rather sleek elongated look; the color is usually black or dark brown. They are tough predators on smaller bugs and aren't above a bit of cannibalism in a cage or pit trap.

On the Kenai refuge we have initiated a long-term study using ground beetles as climate change thermometers. Here is the basic idea: we deployed 24 pit traps (cottage cheese containers) up a steep mountainside (the Skyline Trail), covering an altitudinal range of 2100 feet. The temperature gets colder going up the mountain; soil temperatures this summer were generally 2 to 4° lower in the alpine zone than at the base of the mountain.

We collected the beetles from the pit traps every two weeks. Once we have the beetles identified, we expect that they will be stratified along the mountainside in distinct zones, i.e., temperature zones. We will probably repeat this survey for the next two summers to be sure that the beetles are consistently stratified from year to year. Then—and here is the payoff—every five or 10 years we will repeat the survey to see if the beetles have moved up hill (as expected with global warming) or downhill (in the unlikely chance of climate cooling).

An experiment like this involves a lot of work. The easy part was the six trips up and down the Skyline Trail, collecting the beetles, reading the maximum-minimum thermometers and taking soil temperatures at each station. Back in the lab, refuge volunteer Al Magness pinned and labeled each of the 233 larger beetles, and stored the smaller beetles and miscellaneous other insects and spiders in alcohol, with one bottle for each trap for each collecting period, resulting in 100+ bottles. Dominique Collet helped us organize the collection, and the mountain transect design was suggested by Scott Elias of Royal Holloway College of the University of London.

The hard part is identifying the all the beetles. There are 237 known carabid beetle species in Alaska, out of the estimated 40,000 species described worldwide and 2200 in North America. Identifying a beetle requires hours of patient work under a microscope, inspecting the tiny parts and using identification keys that lead through a series of choices to the correct species name. Each step in the key requires a choice, such as "head more than two millimeters wide" versus "head less than or equal to two millimeters wide." If you make a bad choice at any step, you go down the wrong path. Local entomologist Matt Bowser has started working on the collection and tentatively thinks that there may be many duplicates of a fairly small number of species, which will make things easier.

Although we are expecting to do a good part of the identification work ourselves, we will need to have an expert at some museum or university verify our identifications. Experts have cabinets full of known beetles, and the real "moment of truth" comes when the expert compares a tentatively identified beetle with a known specimen in the reference collection. The two beetles either look the same or they don't. If they don't look the same, you go back to the key and try again. If they do look the same, you declare victory and add the name to your species list.

In time we will build up our own local reference collection of verified beetles, which will greatly speed up the identification process.

I chose ground beetles for this study because, in addition to being easy to catch, ground beetles are often used for studying ancient climates. Each beetle species has a preferred range of temperature; if you have ten beetles from a peat deposit, let's say, you can ask what is their shared temperature overlap? If they all can operate in a July temperature band of 50-55°F., you can infer that the July climate spanned at least 50 to 55°F at the time the peat-producing vegetation was growing.

Here is a hypothetical example of how this method can be used to reconstruct past temperatures. Suppose we sampled layered sediments exposed in an eroding bluff, where the sediment age spans the 16,000 years since the end of the last major glacial period. The best sediments would be clay, silt or fine sand rich in organic material; peat is also good if it is composed of sedges rather than sphagnum moss (which tends to be highly acidic and a rather sterile habitat for insects).

We might collect fifty to one hundred pounds of sediment from each layer, and then wash the sediment through a fine sieve to concentrate the organic material. We would then mix the damp organic material with kerosene and water. Kerosene sticks to insect parts much better than does water, and kerosene does not stick to wet plant material. Since kerosene floats on water, the insect parts are concentrated in the floating kerosene, which can be poured off and screened to obtain a pure residue of insect parts.

Ten to twenty layers might be sampled in this way in a typical study, each layer yielding a group of species that shares a common temperature range. The layers would be dated with radiocarbon if they were younger than 40,000 years. (Radiocarbon has virtually all disappeared after 40,000 years.) The beetle method can estimate maximum temperatures in an area to plus-or-minus 4 degrees and minimum temperatures to plus-or-minus 9°F. This amount of sensitivity would not allow you to distinguish the climate of Homer from Anchorage, but it would definitely separate Cook Inlet from the more continental sites of the Interior. It is also more than sufficient to document the shift in climate at the end of the last ice age, when summer temperatures were 15-20°F cooler than now.

Climate researchers have more typically used plant pollen in sediments to study past climates. Pollen is almost indestructible and preserves well for tens of millions of years in sedimentary rocks. For reconstructing past climates, the basic idea is similar to the beetle method, using plant temperature ranges for a number of species to infer a shared temperature interval at a given point in time.

The pollen method, however, can't pick up sudden changes in temperature, which have recently become of interest in the global warming debate. Studies of oxygen isotopes in the two-mile long ice core from Greenland that spans 110,000 years have revealed a number of sudden shifts, where climate warmed or cooled by as much as 15°F over periods of ten years or less. It generally takes plants (especially trees) 500 to 1000 years or more to migrate into or out of a region and come into equilibrium with a new temperature regime, so the plant pollen record misses the timing of such sudden shifts.

Insects, on the other hand, can migrate rapidly and establish themselves in new area in a few years, either by wing power or wind power. That is why we chose beetles rather than plants to monitor the changing climate along the Skyline Trail. I grant that spruce tree-line has moved uphill on this mountain over the last 100+ years with the warming climate, but the tree response is still painfully slow compared to what we should see from the beetles.

One fascinating fact that I have learned from studying the beetle-climate methodology is that beetle temperature preferences haven't evolved through geologic time. Morphologically, beetles are one of the most highly evolved groups of organisms, as shown by the fact that one out of every five organisms is a beetle. On a geological scale, beetle body shapes evolve rapidly, but their chemistry and hence their temperature tolerances are "set in concrete." The same species of beetle can have the same temperature tolerance range for five to 10 million years. If the climate changes, the beetles simply migrate; they don't evolve.

I think that this thermal rigidity is probably due to the hundreds of temperature-controlled reactions that go into ordinary body chemistry, and I would expect that it is true for cold-blooded organisms in general. The synthesis of a single protein from DNA involves many enzyme-moderated steps, with each enzyme having its own optimal temperature that is in turn controlled by its own DNA.

A change of body shape might require only a single gene mutation, but a change in temperature tolerance requires hundreds of simultaneous mutations. A blast of radiation from a super-nova might produce a lot of simultaneous mutations in an organism, but most of them would be harmful and the organism would die. So, even though a bug might mutate with longer legs or stronger wings or DDT resistance, it's going to keep its temperature preferences quite the same, thank you!

Information for this article was drawn from *Quaternary Insects and Their Environments* by Scott Elias, 1994, Smithsonian.

Ed Berg has been the ecologist at the Kenai National Wildlife Refuge since 1993. For more information about the Refuge, visit the headquarters in Soldotna, call (907) 262-7021. Previous Refuge Notebook columns can be viewed on the Web at http://kenai.fws.gov.