TEXT AND PHOTOGRAPHS BY ALEXANDER BADYAEV

THE MAIMING OF THE SHREW

The world's smallest mammal, and one of the most resilient, finds itself increasingly vulnerable to the rapid pace of climate change at higher latitudes

Our mandatory evacuation order comes on August 8th. After a long summer of relentless triple-digit temperatures that saw the daily breaking of all-time historical heat records, tinder-dry forests in the Northern Rockies' are starting to burn. For days the fate of Seeley Lake—a nearby Montana town now surrounded by rapidly advancing fires—has been in the national news, while several larger fires are burning uncontained throughout vast uninhabited wilderness.

My research assistants and I are in the northern part of the Bob Marshall Wilderness—at 2.5 million acres one of the nation's largest wildlands. Its vast roadless habitat connects the unique ecosystems of Glacier National Park in the north to the lower Blackfoot Valley in the south. It is one of last remaining corridors for seasonal movements of grizzlies,

AN ADULT VAGRANT shrew in a Montana mountain bog makes a meal of a monarch butterfly. The bogs offer several species of shrews the complex habitat they need to find food without intense competition.

MONTANA BOGS ARE SHREW HEAVENS; EVEN A SMALL ONE BARELY 400 FEET IN DIAMETER CAN BE HOME TO MORE THAN 130 SHREWS OF FOUR SPECIES

IN A RARE PHOTOGRAPH, a pygmy shrew (left) eats a spider. The pygmy shrew is the world's smallest mammal, weighing only 0.07 ounces fully grown. A masked shrew (above) emits an ultrasonic sound that, like bat echolocation, allows it to locate prey, such as insects. High metabolism requires shrews to eat three times their body weight daily.

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wolves, wolverines and thousands of elk, providing a glimpse into Montana's wilderness past. But we are here to study far more ancient mammals. At least five species of shrew, creatures I have been studying for 14 years now, have inhabited this valley for millions of generations. Among them is the world's smallest mammal—the illusive and poorly known pigmy shrew, which weighs barely 0.07 ounces and fits comfortably on my thumbnail.

Having evolved soon after the dinosaurs' disappearance, 45 million years ago, and remaining virtually unchanged in North America for at least 10 million years, shrews are some of the world's most ancient and widespread mammals. Their speed of life defies imagination—they have the fastest heartbeat (1,200 per minute) and one of the shortest lifespans (11 to 13 months) of any mammal. They don't sleep for more than a few minutes at a time, and they never go into torpor or hibernate. Instead, their brief life is spent in nonstop foraging. To stay alive the pigmy shrew has to eat three times its body weight daily, which means capturing a prey item every 15 to 30 minutes, day and night; a full hour without food equals certain death. In northern Montana, shrews manage to maintain their metabolism throughout winter as well, surviving in temperatures as low as -37 degrees F, building an extensive system of tunnels under snow. Shrews, in short, seem invincible. Yet here, at northern latitudes, they are unusually vulnerable to the most recent of threats—accelerated climate warming. With their neck-breaking metabolism, they cannot survive exposure to temperatures higher than 77 degrees F.

The shrews' Achilles' heel is their dependence on a habitat most affected by global climate change—cool, dark coniferous bogs with dense understory, standing water and an abundance of decaying mossy logs. In this part of the world, bogs are small island-like areas, typically near secluded forested lakes, separated by dry sage hills and meadows. Such cool and moist habitats prevent hyperactive shrews from overheating. Once abundant throughout the valley, the bogs have been declining slowly over the past century, a casualty of farming and logging demands. But now the pace has picked up dramatically as rapidly advancing summer temperatures dry the bogs, making them newly vulnerable to large late-summer fires. Smaller and shallower bogs on our high elevation sites are especially vulnerable. More than a dozen had dried out since we started our work here.

The bogs are shrew heavens. Even the smallest one on our study sites, barely 400 feet in diameter, is home to more than 130 individual shrews of four species. Such density and diversity of shrew sizes—from the tiny pigmy shrew to the four-times-larger, almost vole-sized montane shrew—demands careful partitioning of food resources, with each shrew species specializing in a particular prey. Pigmy shrews search for small spiders in the litter, while numerous masked and vagrant shrews patrol the understory for snails, beetles and larvae.

High-speed photographs of hunting shrews show them "yawning" repeatedly in quick succession as they approach prey. Intrigued, we recorded the sounds accompanying the hunt and found that the mouth openings coincide with rapid pulses of low intensity ultrasounds in the 40 to 90 kHz range—shrews are echolocating, using sound much as bats do to find prey! Experiments show that shrews also use echolocation while navigating through leaf litter or in the close quarters of under-snow tunnels.

Shrews' swift and synchronized mating "season" lasts only a few hours on a single morning in late March. During the following month, mother shrews give birth and wean young, after which the adults die, leaving juveniles to discover and partition their prey anew. Juveniles have no prior experience with solid foods, as adults do not bring insects to the young and don't feed them after weaning, so for a while every marsh is filled with wild experimentation as hungry juveniles try to catch an occasional butterfly or moth or try to eat spiders larger than themselves. Because each bog differs in the abundance and diversity of competing shrew species, and because shrews are so short-lived, it is difficult to predict their diet from one generation to the next. Indeed, shrews of the same species can specialize on hard beetles in one bog and on soft larvae in a neighboring one.

How shrews can physically accommodate such dietary diversity remained a mystery until the early 1970s, when biologists discovered that, uniquely among living non-marsupial mammals, shrews delay the formation of bone in the large portion of their jaws, retaining them in flexible cartilage until the start of independent foraging as juveniles. Intrigued by this discovery, my research team has been coming to northern Montana every spring since 1994 to study the developmental and evolutionary underpinnings of such a unique foraging morphology. The delay in bone formation is puzzling and certainly not a side

A MONTANE SHREW sniffs out a frozen dragonfly before eating it. The need for an almost constant food supply, coupled with a short lifespan, makes shrews vulnerable to environmental changes such as global warming, which jeopardizes their bog habitat.

effect of shortened development. A newborn pigmy shrew, weighing less than 0.009 ounces, not only completes all of its skeletal development, sans jaws, during its 18 days as an embryo but also manages in that time to grow a complete set of milk teeth and to replace it with permanent dentition. Delaying the formation of bone in the jaw is a specific adaptation. Our research showed that when juvenile shrews start their experiments with food, the bite force needed for the most prevalent prey in each bog determines muscle pull on still flexible jaws and induces appropriate bone formation for each location.

The ability to modify bone and cartilage tissues well into adulthood works in reverse as well. Prior to winter, these animals resorb parts of skull bones and reduce the mass of internal organs, such as brain and liver, by as much as 40 percent. These reductions may help to lower the energy demands during winter months. Shrews are the only mammals that are known as adults to be able to reverse the direction of bone-cartilage transition.

At first glance, this ability to fine-tune their anatomy to their surroundings seems like a sort of immunity against all kinds of environmental disruptions, perhaps even rapid global warming. Unfortunately, our work shows that this is not the case. When changes are too fast, such as when logging rapidly transforms a moist coniferous forest with an abundance of soft-bodied invertebrates into a sun-baked, dry clearcut dominated by hard-bodied beetles, the stress of malnutrition on pregnant shrews results in numerous developmental abnormalities in offspring, such as greatly asymmetrical jaws and disrupted dental and skeletal development. The shrew's special adaptation—allowing environment literally to shape early skeletal growth—backfires severely when the changes are too drastic and when environmental fluctuations during growth instead cause major skeletal malformations. Particular vulnerability also comes from the animal's very limited dispersal. In our study populations, a pigmy shrew that disperses 100 yards from its birth nest is a world traveler. Most spend their lives within a 50 yards or so of the nest, hardly enough distance to reliably move from a burning bog to a safe one during late summer fires. Add to the mix synchronous population cycles, preferences for fragmented habitats and intolerance of heat, and whole populations can disappear in just few years under rapid and accelerating global warming.

We leave our research camp just in time—nearby towns are under mandatory evacuations, and we are driving out on closed, smoke-filled highways. In a couple of months the raging fires in the wilderness will be put out by an early snow. The juvenile shrews that survive the fire, by then middle-age adults, will continue their neck-breaking speed of life under snow over a long winter. The holder of many records in the mammalian world, and one of the world's most resilient animals, now finds itself increasingly dependent on our ability to slow down the rapid pace of global warming.

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THE FIGHT AGAINST GLOBAL WARMING

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ALEXANDER BADYAEV, *an evolutionary biologist at the University of Arizona in Tucson, divides his time between long-term field research projects in southern Arizona and northern Montana.*

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