Great blue herons brave a winter storm

THE COLD FACTS OF WINTER

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For animals spending the winter in and around Yellowstone, calorie counting is a matter of life and death

Yellowstone's mice and voles protect themselves from the cold by living in tunnels under the snowpack, but occasionally they may visit aboveground shelters, such as this marsh wren's nest, right. Thanks to their big size and bulk, moose, below, can produce more heat than they need to keep warm, even on breezy winter days.

It was the winter of 1978, the coldest on record in North America. One night in January, temperatures at my camp on the Lewis River in Yellowstone National Park fell to −54° F, the tenth night in a row the thermometer had dropped below the −40° F mark, and saucer-sized hoarfrost crystals lined the river's edge.

The next morning, as I welcomed the first rays of sunlight, a coyote pranced into view, paused, listened, and then pounced, sticking its nose beneath the snow in pursuit of a vole. About half a mile away, an elk plowed through the chest-deep snow, browsing on lodgepole pine needles. An increasing sensation of cold in my toes reminded me to wiggle them as a protection against frostbite, for at such low temperatures, energy—in the form of heat—is quickly drawn out of the body.

Energy, or perhaps more accurately, coping with the lack of it, is the key to winter survival. Winter itself is the result of a loss of energy: as the earth moves around the sun, the tilt of its axis causes the Northern Hemisphere to slant away from the sun during the winter months. Every sunbeam of incoming radiation must cover a larger area in winter, which results in a significant reduction in the amount of energy (measured in Calories, or Cal) per given unit of area. Each day in

A coyote, left, feeds on a dead elk. Omnivorous scavengers, coyotes make carrion a big part of their diet in winter, but they also dive through snow after rodents and race along hard snow crust in pursuit of larger prey. Below: To rest, coyotes curl up in soft snow, preferably where there is protection from the wind.

December, for example, every square inch of the Yellowstone area receives an average of 4.080 Cal of solar radiation, while energy lost from the earth's surface averages 4.118 Cal per square inch, producing a net loss of 0.038 Cal. (In June, by contrast, every square inch receives 1.850 Cal more than it loses.)

The most obvious and striking results of Yellowstone's winter energy deficit are the polar air masses that pour in from the north and the snow that often covers the region for six months or more. For the animals of Yellowstone, the margin for survival in the long winter is often narrow, and a few calories may be the difference between death and sprawling in the green grass of spring. Since 1970, I've studied the progression of winter in the Greater Yellowstone Ecosystem, watching those animals that make it and those that don't. (The Greater Yellowstone Ecosystem includes Grand Teton and Yellowstone national parks and all the national forests surrounding them.)

Faced with dramatic energy loss each fall, animals generally resort to one of three basic strategies: they may migrate, hibernate, or face the cold and snow head-on. Those that leave for the south, such as white pelicans and most of the region's great blue herons, do so by about October. The great blues are gone for only a few months, some returning by February to look for nests. Other animals migrate to lower elevations. By November, great herds of elk—often single-file processions led by an old cow—wend their way down from summer meadows in search of a winter range where only a thin blanket of snow covers the grass from the summer growing season. Many creatures—such as reptiles, jumping mice, marmots, and bears—hibernate, disappearing usually until spring.

Those animals that remain active must contend with what may be the coldest, harshest winter conditions in the contiguous United States. The Yellowstone plateau is perched high in the central Rocky Mountains and surrounded by lofty mountain peaks. Official U. S. Weather Bureau records for Montana and Wyoming list record lows of −70° and −63° F, respectively. Unofficially, temperatures on the landlocked plateau drop much lower, and cold snaps often last for weeks. Snowfalls, which begin in September, add up to an average of 600 inches per winter and may last into June.

Preparations for winter are critical. Many species store food. I have watched nonhibernating pikas (rock "rabbits" of the alpine boulder fields) and pocket gophers making bushelbasket-sized caches of greens and roots, respectively. The pikas store their hay above ground in boulder fields; gophers cache their supplies below ground and in the snowpack. Many animals add body fat: black bears put on as much as four inches of fat prior to hibernation. Other types of physical changes are also common. Following coyote tracks, I can tell when additional hair begins to grow on the animals' feet, to reduce heat loss via conduction to winter snows. All species molt to their thicker winter coats; even chickadees add more feathers. Some change color: weasels, for example, molt to white, becoming winter ermines.

The timing of color change is crucial. Normally, the snowshoe hare's internal clock coincides with the coming of snow, and its white phase hides it from all but the sharpest eyes. But when snow has been late in coming, I have seen the white hares sharply outlined against brown autumn vegetation, sitting ducks for raptors.

The snow, or nivean, environment provides two dramatically different situations for active, wintering wildlife: above and below the snowpack. Like all of the region's large mammals, moose must make a go of it above. To estimate the energy budgets of these 900-pound animals, Warren Porter of the University of Wisconsin, physician Roy Ozanne, graduate student Steve Beaupre, and I measured solar radiation, temperature, and wind speeds in different environmental settings. Next we calculated how much energy a moose would lose or gain in various situations. (The most familiar form of energy loss is heat transfer.) The computer model we came up with led us to conclude that even on a breezy winter afternoon, a moose produces more heat than it needs to keep warm. Indeed, during the warmest part of a winter day, we often find moose on shaded, north-facing slopes trying not to overheat. On the same day, elk, with a smaller body mass and less insulation, bask in the sun on south-facing slopes.

At night, the energy budget of a moose does go into the "red." Being out in an open meadow on a calm night at 23° F is energetically expensive, costing the moose

A snowshoe hare may enhance the camouflage effect of its white winter fur by sitting absolutely still. If necessary, however, it will dash away across the snow, springing on its outsize hind feet.

about 4.55 Cal of energy per hour—the equivalent of 1.6 Snickers bars per hour. By moving at night from the open meadow into the coniferous forest, where radiant energy from the trees and lower wind speed help keep it warm, the moose can cut its heat loss by more than one-third.

When the cover of the forest is not enough to stave off the cold, some large mammals take advantage of Yellowstone's abundant sources of geothermal energy. Through steam fumaroles, mud pots, and geysers, heat from the interior of the earth reaches the surface. Elk and bison often wallow on the snow-free ground created by thermal activity and bask in steam from hot pools or geysers.

Saunas may help take the edge off the cold sometimes, but life during the winter for Yellowstone's herbivores is always a race with starvation. Calories stored as fat during the summer must last all winter, when little food is available and what is found by pawing through the snow is of low quality. Carbohydrate- and protein-rich grasses from the summer transport their nutrients below ground in the winter, leaving behind only the dried, hard cellulose stalk for elk to feed on. As Norm Bishop, the research interpreter for Yellowstone National Park, says, "It's as if your annual budget of food consisted of a box of cereal. During the summer you fatten up by eating all the cereal; during the winter all that is left to eat is the box."

Moose and elk face other problems during the winter. They themselves are a source of food not only for predators but also for parasites. Winter ticks feast on them. Skiing on backcountry trails in March, I often find moose beds stained red with blood from engorged ticks smashed when a moose rolled over. Large tufts of hair lying in the bed attest to the irritation caused by tick activity. Elk must deal with mange mites. These small relatives of spiders feed on the skin surface and cause hair loss, mostly in mature bulls. Massive amounts of hair may fall out, leaving nearly bald elk without their insulating fur coat. Weakened by anemia and the loss of blood and hair, many moose and elk simply do not have the energy reserves to survive.

Predators and scavengers benefit from the misfortunes of others. An old bull elk has few fat reserves left after maintaining a harem for breeding during the fall. Too weak to plow through the snow, he may slowly starve to death, or a mountain lion, a grizzly bear, or coyotes may come along to speed things up. Coyotes in Yellowstone often hunt in packs. I once watched three coyotes kill an elk calf while its mother tried to protect it. One coyote would attack, drawing the attention of the mother, which would chase it off, while a second coyote would rush in and bite the calf. Eventually the calf died and was dragged off by the coyotes. As a pack, coyotes can protect their food from such formidable adversaries as mountain lions.

Even for coyotes, though, getting along in winter is not an easy trick. During the winter, a coyote must often travel long distances to find food, whether carrion or some small mammal holed up beneath the snow. The coyote's demise can be the snow surface. Unlike the moose, which can use its great bulk and long legs to plow

As streams freeze over, fish become prizes worth fighting for. This bald eagle has a cutthroat trout firmly in its grasp, but the hungry raven cannot pass up the possibility, however remote, of a fish dinner.

through snow up to three feet deep, the coyote must learn to negotiate the different types of snow. Coyotes detect surface changes in the snow through their feet. Tracking them on skis, I can tell from their footprints that they walk carefully on soft snow (trying to avoid sinking in too deep), trot on medium snow (but lightly, to avoid breaking through thin crusts), and lope on hard snow crusts. Coyotes often follow wind-packed courses on the leeward side of exposed sagebrush, avoiding careless steps to the side where the snow is soft. When the crust is hard enough, they can sometimes travel fast enough to outrun prey.

Patches of snow too soft for traveling may make a good bed, the coyote curling up to be gently covered by a blanket of blowing snow. The coyote's tactile sensitivity also enables it to know when it is safe to dive headfirst into the snow after a vole and when the snow is too hard.

Following the trail of a coyote can be an interesting lesson in energy conservation and, sometimes, humility. One winter night, as I sat gazing across the frozen expanse of Yellowstone Lake, a coyote loped into view on the lake ice. I squeaked like a mouse, and from a half mile out the coyote turned and approached me. Perhaps 100 feet away, it realized something was not right, turned, and trotted off in the direction of my camp. Returning to camp, I discovered my pots gone from beside my tent. In the moonlight, I located coyote tracks and followed them a quarter mile onto the ice. There were the pots in a pile.

As I cooked breakfast the next morning, the full intent of the coyote's prank became apparent. A strong, acrid odor signaled the melting of coyote urine in my oatmeal pot. The coyote had scent marked my pots, telling me that this was its territory and that it didn't appreciate my trick.

Traveling through Yellowstone, I have noted two animals that seem to thrive on winter: river otters and dippers. As much of a cliché as it may seem, for otters, wintertime is playtime. Riverbanks near their dens are covered with slides, and I have watched them repeatedly climb banks seemingly just for the pleasure of sliding right back down. Where thermal activity along the shore of Yellowstone Lake opens up pools, otters will toboggan on the flat ice surface to open water a mile away.

Dippers, or water ouzels, are short-tailed, dark gray birds that live along stream edges year round. Even at −40° F, they wade into rushing streams and, while completely submerged, search for aquatic insects and small fish. At first the idea of these little birds engaging in polar-bear-club dips at subfreezing temperatures bothered me. Wouldn't these dips be energetically costly? Shouldn't a wet bird lose heat rapidly? When the air temperature is −40° F, however, the water is actually seventy-two degrees warmer than the air. Back at the surface, water is quickly shed from the feathers before it can freeze, thanks to a large waterproofing preen, or oil, gland.

As long as open water can be found, neither otters nor dippers seem to suffer from the food shortages that confront other Yellowstone inhabitants. Fish and aquatic insects are always abundant and probably slower moving—thus easier to catch—because of the colder water temperatures. During very cold winters, when the upper reaches of Yellowstone's streams freeze, both otters and dippers move to open water downstream.

Below the snow there is a different world. Snow is a remarkable material, providing insulation and support for winter housing. For the small mammals of this subnivean realm, however, the timing of the first snowfall each autumn is critical. If cold polar fronts arrive before a protective mantle of snow is on the ground, plants and animals freeze. In years of late snowfalls, many of the tagged mice in our study plots die. But once the first eight to ten inches of snow have built up, the daily fluctuations in air temperature do not reach beneath the snowpack, and temperatures below the snow remain fairly constant, within a few degrees of freezing.

With a snowpack deep enough to provide thermal stability, mice and voles reduce the number of daily trips to the snow surface. Often, I will go for days without seeing a single track. Instead, the animals create a labyrinth of snow tunnels in which they travel around looking for dried grass, seeds, and the occasional insect. The tunnels provide a relatively warm haven from the cold at the surface: our calculations suggest that on a calm, 23° F night, a mouse would lose 3.7 times more energy per minute on the snow surface than it would in its tunnel.

Both river otters, left, and dippers, below, seem to thrive during winter in Yellowstone, as long as open water—and the fish and insects that live in it—can be found.

The tunnels are dark most of the winter, as accumulated snow more than three feet deep filters out all of the sun's rays. At the end of dark tunnels, mice construct grass nests where many huddle for warmth. The aggressive behavior typical of these small rodents during the summer quickly breaks down during the cold winter, when I have even found two different species of mice together in the same nest. Cuddled in their nests, mice wait out the worst winter weather.

Early naturalists noted tunnel entrances at the surface of the snow, especially as spring approached. They postulated that tunnels provided an outlet for the high concentrations of carbon dioxide that build up beneath the snowpack and also allowed the animals to emerge periodically to check for signs of spring. Because of the carbon dioxide theory, these tunnels became known as ventilator shafts.

I, too, observed ventilator shafts, but with some differences. In the Yellowstone area, shafts appeared mainly in January and February and especially after clear nights with very cold, subzero temperatures. By tracking, we discovered that, for unknown reasons, mice and voles not only venture above the snowpack on cold nights but also travel up to a quarter mile in open meadows. Following mouse trails and digging out the shafts, we found that most shafts descended only an inch or two beneath the surface and then leveled off and went about three inches horizontally before returning to the surface. In cross section, a shaft formed a roughly horseshoe-shaped tunnel. At the bottom of each tunnel were often three or four pieces of scat, indicating that the animals had rested there for a few minutes.

We hypothesized that because of its large surface area in proportion to its small body, a mouse traveling in open meadows radiates a large percentage of its body heat to the clear night sky. When the mouse begins to get dangerously cold, it quickly burrows into the snow, which, although cold, radiates some energy to the mouse. In its warming hut, the mouse regains enough energy to resume its trip. On a particularly cold night, a mouse might dig several warming huts before successfully crossing a meadow.

Steve Beaupre, Roy Ozanne, and I tested the hypothesis by implanting a radio-transmitting thermometer into a deer mouse. At 3:00 A.M. on one January morning with the temperature about −30° F, we released the mouse back onto the snow. It began jumping swiftly across the snow surface. After a few minutes, our radio signal indicated that its internal body temperature (normally about 99° F) was dropping. The mouse quickly dug a warming hut, where it waited with the tip of its tail still visible. Twenty minutes later, rewarmed, it was again ready to venture out. We observed this behavior three times; each time the mouse's internal temperature dropped by as much as twenty degrees before returning to normal.

Other tunnels that go up to the surface

Opportunistic hunters of the waterways, minks catch everything from crayfish to muskrats and ducks. Large prey, such as this mallard, may be carried back to one of the mink's dens and eaten later.

do exist. Researchers have recently documented the long-postulated pockets of carbon dioxide beneath the snow, perhaps caused by decomposing plant material. The new evidence supports the notion that some tunnels may serve as ventilator shafts. Such tunnels, however, have definite disadvantages: given an opening, long and lean members of the weasel family can also navigate the labyrinth.

Ermines perhaps take advantage of these passages most frequently. But martens, normally considered to be surface and tree predators, may also use the tunnels. In 1986, Christie Shultz and I discovered the tracks of a marten leading from lodgepole pines to a small, frozen, snow-covered pond. Marten tracks around the edge of the pond led to thirty-eight holes. After excavating many yards of snow, we located muskrat tunnels around the pond. We also discovered partly eaten remains of five muskrats, indicating that the marten had had a successful hunt.

One April, perched on my pack on a frozen stream bed, I watched a blue heron fly to its nest. Suddenly, I heard familiar creaking, rumbling, and cracking sounds. Jumping to my feet, I grabbed my pack and skied up the bank just in time to watch the stream channel turn sky blue and the snow and ice become saturated with water. Within minutes, the ice began to break up and flow downstream.

Watching spring return to Yellowstone is still thrilling, even after all these years. With every passing day, more and more energy pours back into Yellowstone. On south-facing slopes, where the snow has already melted, cow elk, round with soon-to-be-born calves, feed. Soon sow grizzlies will emerge with their young, born during the long winter's sleep. The calls of pikas signal their return to the surface, and marmot tracks tell of their awakening from hibernation. If a heavy late snow doesn't catch them off guard, all these animals—newborns and survivors—can look forward to several months of a gentler, lusher Yellowstone. Many will soon be dedicating their energies to courtship, mating, and rearing young. As for me, my energy will be spent counting the weeks until the next winter season. □