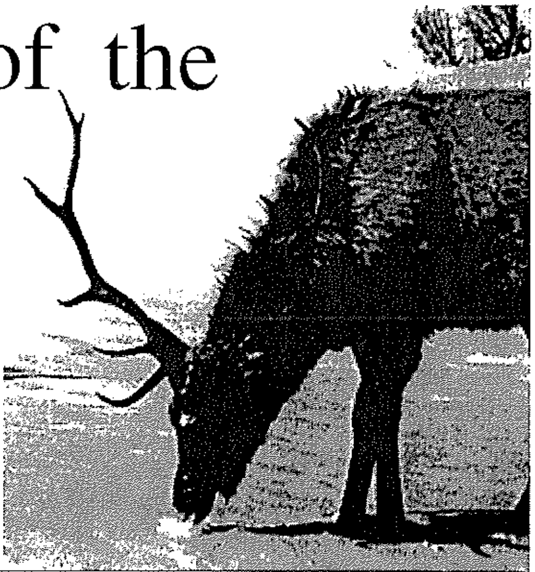
Migratory Behavior of the Jackson Elk Herd



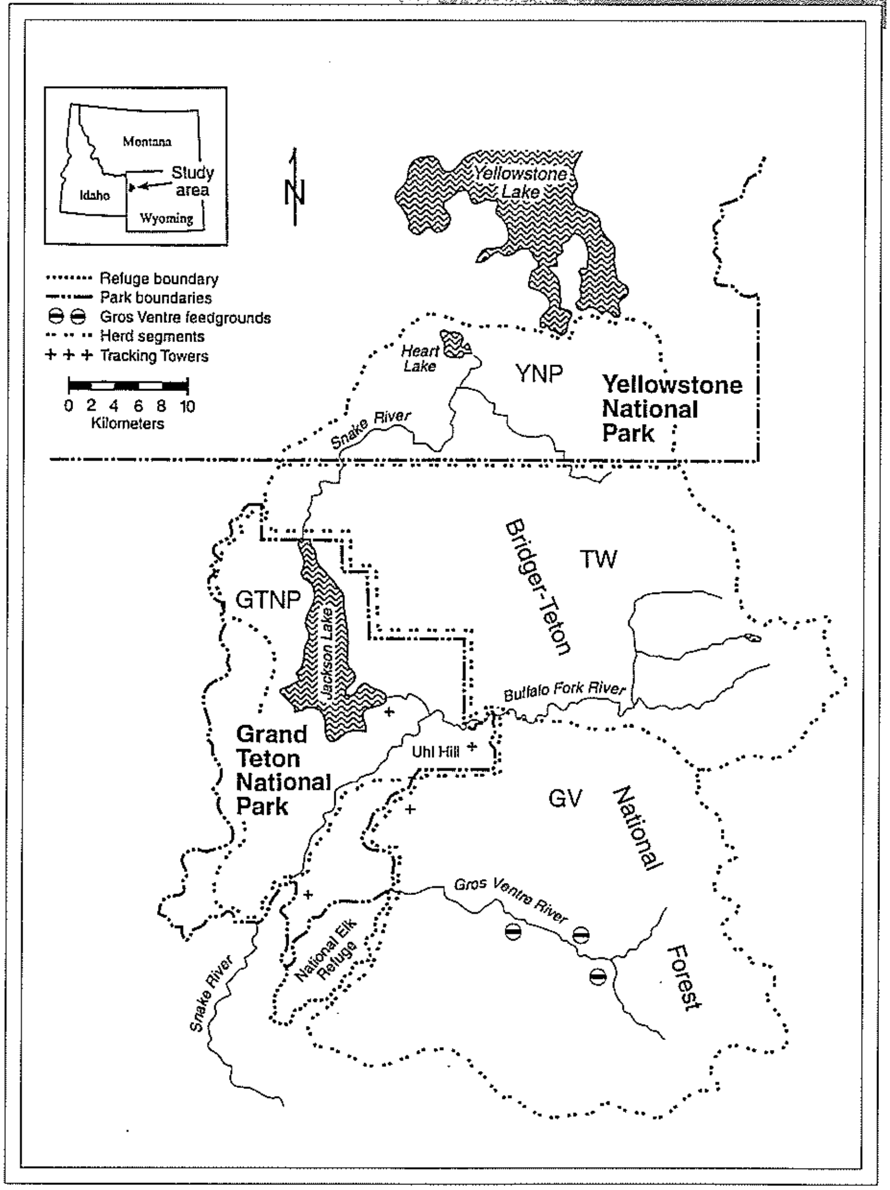
by Bruce Smith

Species inhabiting strongly seasonal environments often display a host of traits not possessed (or needed) by species living in environments lacking distinct seasons. These evolved traits enable animals to cope with periods of adverse conditions (drought, prolonged cold, deep snow) that influence individual fitness. These traits are both physiological (fat deposition, heavier winter pelage, reduced metabolic rates, water conservation, hibernation) and behavioral. One of the most widespread behavioral adaptations that animals have evolved is migratory behavior.

Migrations of large mammals between summer and winter ranges generally follow traditional routes that are learned, that is, passed on from mother to young. Even the casual observer will note that adult animals typically lead these movements. Bison and elk of Yellowstone National Park's northern range demonstrate a penchant to migrate down the Yellowstone River valley, perhaps as they did prehistorically. Unimpeded by humans, would bison and elk eventually relearn to winter across much of this valley and beyond each year?

Dr. Valerius Geist [*author of numerous papers and books on North American ungulates*] has pointed out that in mammal species that use patchily distributed habitats, the maintenance of traditions in a population is important. If the only bighorn sheep familiar with the location of desirable habitat patches are lost to the population, the traditional transmission of knowledge will be lost, and the use of the habitats discontinued. In populations that undertake long-distance migrations between summer and winter ranges, a similar loss of knowledge of migratory pathways could occur.

This is apparently the case in the Jackson elk herd, a portion of which is believed to have historically migrated out of Jackson



Summer ranges and winter feedgrounds of the Jackson elk herd.

Selection for Migratory Behavior

It seems logical that animals expend considerable energy to migrate to areas with more favorable environmental conditions. Therefore, migration has often been cited as an adaptive behavioral strategy that has evolved to avoid resource bottlenecks in temperate regions. The reasons that mule deer travel downslope to wintering areas with less snow and more available browse, or that waterfowl leave the frozen tundra for warmer climes each fall are apparent to us. It is less clear why they don't remain in those favorable climes yearlong. Thermoregulatory advantages, avoidance of insects, search for breeding areas, and other explanations of why migratory animals do not remain yearlong in the most mild of their seasonal ranges do not hold up. Some mule deer *do* remain on winter ranges all year, and Arctic nesting ducks and geese could find food and nesting habitat on their wintering grounds. Nor does aversion to crowding spur animals to migrate. Some of the most social species (colonial nesting birds and gregarious mammals like caribou) are migratory. The most parsimonious explanation for migration lies not in why individuals leave their most favorable seasonal range, but rather the evolutionary advantage of traveling to the least favorable one during relatively short periods of benign conditions.

Ultimately, migration improves long-term reproductive success by optimizing food available to parents before giving birth or laying eggs. Among mammals, the better the food resources during the pre-birth period, the more successful mothers are in providing milk and conceiving again. Milk production is highly correlated with growth of neonates, which positively influences winter survival in temperate latitudes.

Drs. John Fryxell and Tony Sinclair [*researchers of migratory mammals on the African savannah*] suggest that in addition to reproductive advantages, regulation of resident herbivores by predators may also favor selection of migratory behavior. In grassland ecosystems, migratory species of ungulates vastly outnumber sedentary species. In Africa's Serengeti, for example, nonmigratory herbivores often suffer higher rates of predation than migratory herbivores whose movements extend beyond the home ranges of lions and hyenas.

Hole to winter ranges in southwest Wyoming. The Jackson pronghorn antelope herd still undertakes this world class migration between winter ranges in southwest Wyoming and summer range in Jackson Hole. Although pronghorn all but disappeared from Jackson Hole between 1910 and the late 1950s, a handful of survivors apparently perpetuated this 300-mile migration.

The Value of Understanding Migratory Behavior

Aspects of migratory behavior are of particular interest to wildlife ecologists working in the Yellowstone ecosystem. Many of the bird and large mammal species of this highly seasonal environment are migratory. Understanding the location of migration routes and corridors is basic to conservation of individual populations. These corridors not only link geographically separate seasonal ranges, but often provide pathways for outbreeding and gene flow among populations. For example, in the upper Yellowstone River drainage, at least three distinct elk herds commingle during the fall rut and exchange genetic material.

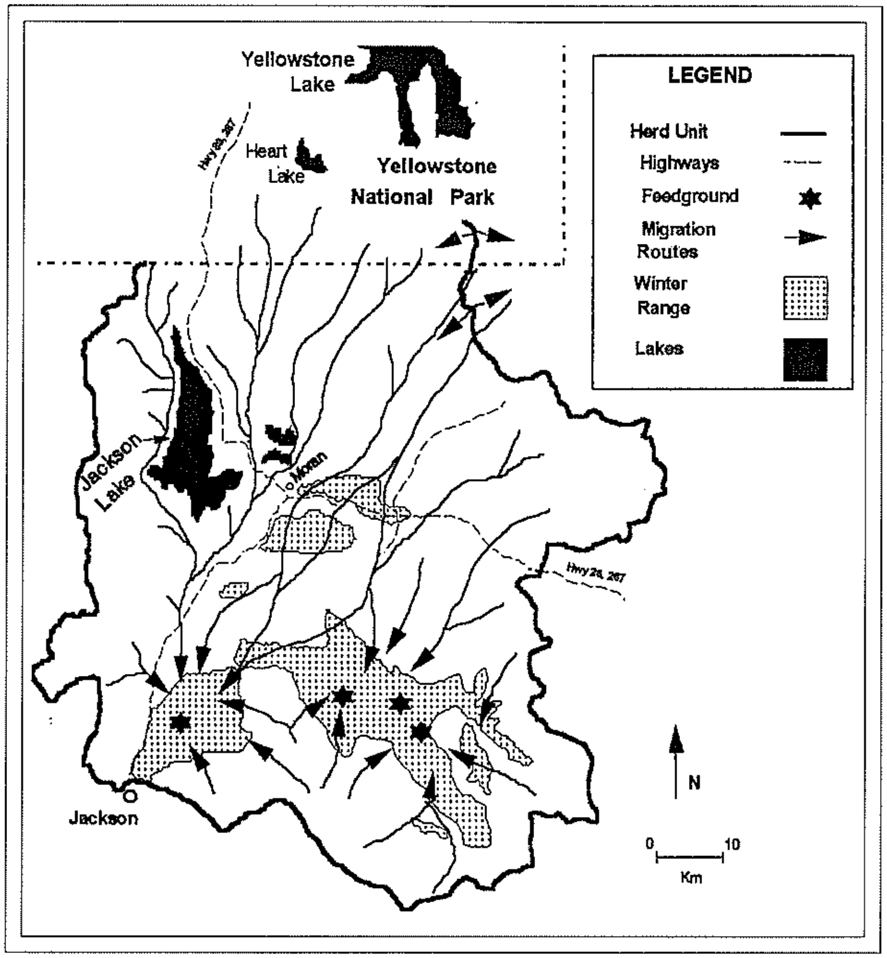
Wildlife managers who use hunting as a management tool must understand when and where populations migrate to design successful hunting seasons. The population that best exemplifies this is the Jackson elk herd, which is centrally located in the Yellowstone ecosystem. As elk stream southward each fall from their high-elevation summer ranges in southern Yellowstone National Park, the Bridger-Teton National Forest, and Grand Teton National Park, some 3,000 elk are harvested from a fall herd numbering 19,000-20,000. But all elk are not equally vulnerable to hunters. Therein lies the need for wildlife managers to understand when and where elk from various summer ranges make their annual pilgrimages to their winter ranges. Otherwise there could be heavy harvests of animals from some summer ranges and little harvest of others. This occurred in the Jackson elk herd 20-30 years ago.

Aside from the notoriety of its large size and 70-mile seasonal migrations, the Jackson elk may represent the largest challenge of any big game population in North America. So complex is the herd's management that private citizens are deputized as park rangers to carry out an elk reduction program in Grand Teton each fall. This is the only big game "hunt" conducted in a national park in the lower 48 states, although some other NPS units (i.e., national recreation areas) allow hunting. Moreover, elk are hunted on the northern half of the National Elk Refuge (NER), where 60 percent of the Jackson herd spends the winter. A key feature of the herd's ecology that necessitates these elk reductions is the winter feeding of much of the herd on the NER and on three additional feeding areas operated by the state of Wyoming. Feeding was initiated in 1911 to mitigate the conversion of former elk winter range in Jackson Hole to human uses.

Research on the Jackson Elk Herd

Two recent investigations have helped clarify migratory behavior of Jackson elk. In both studies my coworkers and I radiocollared elk and closely monitored their movements in relation to environmental conditions. In 1978, we initiated a study of the approximately 7,500 elk that winter on the NER. Our objectives and results, detailed in *Migrations and Management of the Jackson Elk Herd*, published by the National Biological Survey in 1994, are summarized briefly here.

We sought to gather information on the seasonal distributions of elk that wintered on the NER and to identify their calving locations, the timing and loca-



Migration routes of the Jackson elk herd.

tions of their migration routes, and the degree of fidelity elk had to these locations and patterns of behavior. We also intended to estimate annual harvest and survival rates of elk in each herd segment.

From 1978 to 1982, we captured, immobilized, and radio-collared 97 elk at random on the NER. From 1978 to 1984 we attempted to locate the 97 radio-collared elk (80 females and 17 males) three times each week during migration and approximately weekly at other times. We plotted radio locations on USGS topographic maps and determined membership of each radio-collared elk to one of the following herd segments: Grand Teton National Park (GTNP), Yellowstone National Park (YNP), Teton Wilderness (TW), or Gros Ventre (GV) drainage. Fidelity to seasonal ranges was measured as an elk's frequency of return to its previous year's winter and summer range. We delineated specific calving areas from relocations of radio-collared female elk.

In the second study, we captured 164 elk on Bridger-Teton National Forest (BTNF) during 1990-1992. Calves were fitted with expandable radio collars, which were replaced with adult collars during the animal's second or third winter.

Forty-eight percent of our adult radio-collared elk summered in GTNP, 28 percent in YNP, and the remainder summered on the BTNF (12 percent in the Teton Wilderness Area and 12 percent in the Gros Ventre drainage). Fidelity to winter range on the NER was 97 percent among adult collared elk that survived one or more years. Fidelity to summer ranges was 98 percent, and the fidelity of most animals went beyond returning to one of the four general summer ranges. For example, ten of the eleven adult radio-collared elk that summered in YNP returned to the same drainage or mountain complex each summer.

The migratory patterns we found were very similar among adult and juvenile elk. This is not surprising, given that elk generally migrate in mixed groups. The peak of spring migrations from the refuge occurred about three weeks after managers ended supplemental feeding in late March to mid-April, when new growth of grasses and forbs appeared over several thousand acres of the refuge. Growth began sooner when March temperatures were warmer, melting winter's snow and warming the soil. After a winter of eating dried grasses and a supplemental ration of alfalfa pellets for two to three months, the elk clearly preferred nutritious spring grasses. They grazed across the refuge and adjacent national forest slopes for two to three weeks and then began moving north, mostly at night, along traditional routes . The higher ridges were still snowbound in April and early May, so the Snake and Gros Ventre river valleys and their tributaries provided travel lanes.

Adult bulls arrived at distant summer ranges in southern YNP and the TW three to four weeks earlier than cows. This was largely a consequence of the cows interrupting spring migrations to give birth in favored habitats along the way. However, both bulls and cows arrived on summer ranges equally soon during spring 1981. What little snow fell the previous winter melted early that spring. Many of our radio-collared cows calved in 1981 on or very near summer ranges that in years of more typical snowpack would have provided poor foraging for females nearing birth and needing abundant nutritious forage for production of milk.

Annual fall migrations were likewise correlated with environmental conditions. During both studies, more than 85 percent of radio-collared elk wintered on refuge winter range (including the NER and adjacent national forest slopes, less than 2 miles to the east). Fall migrations commenced in October or November. Elk funneled southward along migration routes; topographic features such as Jackson Lake and steep escarpments concentrated elk in places. Ninety-four percent of radio-collared elk had arrived on the winter range by December 15. Duration of fall migrations varied with distances between the summer ranges and the refuge winter range. Elk from GTNP spent significantly less time migrating to win-

A four-day old elk calf radio-collared by the author.

Replacing the expandable radio collar on a yearling elk.

ter range than other Jackson elk. Some elk that summered in southern GTNP and the western Gros Ventre drainage migrated in one day or less. Elk that summered in the eastern Gros Ventre, Teton Wilderness, and YNP took from several days to eight weeks to reach the refuge after leaving their summer ranges.

Radio-collared elk from all summer ranges began migrating at about the same time. October precipitation was the foremost factor influencing when both males and females, juveniles and adults left high-elevation summer ranges in YNP and the Teton Wilderness. Annual arrival dates of migrating elk at the refuge winter range were inversely correlated with two variables: combined mean monthly July and August temperatures and snow depths at the south entrance of YNP on November 10. It is not surprising that greater snow accumulations prompted elk to migrate to the refuge sooner. But what effect could temperatures four to five months earlier have played?

The Need to Feed

In the Yellowstone ecosystem, below-normal precipitation accompanies high summer temperatures. Paltry precipitation during the growing season reduces vegetation production. Furthermore, when summer temperatures are high and precipitation low, plants become stressed and cease growing sooner. This affects not only the total biomass produced, but also the length of time that elk enjoy the more nutritious and digestible green vegetation. Elk must consume copious amounts of high-quality forage during summer to lay on fat, which is later burned to alleviate nutritional deficits during winter. Nearly 25 percent of the NER is either irrigated by refuge staff or sub-irrigated (a high water table provides moisture to the plants' root zone). This, combined with the fact that the refuge is largely ungrazed during summer, means that abundant forage, some of it still green, remains when elk arrive each fall.

There is additional evidence of the importance of forage. Elk spend summer and fall primarily in GTNP west of the Snake River where hunting is not permitted. Elk leave the west-side sanctuary each fall and migrate to the refuge winter range when little snow covers the ground. When they cross the Snake River, elk are hunted in both the park and the north half of the refuge. My studies of forage production and forage use in GTNP suggest that elk leave the park because they are forage-limited, in quality and/or quantity. They migrate to the refuge earlier in years of lower forage production and when less forage remains in areas where large herds congregate west of the Snake River. They chance the perils east of the river to garner the forage bonanza at migration's end.

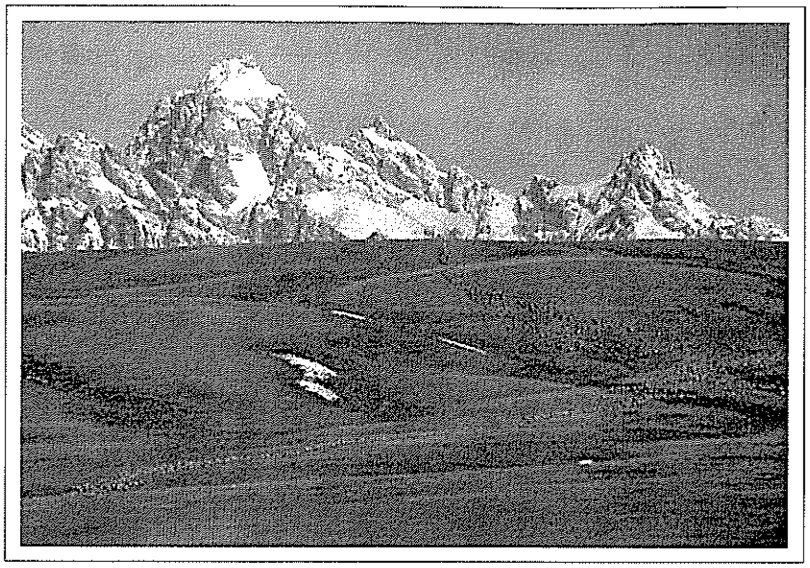
From an elk's viewpoint this strategy has been successful. Winter mortality has averaged just 1.4 percent of the elk that wintered on the refuge in recent years, and early migrations have not resulted in significant proportions of the herd being culled annually by hunters in the park and refuge. The number of elk wintering on the NER has doubled since 1984. The elk often migrate in large herds and many migrate under cover of darkness. For example, 2,700 elk streamed into the refuge the night of November 12, 1988. And when forage supplies become depleted or frozen beneath a blanket of snow on the refuge, the elk are fed. These migration strategies can therefore be considered adaptive.

Managing Migratory Elk

Our experience leads us to conclude that refuge and park hunts are vital in controlling elk numbers in GTNP, given the low rate of winter mortality of the Jackson herd. All but a few elk that summer in Grand Teton migrate to the refuge winter range. Thus the park and refuge are the only lands on which those elk can be harvested. Their shorter migrations result in GTNP elk arriving an average 6-29 days earlier at the refuge each fall than elk from the other summer ranges, which migrate and are hunted across large expanses of the BTNF. Numbers of elk that summer in GTNP have quadrupled over the past 40 years and are now approaching 5,000. The reasons for the increase in the elk population include the removal of livestock and the cessation of hunting from park lands west of the Snake River that were privately owned, hunted, and supported few elk before 1950.

In large measure it is the migratory behavior of the elk and the number of permitted hunters that dictate the harvest. These limits are most evident within the confines of GTNP and the NER where the harvesting of elk is essentially a herd reduction program. Wildlife managers schedule hunting seasons in the southeastern part of GTNP and in the NER to coincide with the start of the earliest-recorded migrations. The U.S. Fish and Wildlife Service maintains about 60 radio collars on elk to monitor the migration's progress. The refuge hunt ends when 80 percent of the radio-collared elk that summered in GTNP arrive at the refuge. This percentage best coincides with the maximum arrival of GTNP elk and the least number of elk arriving from more distant summer ranges. Closing the refuge season at that time permits migrating elk to disperse and forage across much of the refuge and onto the adjacent national forest winter range, where hunting closes before or in concert with the refuge season. The refuge has weekly drawings for permits, and its hunting season can be terminated on a week's notice to the public.

The GTNP season continues longer some years to encourage hunters to harvest elk from southern YNP that migrate later through Grand Teton to the refuge winter range. In years when the migration has begun late, such as in 1993, hunting seasons in the Jackson area have closed before many elk have left Yellowstone. Ending dates of hunting seasons, which must be decided by the Wyoming Game and Fish Department the previous spring (with no hint of how the fall migration will shape up), are difficult to change on short notice. Heavy October snows can render even the best of forage crops unavailable and speed the progress of migrations. Consequently, data from past fall migrations still provide the sideboards for next year's hunting season dates. However, because one of the goals of science is to predict future events, the potential to predict elk migrations from growing-season conditions has been an exciting discovery. Our research also helps us better understand the role that density-independent factors (those independent of the number of elk) play in the migratory behavior of elk.


Exodus of 2,000 elk from the National Elk Refuge in spring.

Harvesting Yellowstone's northern range herd is likewise dependent on migration of elk from the park. Heavy fall snows and the size of the herd both affect the timing of migrations, the number of migrants, and the potential harvest. Similar patterns are seen in other parks that provide safe havens for deer and elk populations. These animals know the park boundaries and avoid leaving them until the threat of starvation overcomes their fear of human predation. In many of these parks, heavy browsing has seriously altered the composition and structure of woody plant communities, impacting many other wildlife species and the diversity of park landscapes. In some cases, human activity has curtailed migrations out of the parks and increased densities of herbivores within park boundaries.

Conserving the Spectacle of Migration

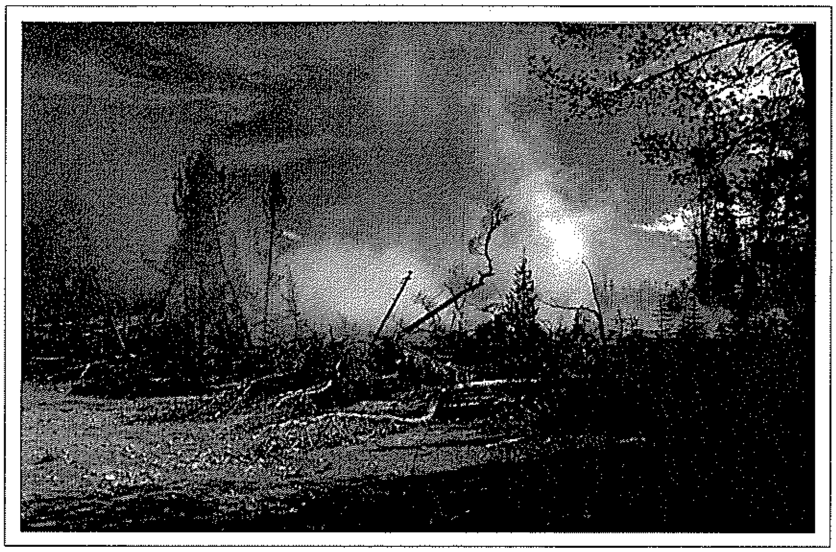
The establishment of Yellowstone National Park in 1872 and the National Elk Refuge in 1912 has been critical in the protection of elk from market and antler hunting and usurpation of critical habitat for human uses. The restoration of pre-1950 distributions and migrations of elk east of Grand Teton National Park remains an important objective of state and federal agencies because of the recreational, aesthetic, economic, and ecological benefits of conserving elk throughout all summer ranges in the national forests and the national parks.

Management of migratory herds of elk and other animals will continue to challenge wildlife and land managers as these herds become squeezed into smaller and smaller ranges by the encroachment of human enterprise. Former wildlands become fragmented, populations become isolated, their winter ranges compressed, and migration corridors obstructed.

The large predators on these migratory herds are often the first to decline in numbers as wildlands are "tamed" by humans. Bears, lions, wolves, coyotes, and other carnivores serve to facilitate a balance among the herbivore species and their densities in natural systems. Our large remaining ecosystems, such as the greater Yellowstone area, must be conserved to provide a remnant of what was common across western North America just 150 years ago. Only in these large blocks of habitat can the spectacle of migrating elk, other large migratory herbivores, and their complement of predators continue to flourish.

Dr. Bruce Smith is a wildlife biologist with the U.S. Fish & Wildlife Service, stationed at the National Elk Refuge in Jackson Hole, Wyoming.

The Ongoing Thermal Evolution at Astringent Creek



Extensive stand of trees killed by heat flow that preceded the emergence of the violent 1995 mud volcano.

by Roderick Hutchinson

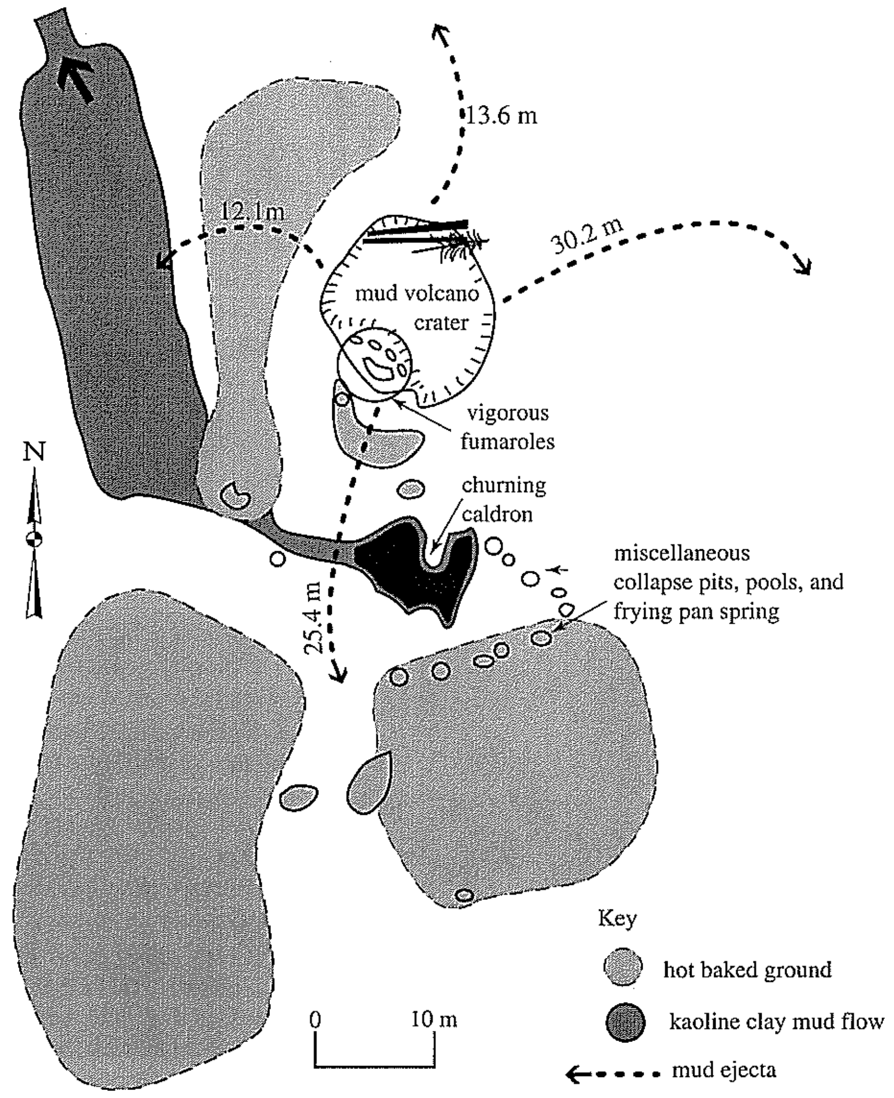
On the southeast flank of the Sour Creek Resurgent Dome near Pelican Valley, in the 600,000-year-old Yellowstone caldera, is an extensive acid-sulfate hydrothermal system. Surface expression in a newly active 3km^2 thermal area west of Astringent Creek, includes discontinuous high-temperature-altered ground, turbid springs, pools, seeps, fumaroles, and mud pots. There is also a large, gassy, sulfur-rich acid lake, and numerous sublimated sulfur-mound deposits interspersed among low-temperature, forest-covered ground.

1985: A Thermal Cycle Begins

An evolutionary cycle was first observed beginning in 1985 at the upper eastern margin of the Mushpots thermal area. This cycle has been characterized by areas of new hot ground, dying mature forests, and the vigorous breakout of a dry, super-heated fumarole with progressively hotter temperatures over time, followed by the sudden emergence of a large and violent mud volcano. The Mushpots thermal area is located near the western flank of Pelican Cone, about 4.5 km (2.8 m) east of the new Astringent Creek area, which has similar chemistry and is part of the same hydrothermal system.

Sometime during early 1990, a significant rise in temperature there began killing a grove of pine trees. Within a year, a new super-heated fumarole emerged among the roots and centuries-old fallen trees, quickly blanketing them with a layer of hydrothermally altered coarse sand from a directed blast to the north. The dynamic activity of the fumarole and surrounding hot ground was closely monitored twice a year starting in 1991. More frequent visits were not possible due to the area's remote location and restricted access through the Pelican Valley Bear Management Area. The feature's temperature and the volume of dry steam from the deep shaft-like vent steadily increased over the next three years to a maximum of 104.3°C (220°F), measured on October 8, 1994. The local boiling point at the feature's 2,585 m elevation (8,481 ft) is about 93°C (199°F).

Inspections after 1991 of the acid-sulfate thermal area west of Astringent Creek showed ample evidence that a series of seven large craters had apparently followed the same pattern as the Mushpots. They were progressively younger in a



Sketch map of new emerging features and unstable hot baked ground in thermal area west of Astringent Creek, June 7, 1995.

southwesterly direction, ending at the site of the current new hot ground and fumarole. A prediction that the newest super-heated fumarole would soon evolve into a large mud volcano was published in an article I wrote for *Eos Transactions* in December 1993.

1995: A Mud Volcano Erupts

As part of routine monitoring, the site was inspected on June 7 and September 12, 1995, and again on April 22, 1996. In place of the former 104.3°C (219.7°F) fumarole was a large, vigorous mud pot with an extensive area of ejecta produced while it was active as a mud volcano. Also new were two smaller roaring fumaroles at or slightly above boiling temperature, three moderate-sized churning cauldrons, and numerous smaller muddy pools, collapse pits, and frying pan springs. Under the fallen trees were extensive areas of unstable quicksand-like saturated ground made up of scalding mud. Some regions were heavily encrusted with sulfate minerals or sulfur crystals; others were deceptively covered by baked pine needle forest duff.

Extending northwest from the largest parasitic churning caldron was a spectacular white kaoline-clay mud flow. It rapidly spread out to an average width of 13.8 m (45.3 ft) in the first 55 m (180 ft) of its length in the dead forest grove before terminating on the treeless, acid-thermal basin floor 114 m (374 ft) from its source.

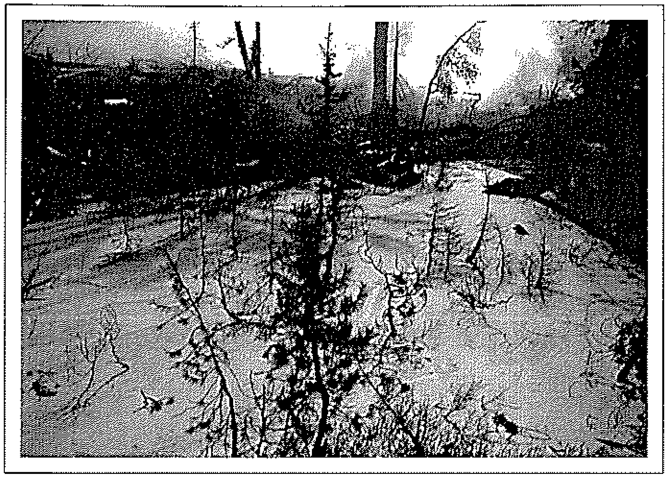
Judging by the freshness of the ejected mud and incorporated, semi-coarse sandy material, the rapid collapse and transformation of the super-heated fumarole into the powerful mud volcano is estimated to have occurred sometime between mid-April and mid-May of 1995. The volcano crater, which was active as a vigorous, moderately thick mud pot, was 13.5 m (44.3 ft) long , 11.3 m (37.1 ft) wide, and 3.9 (12.8 ft) to 4.9 m (16 ft) deep. Conservatively estimated, the crater volume was 315 cubic m (11,000 cubic ft).

Large bombs of mud probably attained heights of 20 to 30 m (65 to 100 ft) above the crater rim, based on the maximum distance that mud had been ejected—more than 30 m (98 ft) from the eastern rim. When the site was last inspected, mud was still being thrown up between 0.5 and 1.5 m (1.5 to 5 ft) from dozens of points all over the crater floor. Total area

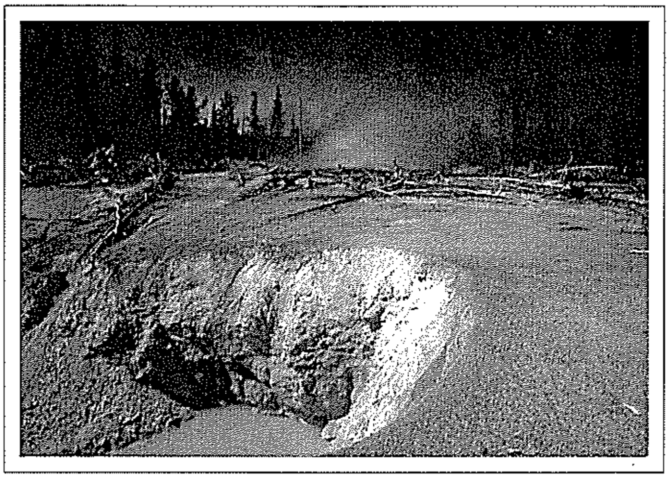
A GLOSSARY OF THERMAL FEATURES AT ASTRINGENT CREEK

- **Cauldron.** A hot spring pool with churning or agitated water.
- **Collapse pits.** Small depressions in thermal ground produced by removal of material at depth by hydrothermal processes.
- **Frying pan springs**. Shallow, vigorously active bubbling or boiling hot springs, usually in sand or gravel, with agitation similar to the sizzling of hot grease in a frying pan.
- **Fumarole.** A steaming and/or gaseous vent lacking water.
- **Mudflow.** A mass of mingled earth particles and water that flows like lava from a volcano.
- **Mud pot.** A hot spring with fine clay mud of any viscosity (soupy to stiff mortar), usually having no discharge.
- **Mud volcano.** A large, violently active mud pot with material ejected out to build up a cone or mound.

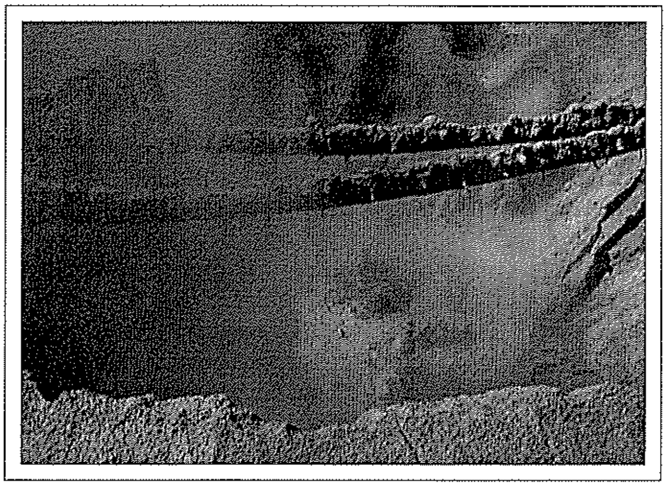
NPS photos Rick Hutchinson



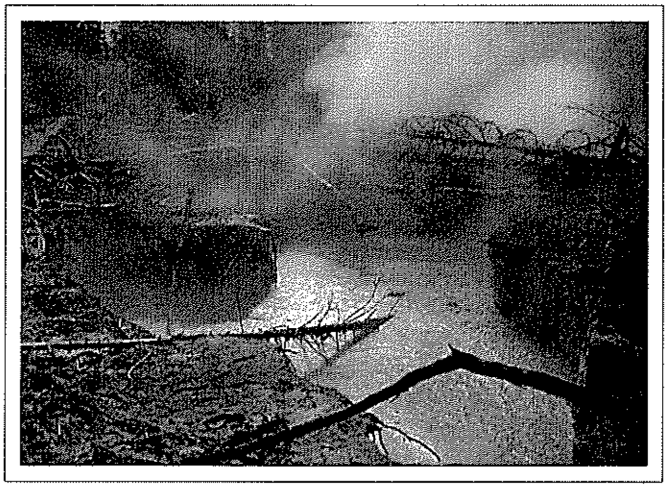
A large white thermal clay mudflow issued from a parasitic caldron-like vent below the 1995 mud volcano in an area of unstable hot ground (steam in background). The mudflow has buried sapling trees.



There is a chain of seven craters that pre-date the 1995 mud volcano (steam in background); the youngest is in the foreground.



View into new mud volcano crater. Its buried rim is bridged by mud-encased tree trunks killed by the thermal activity.



Closeup view of source vent of thermal mudflow.

covered by the ejecta and crater was approximately 2,100 m^2 (22,000 ft^2).

In the southwestern quarter of the crater, a large, slightly elevated projection was visible with an arcuate (curving) line of dry white, probably super-heated fumarole vents. A pair of large logs bridged a portion of the northern crater rim that appeared on the verge of collapse.

The largest cauldron had numerous points of ebullition (bubbling activity) in its irregularly shaped pool, with maximum dimensions of 10.8 x 7.9 m (35.4 x 25.9 ft) and a water level 0.7 to 1.4 m (2.3 to 4.6 ft) below the sloping forest floor. The cauldron's churning water was near-boiling, opaque, and light tan in color, and partially covered with a medium-brown, organic-rich foam derived from cooked plant material. Both of the cauldrons are interpreted as being parasitic to the mud volcano crater, because they appear to have evolved shortly after the initial fumarole collapse, then subsequently drained away much of the fluids. Such a relationship seems to have rapidly lowered the crater floor and prevented accumulation of a thick ejecta cone on the crater rim.

The mud volcano crater, parasitic features and vents, plus most of the associated hot ground, remain extremely dangerous and unstable. Additional changes in the manner of new or enlarged springs and perhaps even another mud-volcano crater are anticipated. With respect to geologic hazards, the acid-sulfate thermal area is being monitored regularly. Photographs were taken to document the activity in June 1995 and on subsequent visits. Like the recent intense swarms of seismic activity noted by Robert Smith [*professor of geophysics at the University of Utah*] at the Western Wyoming Earthquake Awareness Symposium in Jackson Hole on June 15, 1995, hydrothermal outbreaks at the Mushpots, Norris Geyser Basin, and west of Astringent Creek are wake-up calls warning of future life-threatening geologic unrest in the Yellowstone region.

Roderick Hutchinson is Yellowstone National Park's research geologist; he has been studying and exploring Yellowstone's thermal areas for more than 25 years.