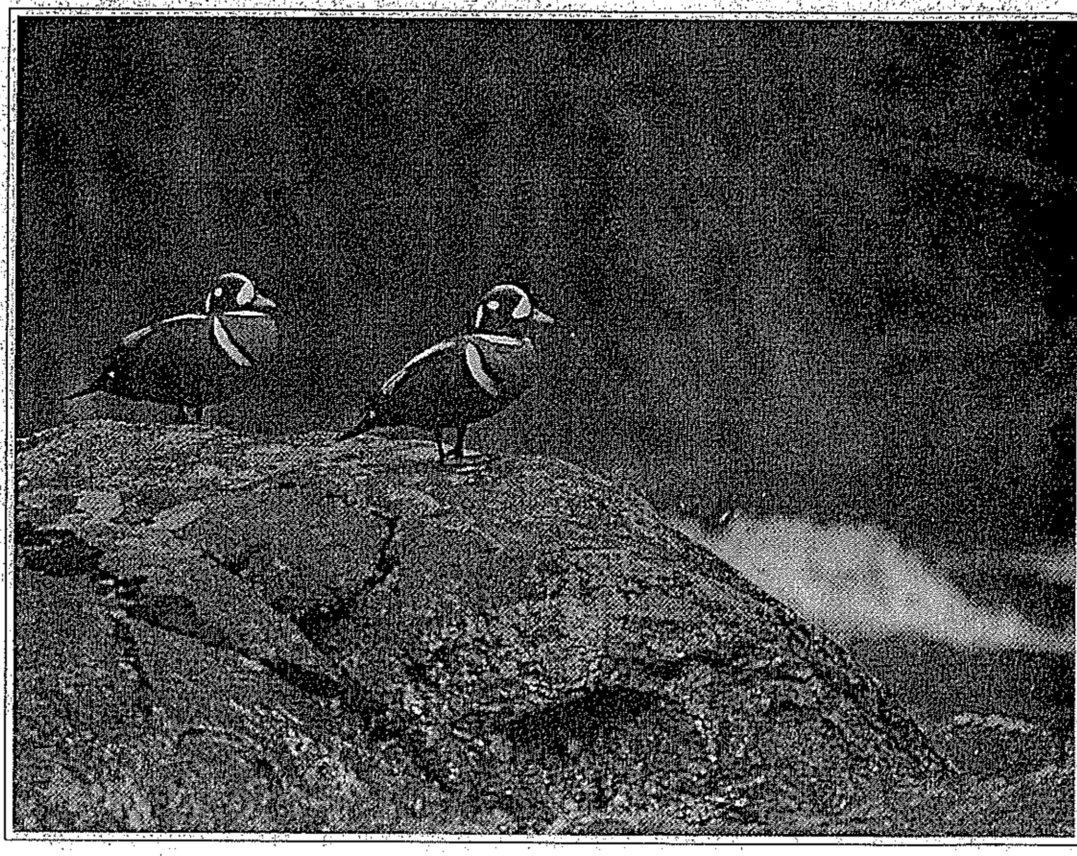
Yellowstone Science

A quarterly publication devoted to the natural and cultural resources



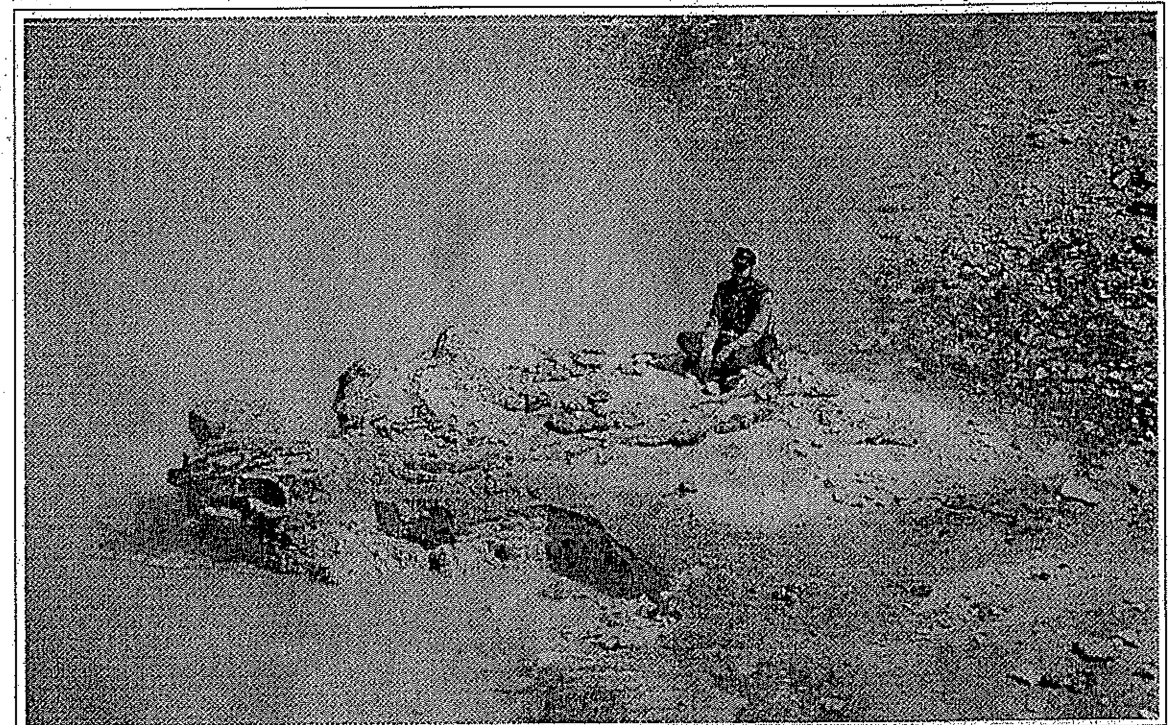
Documenting Landscape Changes

Using the Snow Database

Harlequin Ducks

Volume 5 Number 2

Photo by Sue Consolo-Murphy



Rick Hutchinson observing an eruption of Excelsior Geyser.

The Gravity of Snow

I had long planned this issue to focus on Yellowstone's climate and how it affects the park and its inhabitants. An article on the snow database, and how it can be used as an index to winter severity. An interview with Dr. Mary Meagher about her long-term collaborative project to document the changes (or relative lack thereof) in the park landscape through the re-taking of early photographs of Yellowstone. An article on harlequin ducks, one of many animal species that (like most human visitors) comes only seasonally, attracted—and ultimately, driven away—by the changing of the weather. And a review of a book about intrepid early explorers and rangers who braved the elements to document and protect park resources, entitled *Yellowstone's Ski Pioneers: Peril and Heroism on the Winter Trail.*

Lest we ever be complacent about the dominance that climate exerts upon Yellowstone, we received a harsh reminder when winter reached out its cold, powerful fingers to grasp from the earth two of our own present-day scientific explorers. Roderick Hutchinson—Rick, to us—park geologist and 27-year veteran of Yellowstone's staff, and his visiting colleague, Diane Dustman from Boston Dynamics, a computer software company, were on a foray to document thermal activity in the Heart Lake Geyser Basin when they were killed by an avalanche on March 3, 1997. Peril and heroism on the winter trail, indeed.

I did not know Diane, though like all of the park's cooperative researchers from around the world, she surely loved Yellowstone, and we are grateful that she offered her professional skills and expertise to benefit the park's science program.

I knew Rick for 15 years, and count myself privileged to have shared many journeys with him, to and among his beloved thermal basins. He relished the quest for knowledge, and he shared some of his scientific adventures by contributing to *Yellowstone Science*. His most recent article, which appeared in the first issue of this magazine that I edited, described the evolution of features near Astringent Creek. Well do I recall accompanying Rick to this wild area, standing on the opposite end of a measuring tape from him with the turbulent, boiling mud pot between us. On another trip, we were thrilled to discover a previously unrecorded natural bridge near the headwaters of Sour Creek. On each journey, Rick took photographs and detailed notes. The documentation of his geological explorations will be used by other scientists and protectors of park resources for many years to come.

Friends and families of Rick and Diane take comfort in knowing that these two scientists loved their work and being out in the wildness of Yellowstone. Their legacy, and their heroism on the winter trail, will not be forgotten. SCM

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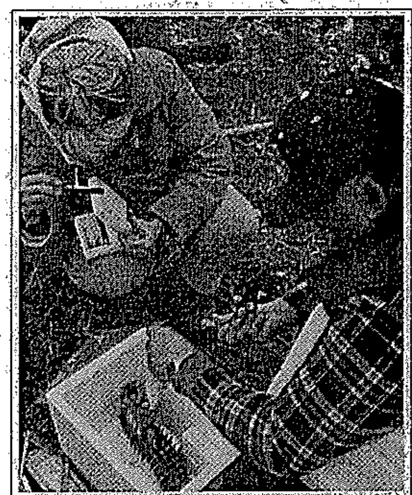

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On the cover: Male harlequin ducks perched above the fast water of one of Yellowstone's streams. See Terry McEneaney's article on these "noble ducks," page 2. Cover photo by author.

Above: Dr. Mary Meagher and an associate take bison blood and tissue samples in the field. Mary discusses bison and her book, Yellowstone and the Biology of Time, *in an interview on page 12. NPS photo.*

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Yellowstone Science is published quarterly, and submissions are welcome from all investigators conducting formal research in the Yellowstone area. Editorial correspondence should be sent to the Editor, *Yellowstone Science*, Yellowstone Center for Resources, P.O. Box 168, Yellowstone National Park, WY 82190.
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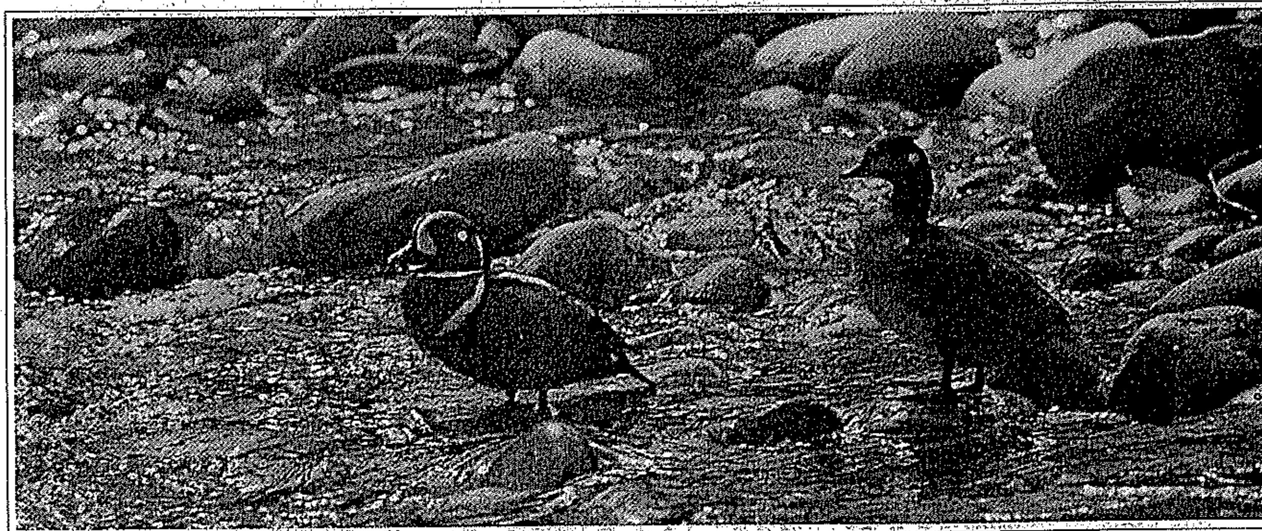
Harlequins: Noble Ducks of Turbulent Waters

by Terry McEneaney

Photos by Terry McEneaney



Harlequin Lord and Lady

The setting is a rainy summer day along the rocky coastal shores of the Pacific Northwest. The liquid horizon is dotted with familiar objects such as western gulls, bald eagles, breaching whales, fishing boats, ferries, and oil tankers. Our senses confirm that this is the ocean, due to the omnipresent smell of fish and saltwater. Our attention is focused on sounds of fog horns, pounding surf, and strange mouse-like noises that resemble a squeaking squeeze toy. Closer than the distant kelp beds, near the turbulent breaking waves of sea foam, we find the mouse-like sound is coming from two small objects just out from shore. At first glance they appear to be apparitions, but after wiping the rain and the surf spray from our eyes, we come to the conclusion that these are ducks. Not just any generic species of duck, but a brace (or pair) of harlequin ducks (*Histrionicus histrionicus*).

Native peoples and European settlers who inhabited the northern North American coasts gave the bird different names based on personal experiences and associations: blue streak, canne de roche, rock duck, circus duck, painted duck, mountain duck, sea-mouse, squealer, lord and lady, and totem-pole duck.

Because of the influence of the English language and culture, the name that stuck most often was reminiscent of nobility, the "lord and lady of the sea," in reference to the harlequin's elegant coloration and regalia. The male harlequin (still called the lord) in colorful breeding plumage is beyond reasonable description. The lord is a gray-blue, almost purple-attired duck slightly larger than a pigeon or rock dove, with chestnut-colored sides, two chestnut streaks on either side of the crown, and neon white crescents and spots on the head, breast, and back.

It is the male of this species from which the name "harlequin" is derived—a likeable clown with beautiful yet unique attire, gestures, postures and behavior. It is no wonder this bird received the tautonym *histrionicus* in reference to its theatrical acting ability. The harlequin is the consummate bird entertainer of the natural world, combining pantomime with comedy. One can spend hours observing these fascinating ducks. The information presented here is the culmination of ten years of field experience studying harlequin ducks in Yellowstone, including their ecological role, distribution, and population status. I also discuss census techniques, survival threats, conservation measures, and anecdotal tidbits.

The female harlequin, or lady, is nearly opposite to the male in coloration, yet both have the energy reminiscent of wind-up toys. The female is slightly smaller than the male and in breeding plumage is a drab, dusky brown in color, with three small, white, asymmetrical facial marks in a triangular arrangement around the eyes. When adult harlequins molt their feathers in the summer, both show duller plumages than previously described for breeding adults. During the summer molt, the white spots on the head of the female become even duller, and the male totally transposes from a bird of sensational colors to a drab brown plumage nearly identical to that of the female.

Life History of the "Totem-Pole Duck"

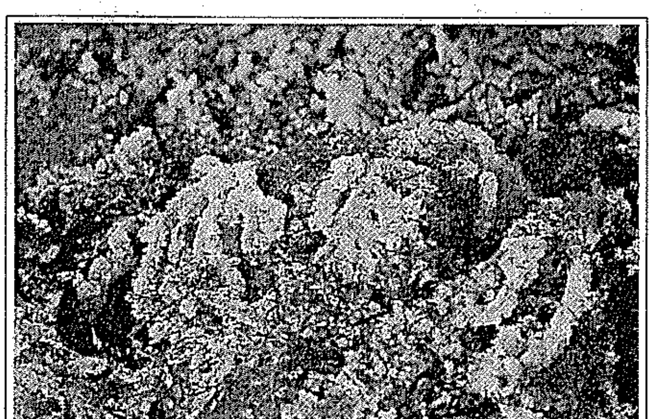
In addition to size and coloration differences in the sexes, there are weight and behavioral differences. The male (674 grams or 1 1/2 pounds) slightly outweighs the female (529 grams or 1 pound). The bill of the harlequin is small, short, and totes a large, fused nail at the tip of the bill, making it ideally suited for securing a specific diet. Both sexes have gray bills and feet, with the bill of the male slightly more blue-gray during breeding season. The webbed feet are extremely large for the size of the duck, making it ideally suited for its environment. Harlequins are also equipped with relatively long, stiff tails and small, rudder-like wings that assist in steering and propulsion both on the water and while in flight.

A question asked is whether this is an inland duck that moves to the sea, or a sea duck that moves inland. Harlequin ducks are sea ducks, aligned in the Mergini Tribe, which is in essence a collective group of sea ducks—their closest relatives are eiders and scoters. Ecologists group sea ducks in a convenient but crude survival category known as "K-strategists"—typically large birds with low reproductive rates and relatively stable populations in predictable environments. Even though they are long-lived, they typically colonize new environments slowly and are consequently ecologically restricted. On the other hand, r-strategists tend to be small birds with high reproductive rates and marked fluctuations in populations that are widely dispersed. They are typically short-lived, colonize quickly, and are found in unpredictable environments. Songbirds are r-strategists, whereas bald eagles are classic K-strategists. Harlequin ducks are more strongly weighted toward being K-selected than r-selected. Their strategy is important as we assess the future survival of the species, particularly as more human-induced variables enter the picture.

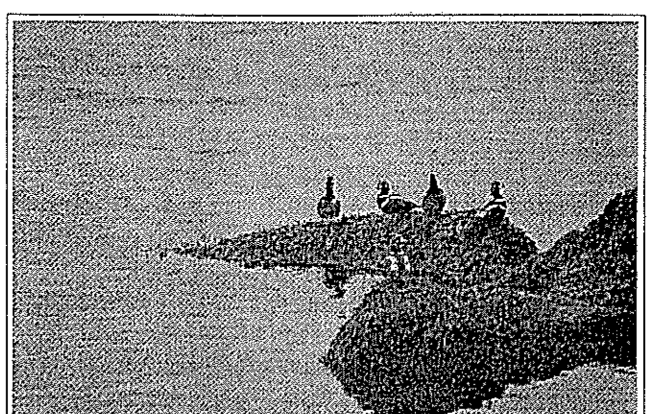
Harlequin ducks can live up to 18 years and have high adult survival, low reproductive rates, and small population sizes. They first breed at the average age of three years, and don't breed every year. They display a tendency to return to the same place every year, although if their nest is disturbed or destroyed, they will not re-nest that year. Globally, harlequin populations appear to be large, although the orders of magnitude are quite different depending on the locality. For instance, harlequin ducks are listed as endangered in eastern Canada and as a Category 2 species under the Endangered Species Act in the United States. In the intermountain west, and particularly in greater Yellowstone, their numbers are extremely low, and just the slightest change in magnitude of the adult population could be detrimental to the species.

The harlequin duck is one of a kind because of its adaptations and the niche it fills in the environment. Two species of ducks in the southern hemisphere utilize a similar niche: blue duck *(Hymenolaimus malacorhynchos)* in New Zealand, and torrent duck *(Merganetta armata)* in South America. But the harlequin is the only genus and species of its kind in the world and is restricted to the northern hemisphere.

During winter, harlequin ducks are found mainly along rocky shorelines of northern sea coasts, and rarely in the interior of the country. They feed on a variety of foods, including crustaceans, mollusks, sea urchins, roe, and occasionally small fishes. During summer, harlequins are typically found in turbulent, fast-moving freshwater rivers and streams lined with rocks or cobbles. Riffles, rapids, cascades, torrents, and even waterfalls are their domain, where they feed primarily on submerged aquatic insects, although I have seen them feed on worms, crickets, grasshoppers, and salmon flies on rare occasion. Harlequins can be found on relatively calm water, but it is very atypical.



The winter diet of harlequin ducks on the Pacific coast consists of a variety of foods, including roe (fish eggs).



The ducks begin courtship activity in spring along the rocky shoreline of the Straits of Juan de Fuca.

As April fast approaches, we return to the rocky shores along the Pacific coast to resume the fascinating story of the painted duck. Along the ledges and rocky points we witness a behavior that has been happening all winter, but this time it is more intense; the unique head-nodding and chasing characteristic of a courting male. Environmental factors, such as the length of light in a day (known as photoperiodism) coupled with temperature, begin to stimulate hormonal production—the nesting season is near. By this time of year, the pair-bonded couple has stored up large quantities of fat, often underneath the skin on the breast. The fat will be used as extra fuel for the journey, courtship activity, breeding, and production. Paired adults at least three years of age become restless and are the first to leave; migration has begun. They will soon be followed by others just coming into adulthood. Younger birds not capable of breeding spend their adolescence on the sea until they too are hormonally ready for the journey.

Migration, that ancient, instinctive ritual that stimulates animals to move, is still not well understood. In the bird world, harlequins are considered anadramous migrators, passing from the sea to fresh water at stated seasons to breed and then return to the sea. (Salmon also perform this same type of migration.) What routes do harlequins take to Yellowstone? How long does it take? These questions are part of the mystique of this unique bird. Speculation has it that they travel mostly by following water drainages, since they have an affinity for moving water. Yet to reach their final philopatric breeding areas in Montana and Wyoming, they have to cross land barriers such as the Continental Divide. How long it takes to complete the journey is again speculation. It is thought to take up to several days, particularly to and from areas like Yellowstone, in the far interior of the continent.

Western Pacific Harlequin Subgroup

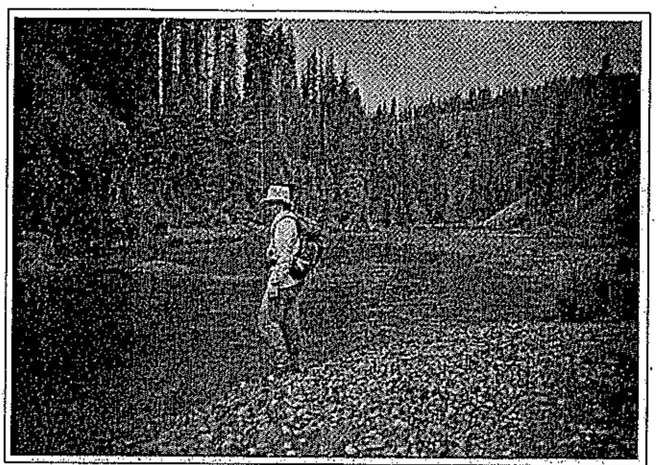
There are basically two populations of harlequin ducks in the northern hemisphere. The Atlantic group is subdivided into the Greenland-Iceland subgroup and the eastern Canada-United States subgroup. The Greenland-Iceland subgroup summers inland and winters and molts on the coasts of these islands. Vagrants may make it to places like Great Britain, Norway, and Italy. Their populations are estimated to be 5,000 to 10,000. The eastern Canada-United States subgroup includes harlequins breeding inland in Labrador, Newfoundland, and on the Gaspe Peninsula of Quebec. They are typically found wintering from Newfoundland south to Maine, with far fewer south to Rhode Island; vagrants occur as far west as the Great Lakes and as far south as Texas and Florida. Populations in eastern North America are estimated to be fewer than 1,000.

The Pacific population is also divided into two subgroups. In the Russian Far East group, harlequins breed in the interior from the Chukchi Peninsula west to Lake Baikal and south to Sakhalin. These birds winter along the coast from the Kamchatka Peninsula to Japan, including the Aleutian Islands. Vagrants have been found as far south as China. Population levels are unknown, but their numbers are believed to be substantial. The western North American subgroup breeds from interior Alaska and the Rocky Mountains of Canada and the United States, as far south as central Wyoming, with another finger extending south through the Cascades and the Sierras as far south as Yosemite. The winter range of these birds stretches along the Pacific coast from the Aleutian Islands to the coast of Washington, with vagrants making it as far as southern California; a recent record exists from northwest Mexico. We have only one substantiated record of a harlequin duck wintering in Yellowstone. The western Pacific subgroup is estimated to be at least 100,000 ducks, possibly as high as 200,000. Although these high figures have been published, they are not factual and should be treated with caution.

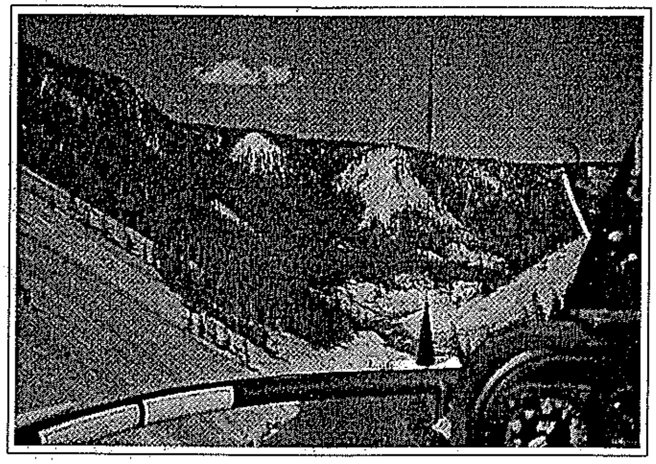
Harlequins in Yellowstone

In late April to early May, mated pairs start arriving in Yellowstone. I once witnessed a pair of harlequins in the Black Canyon of the Yellowstone, early in the crepuscular hours of the morning, that I am convinced had just arrived for the season. The birds were resting on a gravel bar and were so tired they were both sleeping soundly. This is very unusual for harlequins, for usually they are on the lookout, even through the corners of their eyes. I figured they must have travelled that night.

These mountain ducks live on the move in an environment on the move. Action is omnipresent, whether it is the ducks themselves or the fast-moving water they call home. Although a female accompanied by a male is not difficult to detect, she can be difficult to see because of her small size. Glaring sun on the water helps camouflage these ducks, as does their habit of hiding behind rocks and logs to avoid predators. I often look for what I call a "rock on a rock," for harlequins are mas-



The first harlequin duck surveys were conducted on foot and were very labor intensive. Here an assistant surveys the Snake River.



Helicopters have helped us to better determine populations, production, and distribution of harlequins in the park.

ters at blending into their environment. You will find even colorful males are hard to see at times.

Once here, harlequins travel from one location to another either by flying close to the water or by floating in the whitewater. To avoid predators they will take the plunge through rapids, cascades, and drop pools, or hide in eddies and back pools, especially if accompanied by young. Pairs or single birds will even sometimes skip fly over the surface of the water in order to overcome natural obstacles. The novice harlequin watcher should also realize that this bird has tremendously acute eyesight. It is well aware of any new motion or object in its environment, enabling the colorful male to avoid excessive predation. At times it pretends to be sleeping, but the harlequins I have watched over the years hardly ever sleep by my definition. Documenting predation is difficult, but I have seen a bald eagle feeding on a male harlequin duck. This was quite a rare sighting. Based on behavioral responses by harlequins that I have witnessed, it is safe to say that mink, long-tailed weasel, coyotes, and river otter are also highly feared predators.

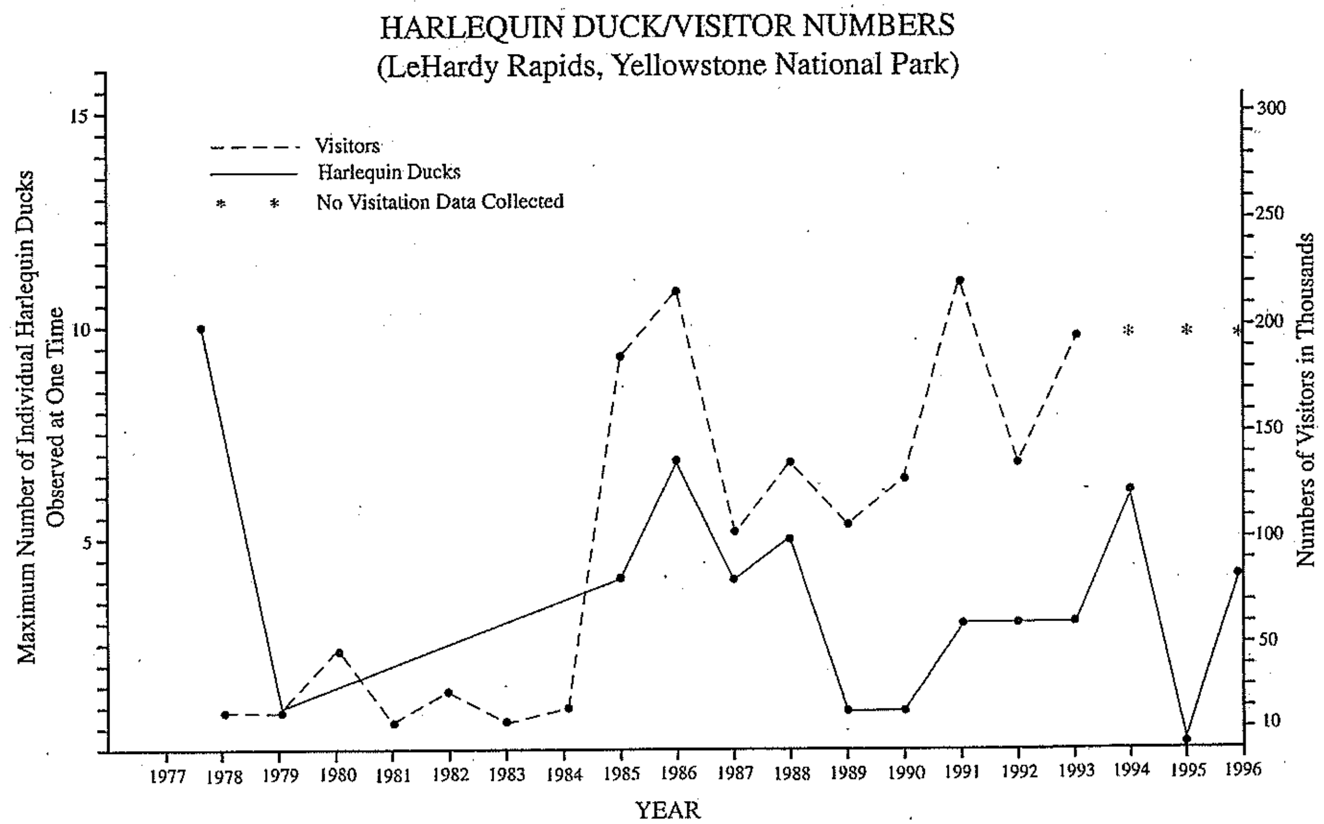
Nesting season typically begins in mid-June and can extend into July. Males far outnumber females in the population, thus ensuring all available females an opportunity to nest. However, successful nesting, doesn't always occur, due to the constant problem of being flooded out or having the nest destroyed by predators. When females are ready to nest they seek out safe, secluded and relatively undisturbed areas. Their nests are well hidden and can be on the ground, in a log jam, or in a tree cavity. Ground nests are simple hollow depressions lined with grasses; cavity nests consist of a hollow with wood shavings. They lay a clutch varying from five to ten cream-colored eggs. When the eggs are laid, the female plucks gray-brown down feathers from her breast to cover them, which aids in camouflaging and keeping the eggs warm when she is out feeding or escaping a predator. The male harlequin plumage starts to turn a duller color around the time the female initiates incubation. Incubation is approximately 30 to 32 days. Once incubation begins, almost all the males depart for the coast before serious molting of the feathers begins. Sometimes, what appear to be lone male stragglers can remain in the park until the fall. However, this is rare; usually it is only females that remain here until autumn.

Like anadramous fishes, harlequins return to the sea after a short breeding period, possibly using similar travel corridors. Once the male reaches the coast, he molts with flocks of other molting adult males and non-breeding individuals. The cycle for the male is completed.

The female, meanwhile, resumes incubation and raises the brood by herself. Because of their cryptic plumage, the female and the brood are not easily detected, frequenting backwater areas at first, then feeding in the main stream channel when the young are larger. The female keeps the brood close to her at all times. However, predators and disturbance can force young ducks through cascading water, moving broods to less secure areas increasing the chances of predation or displacement. Between mid-August and early September the female leaves her young and heads for the coast, usually by herself, to complete her molt. The young soon follow the same path, returning to the sea.

Although I have been observing harlequins ducks in Yellowstone since 1968, the first parkwide census did not begin until 1986. At first, I used ground reconnaissance to determine population numbers and distribution. However, pioneering work took off beginning in 1988 when I first employed the use of helicopters. The helicopter has become an excellent tool for determining populations, production, and distribution. Although this technique is relatively expensive, it enables me to cover large, inaccessible areas in a short period of time.

Through the combination of ground and aerial census techniques I have been able to determine the distribution of harlequin ducks in Yellowstone. In addition, approximately 16 to 20 pairs of harlequins have been documented to nest in the park in any given year. The number of adult pairs, monitored over time, provides the best information on population trends, whereas production is too variable to adequately assess population vigor.



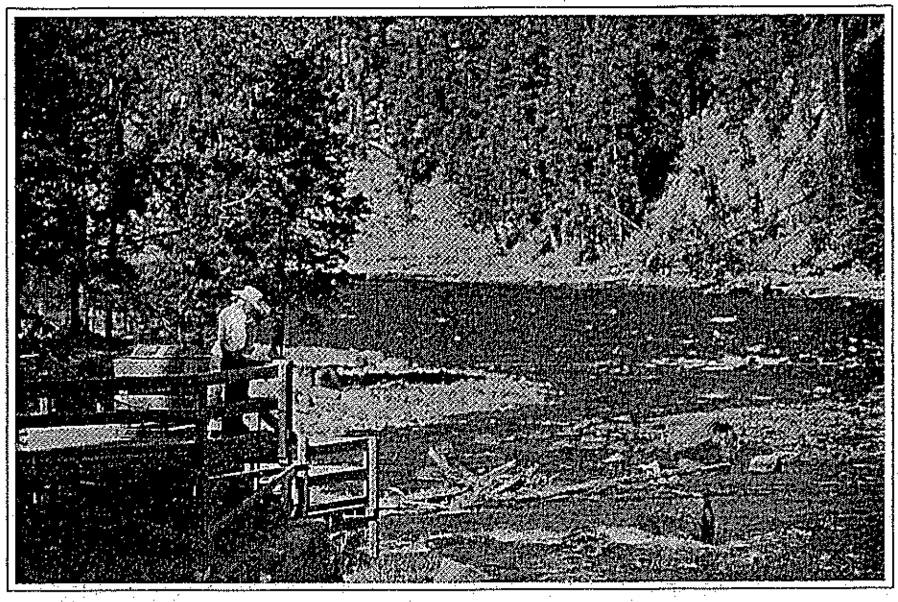
Monitoring at LeHardy Rapids

LeHardy Rapids, located three miles north of Yellowstone Lake in the Yellowstone River, is a traditional resting, feeding, congregating, and pair-bonding area for harlequin ducks. In recent years, harlequins have not been observed regularly at the rapids, causing concern among biologists and the public. At the same time, the area has become a popular place for park visitors interested in seeing spawning fish jump the rapids. In 1978, the Yellowstone fisheries staff (then the U.S. Fish and Wildlife Service) began monitoring human use at LeHardy Rapids. From 1978 to 1984, human visitation varied from 12,200 to 45,600 visits per year. Beginning in 1984, a boardwalk and observation platform were installed to prevent environmental damage. In 1985, two signs were installed on the Grand Loop Road advertising LeHardy Rapids. Because of these signs, visitation jumped from 26,800 visitors in 1984 to an eye-opening 185,500 visitors in 1985. Since then, visitation has consistently exceeded 100,000 individuals per year, reaching a record high of 220,400 visitors in 1992. In addition, a second boardwalk was installed connecting both pullouts.

To assess what was going on I designed a simple monitoring study. During 1991 to 1993, the LeHardy Rapids boardwalk and trail were closed to the public from May 1 to June 7 . The dates of the closure corresponded to when harlequin ducks traditionally used the area. Lake District resource management staff assisted with the closure and monitoring. During the closure, or control period, the two location signs were covered with black plastic to divert attention from the area, and educational closure signs were installed. Snow and wooden barricades also discouraged use of the area. During this closure period we collected information on visitor compliance and harlequin numbers. Then from 1994 to 1996, during the same May 1 to June 7 period, LeHardy Rapids was open to the public, but with limited entry restricting people to specific areas of the boardwalk.

Our findings from the study were: (1) the harlequin duck sample sizes throughout the six-year period were too small to permit statistical analysis; (2) harlequin ducks are not restricted solely to LeHardy Rapids; (3) in addition to human-induced variables, environmental variables can affect the outcome; (4) harlequins do use LeHardy Rapids, but only on occasion and most often when there are fewer visitors and the visitors restrict their movements; and (5) harlequin ducks seek out secluded areas where there are few people.

Our management recommendations were to keep LeHardy Rapids signs covered with black plastic and not promote the area until June 7; allow visitors to use only the main pullout until June 7; restrict visitors to the boardwalk and allow them no further than the observation platform; leave room for harlequins to feed, rest, and escape visitors; discourage the use of other pullouts and sections of the boardwalk through signed closures and snow and sign barricades; and report all harlequin duck sightings.



LeHardy Rapids on the Yellowstone River, and the boardwalk that provides access to thousands of visitors annually.

Several other harlequin studies havebeen done recently in other areas of North America. A study on the Maligne River in Jasper National Park found that closing the popular boating river during May and June helped restore harlequins to the river. A May and June closure of McDonald Creek in Glacier National Park to boating has played an important role in protecting brood survival. Studies in Prince William Sound found harlequins to be the number one bird species affected by the supertanker Exxon Valdez oil spill. These are concerns in Yellowstone as well, especially if a fuel truck were to spill petroleum in a river, or if river-rafting and kayaking were permitted on some of the park rivers used by harlequin ducks.

The life of the painted duck is intertwined with natural hazards. In summer the hazards are associated with rivers and streams: predation, flooding, nest destruction, disturbance, and siltation; in winter the hazards are associated with oceans: severe storms, winterkill, and predation. Through evolution, most species can adapt to these natural hazards. Looming on the horizon, though, are human-induced hazards that will test the harlequin ducks' ability to adapt to a quickly changing environment. On one front are people who want to share their lives with the environment: wildlife watchers, nature photographers, anglers, general tour groups, boaters, and kayakers. As harmless as these groups may seem, their presence can be detrimental to species like harlequins; especially if they use the birds' habitat in large numbers, they are competing for the same environment. On another front are extractors whose livelihoods rely on the environment: wood-products workers, water users, oil extractors, and consumers. As important as these industries may be, they too can be detrimental to harlequins if something goes awry. Excessive hunting, pollution, water extraction, stream siltation, clear-cutting, and oil spills can pose serious threats; what the future holds in store for harlequin ducks is anyone's guess.

We should treat this one-of-a-kind bird as a very sensitive species. One of the closest genetic relatives to the harlequin duck is the Labrador duck (*Camptorhynchus labradorius*), now extinct. No one at the turn of the eighteenth century realized how vulnerable Labrador ducks were to human intrusion and persecution; they presumably disappeared due to overhunting and egg-collecting.

Any ornithologist worth his or her weight thinks of the future. When I think of the harlequins' future, I recall the words of Carl Sandburg who wrote, "Here is the place I am now, where I look back, and look ahead, and dream and wonder."

I, too, dream and wonder. I dream and wonder if a place like Yellowstone can withstand the onslaught of people that love it so much. I also dream and wonder whether sensitive species like harlequins can retain their place in the greater Yellowstone ecosystem. This bird is adapted to rough waters. If we respect it and give it some room, it will survive. For these are no ordinary birds, these anadramous migrators, these harlequins, noble ducks of turbulent waters.

Terry McEneaney is the ornithologist for Yellowstone National Park. He has explored the far reaches of the park over the last ten years in search of harlequin ducks and numerous other birds, is a member of the Harlequin Duck Working Group, and the author of several books on the birds of Yellowstone National Park and Montana.

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The Snows of Yellowstone

by Phil Farnes

Snow and winter are considered by many to make for a miserable time of the year, something that we could live without. Yellowstone National Park is often referred to as a cold, frozen wasteland in the winter. In reality, winter and its associated snowfall in Yellowstone National Park are an essential part of this ecosystem.

There have been significant efforts to monitor snow and understand its influence on park resources and ecosystem processes. One of my particular interests has been in how snow influences wildlife, and how changes in the forest canopy influence the snowpack and runoff from mountain watersheds.

Photo by Ward McCaughey

The author preparing to take a snow core sample.

Yellowstone's Snow Database

Data on Yellowstone's snow comes from several sources. The weather station at Mammoth has one of the longest records in the west. The U.S. Army started collecting daily data on precipitation and temperature in 1889 and the weather station still reports daily values for precipitation, maximum and minimum air temperatures, snowfall, and snow depth. Similar measurements are made at many occupied areas around the park. Collection of data from these sites is coordinated and archived by the National Weather Service.

Snow course measurements in the Snake River drainage of the park were initiated in 1919 at Aster Creek, Coulter Creek, Lewis Lake Divide, and Snake River Station to assist in operating the dam on Jackson Lake. Other snow courses were established in the 1930s. Manual measurements of snow depth, snow water equivalent, and snow density are usually made on the first of January, February, March, April, and May each winter. These are reported to and made available by the Natural Resources and Conservation Service (NRCS), formerly the Soil Conservation Service (SCS). In recent years, automated SNOTEL (Snow Survey Telemetry) sites have been installed at some of these locations to report daily values year-round for snow water equivalent and precipitation, as well as maximum, minimum, and average air temperatures.

Remote Area Weather Stations (RAWS) are relatively new and are primarily used for fire weather. Precipitation, temperature, wind, solar radiation, and relative humidity are commonly collected parameters, however, some of these may not be available during winter. RAWS data are available through the Fire Cache at Mammoth.

Many short-term measurements have been taken at weather monitoring sites in and near Yellowstone National Park and at many other locations. These records are available in the park and from NRCS.

Seasonal and annual precipitation is quite variable across Yellowstone. About 30 to 35 percent of annual precipitation occurs as snow at lower elevations and up to 70 percent falls as snow at higher elevations. Average annual precipitation varies from about 11 inches at the North Entrance to more than 70 inches in the higher elevations of the southwestern part of the park. The deepest snow depth measured at a snow course was 167 inches at Lewis Lake Divide. An aerial observation of 211 inches of snow depth was recorded at the Pitchstone Plateau aerial marker. The average annual precipitation for Yellowstone is about 39 inches. Individual years can be as low as 60 percent to as high as 150 percent of the long term average.

From Snow to Water

Snow that accumulates across the higher elevations during winter and early spring provides snowmelt runoff during the growing season. This water supports significant downstream recreation, agriculture, and industry, as the park and surrounding mountains are the headwaters of Yellowstone, Madison, Gallatin, Snake, Shoshone and Falls rivers. Water from the melting snow percolates into underground channels and recharges the soils, as well as the thermal areas and storage areas for springs and seeps. High spring flows carry sediment downstream, redistribute gravels, and maintain creek and river channel configurations.

Growth in most plants is not initiated until snow disappears in the spring and air temperatures exceed biological zero (usually considered to be about 41°F or 5°C). Some shrubs may initiate growth when their crowns become snow-free and air temperatures warm enough to induce plant growth. At higher elevations, the year-to-year variation in when an area becomes snow-free may vary by as much as six weeks. Soil moisture along with warm temperatures and nutrients in the soil enables plants to grow. Trees, grasses, shrubs, and forbs are all dependent on this annual supply of moisture. These plants support an extensive insect and animal biomass which, in turn, are partly controlled by snow and winter.

Most scientific studies use Snow Water Equivalent (SWE) as it better represents the true measure of the snowpack than does snow depth. One inch of SWE equates to one inch of precipitation. New-fallen snow has a density of 5 to 10 percent. This means that it takes 10 to 20 inches of new snow to yield one inch of SWE. As the snowpack goes through various transformations, the density of snow increases up to 25 to 30 percent prior to melt. During this time, it takes only three to four inches of snow to yield one inch SWE. The density depends on depth of the snowpack and winter temperatures. Deeper snowpacks are more dense, as the internal weight of the snow creates additional compaction. Deep snowpacks and wind-deposited snow may reach densities of 45 to 50 percent late in the melt period.

The largest measured SWE was 76.0 inches at Lewis Lake Divide snow course on April 16, 1927. Other high SWEs recorded in greater Yellowstone include 66.6 inches measured at the Black Bear snow course on the Madison Plateau just west of the park and 65.6 inches at the Fisher Creek snow course near the northeast corner of the park in the Beartooth Mountains.

Tidbits to Know About Yellowstone Snow

❄ Snow has many different forms—it may fall as sleet or soft, light flakes. It changes structure from the time that it falls until it melts.

❄ Arctic storms usually deposit small amounts of snow but have very cold temperatures. Storms approaching Yellowstone from the west or southwest usually have moderate to warm temperatures and deposit heavy snowfall at higher elevations.

❄ During non-snowfall periods with very cold air temperatures, moisture vapor leaves the snow pack. This can leave a very weakly structured snowpack often referred to as "sugar snow." This depth hoar or temperature-gradient snow may dominate the lower half of shallower snowpacks. This condition often causes high avalanche danger. It also affects forage availability for grazing animals.

❄ Snow affects wildlife we seldom see or think about in winter. Spawning success of cutthroat trout can be affected by streamflow generated by the winter's snowpack. Very high streamflows can wash out redds, while very low flows may dewater redds and enable water temperatures to rise to less desirable levels. Sediment transported by high streamflows may also affect egg development in redds.

❄ Snow insulates the soil from severe air temperatures. Typically, soils do not freeze under snowpacks that are deeper than 2 1/2 feet. This allows meltwater to percolate into the soil and subsurface zones rather than run off over a frozen layer. This also allows small mammals to burrow and forage in the soil near the snow surface throughout the winter. The insulation provided by the snow protects plants and other organisms from the severe temperatures that occur above the snow profile.

In spring, snow melt usually occurs for only four to six hours during the day. This extends the period that snow remains on the ground. Lower elevations start to melt while higher elevations continue to accumulate snow. As higher elevations start to melt, lower elevations become bare. This sequence helps spread the snow melt over a three to four month period. However, cool spring weather can retard early season melt; then when the weather warms, all elevations may contribute melt water. This was very evident in the spring of 1996, when record levels of streamflow occurred under conditions of heavy, late-season snowpacks, despite very little contribution from spring rains.

The 39 inches of average annual precipitation across Yellowstone produce about 18 inches of runoff. About 3.3 million acre feet of water flow out of the park in an average year. The runoff in any individual year may be as low as 1.6 million acre feet or as high as 5 million acre feet. Yellowstone Lake may reach a summer high level of more than seven feet on the Bridge Bay staff gauge in heavy snowpack years, but may reach only two feet in low snow years.

Effects of Snow on Wildlife Foraging and Movements

Snowfall in the autumn and early winter prompts animals to migrate to lower elevations where forage is more available. During years of lower snow accumulation, most of the elk on the northern range winter within the park. In heavy snow years, more than one-half of the northern elk herd move out of the park in search of available forage. I have compared the location of elk during aerial counts from 1968 to 1981 with estimated SWE across the northern range, and it appears some family groups of elk have low tolerance for snow and will migrate early. Others seem to have a greater tolerance of snow and will stay in an area until the snow levels become intolerable. This may be confounded by social intolerance that affects the animals' movements. For example, when high-elevation snowfall causes herds of elk in the upper elevation to move, elk at lower elevations may be displaced to reduce competition for food and social conflict. This may prompt elk

Approximate Bearing Pressure Exerted by Various Animals	
Species	**Walking Pressure Pounds/Sq. Inch**
Bison	21
Elk	21
Moose	17
White-tailed Deer	10
Mule Deer	9
Grizzly Bear	6.7
Black Bear	5
200-lb. Human in Hiking Boots	5
Mountain Lion	2.8
Coyote	2.7
Wolf	2.5
200-lb. Human on Skis	1.1
200-lb. Human on Snowshoes	0.7
Snowshoe Hare	0.4

at the lower portions of the northern range to migrate before any significant snow accumulates in their area.

Small animals and predators generally exert much less pressure on the snow and consequently do not sink as far into the snow as larger hoofed mammals. This enables the lighter animals to easily maneuver across the snow surface when conditions are favorable. Bigger, stronger animals such as bison can travel and forage in deeper snow than can deer or antelope. Comparisons between aerial elk observations and SWE, and snow measurements made on the northern range over the past few years indicate elk and bison generally winter in areas where there is less than 6 inches of SWE, providing they can move to areas with less snow. This translates to as much as 30 to 40 inches of snow depth in early winter, but only 20 to 25 inches in late winter or early spring when snow is denser. When SWE exceeds these levels, it is difficult for elk and bison to obtain forage and travel is more arduous. Prolonged exposure to deeper snowpacks, particularly when accompanied by cold air temperatures and limited forage, may result in mortality. Animals that feed primarily on shrubs or willows are affected more by snow that impedes travel and less by snow that covers their forage.

Snow under a dense, mature, lodgepole pine forest has about one-half the SWE of snow in an open area. Typically, the density of snow in the forest is less than in open areas. Thus, it may be advantageous for large ungulates to use forested areas for traveling (less snow), whereas smaller animals with less bearing pressure may be able to travel more easily in open areas (greater snow density). Wind, rain, or melt crusts, and depth of new snow may also affect animals' ability to travel and forage. During most winters, the snow remains powdery until mid-March, but occasionally mid-winter melt and/or winter rain followed by very cold temperatures can have a major impact on grazing animals' ability to obtain adequate forage. Also, snow moved by foraging animals "sets up" and may preclude animals from using forage below these feeding craters until snow warms near spring.

The bearing pressure exerted by different animals varies widely. Currently I am developing a relationship between sinking depth and snow depth, SWE, and density for all ranges of bearing pressure. This will make it possible to estimate how far any size animal of any species will sink in any snow pack when traveling. The large variation in bearing pressure explains why some animals sink well into the snowpack and others barely sink into the surface. Where animals frequently travel the same route, packed snow will support the animals' weight while using these trails.

Changes in Snowpack Since the 1988 Fires

Many measurements were made after the fires of 1988 to quantify changes in snowpack as a result of canopy burn. Relationships between habitat cover types, canopy overstory measured with the photocanopiometer, basal area, densimeter measurements, and SWE were compared to measurements made in other non-fire areas. These relationships were then used to evaluate changes in hydrology and snowpack.

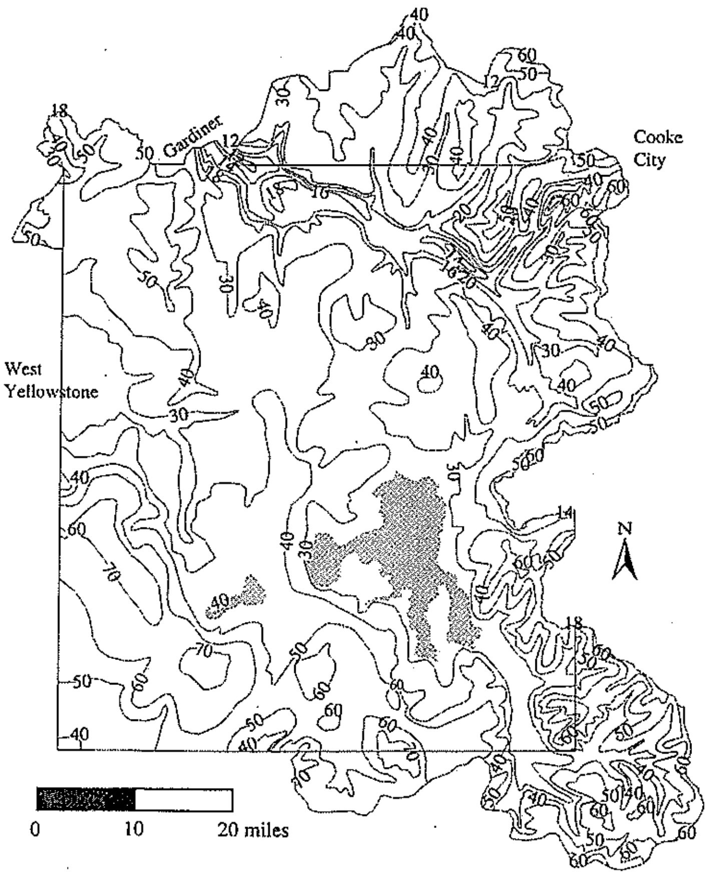
Water yields increased after the fires of 1988. When trees are removed from the system by insects, fires or cutting, the loss of tree canopy enables more snow and rain to reach the ground, which in turn creates more streamflow. Canopy burn occurred on about 20 percent of the Yellowstone area. Studies of the impact of the 1988 fires indicate an average annual water yield increase of about 6 percent or 200,000 acre feet-per-year for the area within Yellowstone National Park. This increase is relatively small; annual variation, may be as low as 50 percent or as high as 150 percent of average. As the burned forest regenerates, the increase in water yield as a result of the 1988 fires will gradually decrease to pre-1988 levels in about 100 years.

Winter travel routes used by elk were probably altered by the fires of 1988. Travel routes through lodgepole pine forests that burned now retain nearly twice as much snow. This forces the elk to find other routes in timber or to move through the burned area before snow becomes deep.

An Index of Winter Severity

Various environmental factors affect wildlife during winter—availability of forage, amount and condition of snow, and air temperature are among the most common. Different wildlife species may react differently to these variables. Conditions may also differ among adjacent winter ranges due to different weather patterns. In general, low-snowpack winters permit animals to use more of the winter range, whereas winters with heavier snowpacks concentrate animals in smaller areas, thereby reducing the area where forage is available.

I used data from snow courses in and near Yellowstone National Park to represent the snow variable on the winter ranges. First-of-the-month SWE, from January 1 through April 1 is used to quantify the winter snow variable. Higher values of SWE indicate a more severe winter. Different methods have been used to represent winter severity. Usually these indices include temperature and a measure of snowfall or winter precipitation and portray severity as a departure from average winter conditions. Although mean monthly temperatures, monthly snowfall, or precipitation are often used



Map showing average annual precipitation, 1961-1990

in these methods, such "mean" data are not always indicative of the stresses that are imposed on wildlife. About nine years ago, I developed an *Index of Winter Severity* (IWS) to help wildlife managers and the public gauge winter severity for wildlife. The IWS is calculated on January 1, February 1, March 1, and April 1 for the winter through these dates. Currently, IWS values are calculated for elk on four segments of the northern range and two segments in the Madison River drainage.

When minimum daily temperatures are below the effective critical temperature, (the animal must increase its basal metabolic rate to maintain its body temperature), from either forage intake or fat reserves, when the temperature is above the critical temperature, the impact to an animal is assumed to be minimal compared to the stress they experience during colder periods. The critical temperature threshold is different for each species, with that for elk being around 0°F (-18°C). Accumulated sums of the daily minimum temperatures below the critical temperature are tabulated for each month from October through March. Larger values of accumulated temperature indicate a more severe winter.

Precipitation at climatological stations for June and July for the previous summer is used as a relative index of forage produced on the winter range. Typically, soil moisture in April and May is high from spring rains and snow melt and is not a limiting factor for forage production. However, precipitation in June and July can limit the amount of forage produced. Less summer precipitation (hence less forage production) indicates a more severe winter.

An index is calculated for each variable based on the probability of nonexcedence and scaled from -4 (most severe) to +4 (least severe). Each variable is then weighted to determine IWS. For winter ranges in and near Yellowstone National Park, the IWS for elk is calculated by assigning the snow variable a weight of 40 percent, the temperature variable 40 percent, and the forage variable 20 percent.

Positive values generally indicate only minor effects on wintering wildlife. IWS values from 0 to -2 indicate some influence on reproduction and minor mortality. Values below -2 usually indicate significant mortality and poor survival of young born in the spring. The IWS can be used to evaluate subtle effects on wildlife—those that are not as visible as mortality, but do affect reproduction and survival of young animals. There also appears to be some relationship between winter severity and the success of predators, the availability of game animals to hunters outside the park, and migration responses during different winter conditions.

Animal populations fluctuate in relation to winter conditions. However, large animals such as elk and bison are fairly well adapted to surviving Yellowstone's severe winters. Excluding human-caused mortality factors, over the past 50 years both elk and bison populations on the northern range have increased an average of about 15 percent per year. At these rates, populations subjected to only natural mortality double about every 5 years.

I would like to develop an IWS for bison and possibly other species, modify the temperature variable to weight the effects of temperature according to fat reserves, and possibly modify the forage variable to incorporate the soil-moisture deficit and growing degree-days during the growing season. In addition, a spring severity index to indicate survival of the young of the year could be incorporated into the IWS to evaluate population dynamics. I would also like to see a complete climatic data base developed for Yellowstone where all of the records are on file at one location and where all missing values have been estimated. This data base would be a very valuable resource that would be readily available to future researchers.

Phil Farnes is a consulting hydrologist with Snowcap Hydrology in Bozeman, Montana. He retired from the Soil Conservation Service in 1990 after 36 years studying snow in the backcountry of Montana, Wyoming, and Yellowstone. He now concentrates on weather influence on plants, animals, and fish. He has measured snow every year since 1955 except during two years of military service.

NPS photo

The Biology of Time

Looking at Landscape Changes Through a Photo Series

Dr. Mary Meagher began her long association with Yellowstone as park naturalist (curator) in 1959. Wildlife was always her interest, but her first NPS job offer was as a clerk-typist at Mount Rainier National Park because "with a Master's degree in hand, I would do a perfectly superb job of filing the natural history observation cards. There was one glitch: I couldn't pass the typing test. I resolved then and there I was never going to learn to type." She later accepted a job as a seasonal interpreter at Zion National Park. After being told by a chief naturalist in Yellowstone that he wouldn't hire her because she was female... "To his dying breath, he always referred to me with an appropriate tone of voice as that woman.*" This attitude did not deter her from pursuing a career as a research biologist, completing her Ph.D. at the University of California at Berkeley under the late Starker Leopold. For most of her career she has focused on the subject of her first book,* The Bison of Yellowstone National Park. *In the late 1970s and early 1980s she supervised the park's [former] research division before returning to her own studies in 1983. In August 1996, we spoke with Mary about one of her long-term projects—the use of old and recently re-taken photographs to compare changes in the Yellowstone landscape over its 125-year history. She and co-author Dr. Douglas Houston (who studied ungulates in Yellowstone from 1970 to 1980 and retired in April 1997 from Olympic National Park) present a series of their comparative photos in a new book* "Yellowstone and The Biology of Time," *to be published in spring 1998 by the University of Oklahoma Press.*

YS: Your early years in Yellowstone were an important time of change for the National Park Service (NPS), weren't they?

MM: The 1960s was a period of lots of controversies, lots of vituperation. It was my first exposure to mob violence, which by now seems rather tame, but listening to people in the drugstore in Gardiner ranting about killing park rangers was a new experience for me. All of this was a spinoff from the elk reductions. My memory suggests that perhaps we were on the verge of Congressional action that would allow hunting in Yellowstone. The state of affairs was generated by a long history of concern about the elk on the northern and Gallatin ranges. Based on the prevailing range management perspective, the concern extended to bison numbers parkwide; there were some memos that, to paraphrase, said: "I think there is a problem, and if there's a problem we should have target numbers, which we should evaluate." In a couple of years, things like trial numbers and evaluation sort of got lost—everyone assumed these were hard and fast numbers for which there was a lot of supporting data, and there wasn't.

Basically the plan was to build a science program—not initially a "policy of natural regulation"—it was more a moratorium: "Let's see what our database is that will support the ungulate reductions." And there really wasn't any. That was not deliberate on anyone's part; a lot of very hard-working and well-meaning people committed themselves—lots of personal strength, lots of backbone—to what they felt was the direction to go with the reductions. The National Environmental Policy Act hadn't been passed—there were a lot of things in transition in that mid-sixties period. We'd never survive a similar program without an Environmental Impact Statement (EIS) process now. It was very much a period of learning for us, and because of the impetus to establish a science program we fortunately had some very good people, in certain positions all at the same time—the combination of Jack Anderson [park superintendent from 1967 to 1975], Glen Cole [supervisory research biologist], and Nathaniel Reed [Assistant Secretary of the Interior]...it was a superb time that I have not seen since, frankly. I think the sum was much more than its parts. The park's data was good enough so that the elk reductions could be treated as experimental management by Doug Houston, even though they weren't planned that way. That has given us a lot to work with for both elk and bison, in terms of evaluating where we are today.

YS: So much is made today about the implications of the 1963 Leopold Report. It's always interesting to me to hear from people who were in the parks at the time when the report began to be implemented—it doesn't quite sound the way the history makes it, as though one day the pronouncement came: here was the new policy. Do you think that Starker Leopold and the other members of the Leopold Committee really had any intent or idea that their recommendations would be interpreted so often and so widely as they are?

MM: No, no, no—it was a period of desperately sort of holding the fort, and haunted by the possibility of public hunting in the park. We were all something of a product of the time. I think the whole Leopold Committee was still more deeply into the idea of manipulation than some of our present data tell us we need to be. Call it the "state of the knowledge."

I'd been in Berkeley—Starker was my major professor; I think I was the only woman Ph.D. student he ever had. Starker wouldn't have expected to be quoted that way—he might have spent a little more time picking and choosing his words. We stayed good friends until his death. He'd come up for fishing every year. I asked him if he had said what is in quote marks in Alston Chase's book, *Playing God in Yellowstone*. Starker laughed and said, "Well, you know, Mary, I might be getting a little senile, but I don't recall ever talking to the man." That was my thumbnail sketch of *Playing God*—lots of quote marks, but what was in the book was not quite what was purported to have been said.

Starker was an absolutely superb conservation politician, and I think he did Yellowstone a great service through that period. I wish now we had talked more about some of the politics—you always think you're going to have more time than you ever do. I wish Starker were here in our present post-fire research period to kick some of that new research around.

YS: Tell us about how you started your bison research. Was there a research department in the park?

MM: No, no. I was still a park naturalist. The NPS is a people agency, but the Leopold Report and the Robbins Report [convened by the National Academy of Sciences] were saying we must do better science, and I was in the right place at the right time. I was laying groundwork to go back to school. I remember contacting the Craigheads [researchers working on grizzly bears in the 1960s]—I knew John Craighead slightly from the time I went to school in Missoula—and I was interested in what they were doing with bears. I compare my background in most of what I've learned about human behavior as parallel to what I've learned about brucellosis—I know more about both of them than I ever wanted to know. John assured me that they'd love to have me go out and see what they were doing with bears, but somehow it never took place. "Gee, tell us when you're free." Well guys, all you have to do is tell me when you have things planned, and I'll be there. And it never happened.

So, I thought bison were interesting and we didn't have a whole lot of information about them. I had several ideas in terms of research, but the period (1960s) was very much one of the range management perspective. Bill Barmore [park ranger and biologist from 1962 to 1970] and I were both out of that period. I'd go up Hayden Valley with Bill and with Bob Howe and the Soil Conservation Service people and listen to them make their field evaluations. I give Bill a lot of credit—to be brought here as a range management person, and to be able to look at his own data and say the elk weren't a problem—watching Bill make that transition was very interesting.

Building a Comparative Photo Set

YS: Tell us about how the concept of working with the historic photos started.

MM: Even when I dealt with bison in my doctoral dissertation in the sixties, I was very interested in what has since become known as environmental history. When Doug Houston came to Yellowstone as a research biologist in 1970, he was interested in using comparative photos as a research tool for a sense of time and what changes humans may or may not have caused.

So we started to assemble a comparative photo collection and agreed from the very beginning that we were going to do the retakes ourselves—it was much too much fun. That proved to be the best way—our own presence at the sites helped us a great deal with interpreting the photos and identifying plant species and so forth. Many early photos were labeled only "Yellowstone National Park." Without knowing the park fairly well, we couldn't begin to guess where those photos had been taken. People who create history, whether it's photographic or written, don't do it for people like us. They're doing what interests them at the time, and most photos tend to be people-oriented. A hundred years hence, someone may not care who the people are, or where the building is unless they are into cultural resources, but the background may tell a lot biologically. Many of the early photos were where people went, and part of that's just ease of access. But oh, bless the geologists, because where they were photographing cliffs, we were interested in, say, avalanche paths and the state of the forest below.

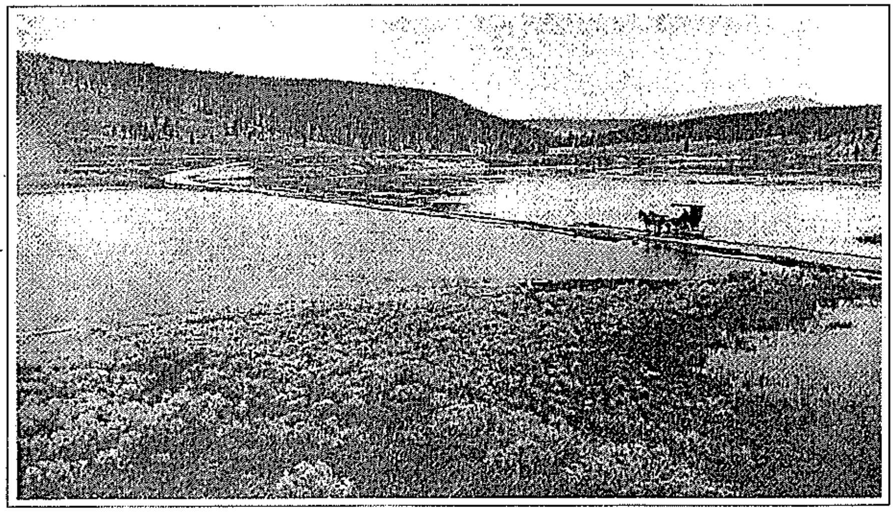
I first started flying with Dave Stradley [pilot and co-owner of Gallatin Flying Service] in 1961; we have probably the longest track record of working as a team in the business. But he had never flown the park then, so we'd take a map along. Now it's much easier; we don't talk much about what we need to do; I just let him sit up front with the Nikon and his skill and sharp eyes.

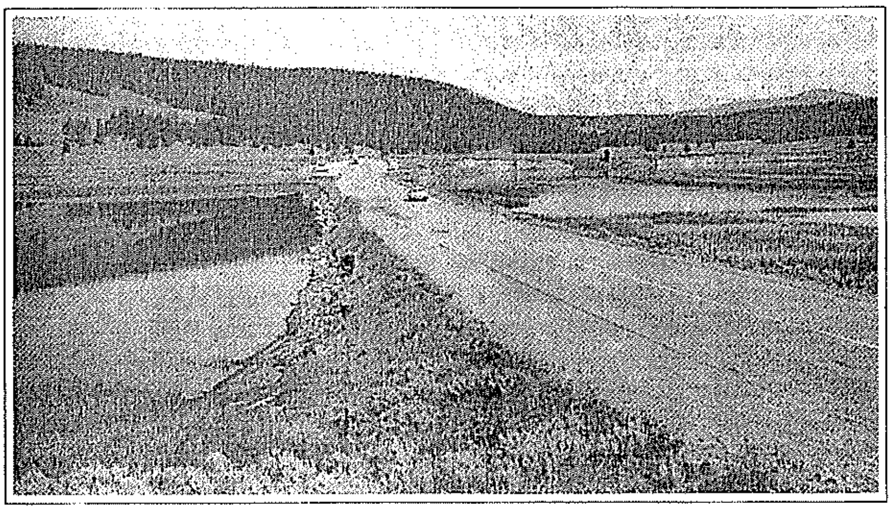
YS: I picture Dave's taping up a photograph in the cockpit of his plane, looking for where these historic photographs were taken. I'd never thought about it as an adventure, but it would be tremendously fun as well as being useful.

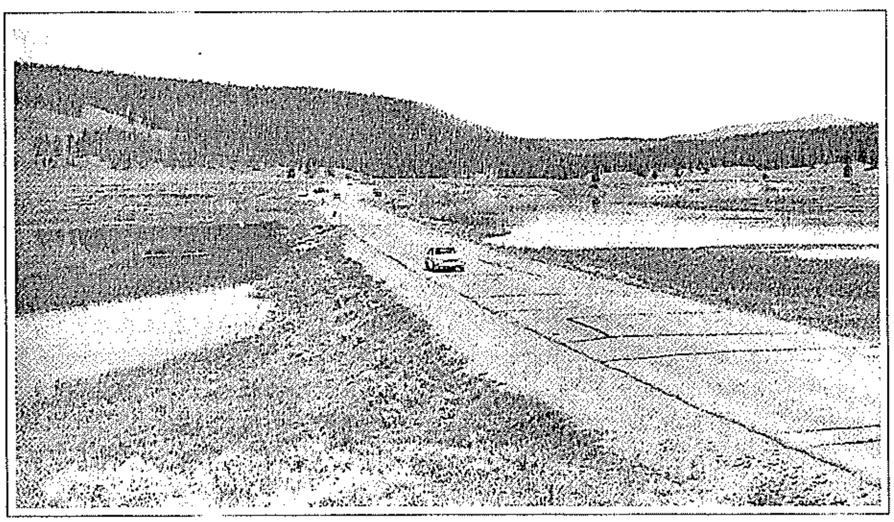
MM: Oh, it was—that's why we never hired anybody. The old cameras had different focal lengths, and I think it took me three trips to Table Mountain to put my feet where that original photo had been taken. I beat all through the whitebark pine trying to get the perspective.

YS: At the time you started taking the photographs, you didn't necessarily anticipate a book 25 years later?

MM: No, we had no thought of a book; the photographs were a research tool. But we had a wonderful time doing it, and Doug used 50 photo sets in his book on the northern Yellowstone elk. In reviewing Doug's work, Sam McNaughton [grassland ecologist from Syracuse University] commented that the photos were much too interesting just to be an appendix. But Doug had transferred to Olympic National Park. We didn't really have a basis for pursuing the idea of a book until the fires of 1988. I will be forever fascinated at watching a natural force like that







One of Meagher and Houston's series of photos. At top is U.S. Army plate 9521, first photographed July 9, 1909 by U.S. Army Engineers. The view is of Alum Creek, a tributary of the Yellowstone River in Hayden Valley, looking north. At center is the first retake on July 27, 1971. The bottom photo was taken July 12, 1991. Between photo 1 and 2, Meagher notes the effects of road construction, influencing riverbank vegetation and sedges, and the forested hill in the background where lodgepole invaded the meadow edges; photo 3 shows the effects of 1988 fires. She also notes that bison were absent in the valley from the 1890s to 1936.

at work. I called Doug every couple of days that summer, and he'd been pacing the floor—talk about a deprived biologist, not to be here! I wanted to rephotograph everything that burned.

YS: Was yours and Doug's the first effort to build a comparative photo set?

MM: Oh, no. This kind of thing has become of great interest in the last 25 to 30 years. One of the first was a very striking effort done in the Black Hills that caught a lot of people's attention. There's a very nice one—*Rangeland Through Time* by Kenneth Johnson—working with [W.H.] Jackson photos in Wyoming. But for Yellowstone there had not been a systematic effort. Having a series of three photos—that is the most unique thing about this effort. I don't know of anyone else who has tried to do three. We were fortunate in having 1988 as a triggering event to do a third set.

Agents of Change: Fire and Climate

YS: You write quite a bit in your new book about agents of change and which ones appear to be most powerful from your long-term perspective of looking at the photos. One thing that I'd forgotten was that, yes, there was fire *before* 1988—some of the old photos had been taken very recently after a fire. It wasn't a 1988 fire scene I was looking at, but an *1888* fire scene. Of course we had fire before!

MM: The Punchbowl, for instance, is one of my favorite sets. It was first photographed by Hillers of the USGS about 1885. Having learned a certain amount about fire, I can look at that photograph and estimate that the background had burned 20 to 25 years before, because most of the trees had fallen. I retook that one in the early 1970s, and then it burned again. As with any history, "what you see is what you have got."

A lot of things were said after 1988 about how some forested areas will come back as meadows. Not if you add a time perspective, because you're still dealing with topoedaphic controls. There are some interesting illustrations of that in the comparative photos. One scene we use looks at the north edge of Hayden Valley from the south edge of Alum Creek. If you look in the background, you'll see an earlier fire and see that the meadow patterns are

"This stark description of the field work does not convey the underlying sense of excitement we often felt when the early camera points were first rediscovered. Part of this was simply opening a window into the past: many retakes showed virtually no change—the pioneer photographer would have been perfectly at home looking through the viewfinders of our cameras. Other scenes provided such stunning contrast that even we at first doubted that the replication was correct. But there was more to it, including such personal thoughts as: Why did you, my photographer predecessor, select this particular scene? Did you too hear elk bugling in the distance, or note grizzly bear tracks in the meadow?"
—*Yellowstone and the Biology of Time*, M. Meagher and D.B. Houston, 1998

the same; these are soil-determined, topoedaphic sites—the longer-term controls are moisture, aspect, and the kinds of soils that have formed. Those meadow patterns tend to persist, no matter what the state of the forest. I remember Doug and I sitting up on the hillside watching the 1976 Arrow Fire. The elk would come back into the smoke to graze—the Bambi syndrome has no validity. Food and sex are the driving forces because otherwise you don't live and you don't procreate. Animals by and large conduct business as usual, even in the face of an event such as fire. The Arrow Fire is the one you can see from the road where the trail goes into Grizzly Lake. The photos we use are taken from the edge of Obsidian Cliff, up high—that's one of my favorite series. We had no idea who took the first photograph in the 1880s. You could see Beaver Lake already silting in. When it was retaken, there was that early 1970s view of the forest, but then it burned in 1976. With all the downed trees, enough time had gone by that it re-burned hot in 1988. It's now a pretty barren-looking hillside, but eventually, of course, there will be a forest there again.

YS: One photo that I recall was from Mammoth looking toward Bunsen Peak and the amazing change is the number of Douglas-fir grown up in the foreground of the picture. Douglas-fir encroachment is one of the more dramatic changes in the northern part of the park. Doug talked about this in *The Northern Yellowstone Elk.*

MM: It seems to be. We're getting more into a post-Little Ice Age climate, and that means that especially where there is an altitudinal zonal transition anyway, there will be some encroachment as those tree zonal changes take place.

YS: That same point relates to the often tossed-around notion of fire suppression; you and Doug comment in *Yellowstone and The Biology of Time* on whether or not it was truly effective and led to a bigger fuel buildup in 1988, or whether there's a distinct difference in its effectiveness on the northern range versus the Central Plateau of the park. Largely that debate comes from little things written in some historical records to suggest that there were fire suppression efforts, but, no, they really weren't effective.

MM: I think when I'm retired, I'd like to go back to doing environmental history because I would bring the biological perspective to the historical information and do more detail on some of these topics. Bill Romme and Don Despain document a major fire episode from roughly 1732 to 1750. Cathy Whitlock, a superb paleoecologist, was able to validate that and take the fire record back further. It makes excellent biological sense to say that on the volcanic plateau, you were dealing with a very long fire interval, because you simply didn't have the burning conditions. There was a fuel build-up, but a natural one. We humans, be the effects good or bad, tend to be very arrogant in accepting credit. "We have done all these disastrous things"—and there's no question we've done some, but you might say we're kind of a bump on the surface, when you start thinking in terms of geologic and even biological time; 1988 was basically a function of the Little Ice Age. Yet our ability to have influenced fire suppression on the northern range would have been greater than on the Central Plateau.

We humans, be the effects good or bad, tend to be very arrogant in accepting credit. "We have done all these disastrous things"—and there's no question we've done some, but you might say we're kind of a bump on the surface, when you start thinking in terms of geologic time and even biological time.

YS: Another change often commented upon is the absence of cottonwood tree regeneration in the river bottoms.

MM: I can look at an early USGS photograph of Lamar Valley, knowing we were at the end of the Little Ice Age but see that there weren't many cottonwoods then. If anything, on a few specific sites, cottonwoods may actually have colonized since. For reasons we may not understand, the Lamar Valley may not always be cottonwood habitat. And yet if you go around to the other side of the Absarokas, where there have been some fires and a different climatic regime, the cottonwoods came in so thickly on some sites you can't walk through the young trees.

YS: In your new book, you mention beaver as another agent of change; you comment that critics have talked a lot about the large herbivores on the northern range, and imply that the smaller animals' herbivory is under-appreciated in this controversy. It was fascinating to see a picture of a place where today there's barely water—a site out near Wraith Falls—but in the old photo it was flooded. It was marvelous in a way, but it points out the ephemeral nature of some of the waters and/or the beaver.

MM: Last year was the year that underscored that stream hydrology systems (and much else, biologically) are often determined not by the usual, but by the events, the *extremes*. Did you ever see a beaver dam here that would hold in a spring like 1996? It's been interesting to walk places like Blacktail Deer Creek, where the water was over the banks in places that I'd never seen it in 37 years. It was just one of those years; if there had been bank-denning beaver there, high water would have taken out some of those bank dens as well as any dams. I've seen it high in other years, but this was the most extreme expression that I have seen.

Coming out of the Little Ice Age—knowing that the Little Ice Age was at its most extreme here toward the end—we had to have had some pretty hellacious spring runoffs in this place; they'd rip out willows as banks washed. Certainly there are places in the park where more willows could grow, but is the lack of willow anything that is wrong, or is it simply our preconceived human notion of how things ought to be? I don't think we understand willows well in this place, which means we don't understand beaver. I don't think we're going to understand either one without addressing the stream hydrology and the extremes that we get. We simply do not have, with site-specific exceptions, what I would call good beaver habitat in this place.

"Slippery Shibboleths": Limiting Ecological Processes

YS: I liked your quote of Graeme Caughley's: "A plant-herbivore system is not simply a vegetation suffering the misfortune of animals eating it." When we get into a discussion of herbivory in the park, there is a faction out there who likes to view it that way: it's a one-way system; the poor plants are suffering at the teeth of those eaters. One of your lessons in the book is "if it's simple, be careful"—as in your discussion of the difference between ecological and economic carrying capacity and how those interpretations have influenced various critics of policy, particularly on the park's northern range.

MM: We borrowed the term "economic carrying capacity" from Graeme Caughley. Economic carrying capacity basically is range management, where you are interested in maximum sustained yield. To do that you maintain a somewhat lower, younger age structure and higher biological productivity because you're cropping all the time. Ecological carrying capacity is a constantly varying number, and your standing crop—in other words, your biological base—is normally higher than would occur with economic carrying capacity, unless you have a major perturbation in the system.

YS: In *Yellowstone and The Biology of Time*, you talk about "conserving animal-plant associations," which might mean intervening, as opposed to "giving expression to the processes," which would mean not intervening, and a third option of combining the two while placing emphasis on the expression of processes. You go on to say, "By defining acceptable limits to the ecological processes of interest, we produce an operational definition of 'natural' that is appropriate for the beginning of the 21st century." It sounds as though bison management falls into that category, where we're going to have to put some limits on a process.

> "The most important message from this photographic study is that the Yellowstone landscape is, above all else, magnificently dynamic—there is no "correct" or "pristine" fixed state to which the Park ecosystem should be held, even if this were possible... In this sense the past serves only as a limited guide to the future because the intensity and frequency of the processes driving ecosystem dynamics change."
> —*Yellowstone and the Biology of Time*, M. Meagher and D.B. Houston, 1998

MM: Frankly, free-ranging bison—and, I sometimes think, I myself as a biologist—we're both anachronisms; the modern world doesn't exactly have a place for either of us. Bison are curious; for many people they're an icon, a wonderful symbol, but the reality is we humans have so taken over the earth that we really don't want to live with them except when they're tidy and fenced and in preserves. We're going to have a tough time allowing the processes that bison represent because they are truly nomadic. They are always on the move and that means they use the landscape in a way, say, the northern range elk would never do. Any population will fill up its habitat if allowed to do so and look for more, and that's exactly what the bison are doing, recognizing that we have changed the energy dynamics. If they could adapt to new winter ranges outside the park, they'd be home free. But we have man-made boundaries and the modern world doesn't want free-ranging bison outside Yellowstone Park.

YS: Is that what you meant when you talk about setting limits? In the post-Leopold years, many people have interpreted Yellowstone's policy as being one of no limits. You and Doug mention the "much abused" term, "natural regulation."

MM: I think that a lot of people have extrapolated and changed the meaning. Perhaps this is a spinoff from the notion that there was a policy pronouncement from on high that said natural regulation could and would prevail inside the park. We [Glen Cole and staff] were looking at it from the standpoint of feedback mechanisms, and the extent to which those feedback mechanisms would impinge on the ungulate populations. I've said natural regulation (as we first attempted to understand it in terms of feedback mechanisms) resulted in the Pelican bison wintering herd being naturally regulated for a period of some 50 or more years within both that time frame and a geographic frame. They aren't any more. We have changed the parameters. Feedback mechanisms are there, but what we have done by providing a snow-packed system of roads in winter has offset and negated many of those feedback mechanisms. It's a question of energetics. By using the snow-packed roads for travel between foraging sites, the bison expend a lot less energy, and so there are more of them.

We have an environmental gradient that is dictated by the Absaroka Mountains on the park's east boundary, and an animal species that is very stolid by temperament. If bison behaved like elk or deer, they couldn't eat enough to fuel that huge body. That is why they could so totally adapt to using the winter road system—it's very energy efficient, and they like to aggregate, so they move to do so. We can't change those fundamental behavioral factors, but by superimposing an energy-efficient road system across that environmental gradient, we are going to continue to drive the changes in bison distribution that we now have.

YS: You're referring to Yellowstone's winter road management operation?

MM: I'm not trying to say snowmobiles

are good or bad—it is the road *system* and not the level of human use that is the issue. Prior to the winter road system, bison mortality in Pelican Valley appeared at least in some years to be very much density independent. Roughly a couple of hundred would survive the toughest winters, partly because of the thermal areas. It didn't matter if there were 200 more bison than that or 500 more; they died. I suspect that such events were major when bison were truly nomadic on the Great Plains, rather than this sort of attrition cropping. You had drought in the southwest over hundreds of square miles, so animals simply starved to death in large numbers, or they drowned in the rivers, or ice storms took them—those kinds of things. We have historical accounts for some pretty impressive mass starvations. Also, we know that bison were in western Mexico, Arizona, and New Mexico just about the time European man arrived. Bison there disappeared, probably naturally, with climate change as the Little Ice Age waned.

I think the bison population and what it's been doing with this road system gives insight into what bison were as a fascinating product of their own evolutionary history that we would not see otherwise, because most bison are fenced. I'd like to examine the accumulated bison data from this standpoint; my title might be, "Free Ranging Bison in a Limited World," and I might add, "A Test of Natural Regulation," to put in the buzz words.

YS: When we get back to the idea of setting limits, would you view them as very specific limits for specific management issues, or for specific species? Some people might say, "Aha! She's saying go back to the idea of carrying capacity."

MM: You're raising a very good point. No, I'm not saying that, and if ultimately "carrying capacity" becomes a management decision, then I would hope it is done case by case, with great care and a certain amount of flexibility, because if we regulate animal numbers, we will affect the system. Bison now represent an ecosystem change just as lake trout do; I would say they're equivalent, although people aren't horrified at bison, because I think we have a notion that with native species, more is better. It's not, if it represents a system change in a park managed as a natural area. No system is open-ended.

In most temperate climates, even though summer range is important in terms of quality and productivity, you might say it's winter that keeps the lid on. We have negated that in this case, so the bison population is fully occupying its summer range in a functional way, the way they use the landscape. We have more bison than the winter range can accommodate—no matter what the number is. Emigration and colonization, or what would become colonization for new winter ranges outside the park, is being prevented by removing bison at the boundaries. At what point do we say that we're getting some major ecological impact that we would not have, if we had not changed the system? You're dealing with very fundamental energy relationships, with and without the road system, and what we've done is change those energy parameters. If you simply cut out the road system, you would re-impose the energy costs. But because bison have developed new destinations, they would still attempt to go certain new places, and they might do so successfully. They would have to pay the energy costs of making those moves, and eventually the system would begin to shift back. But there are some problems attendant with that. Part of the new dynamics of the system will be introduced species of plants, and that is one of my concerns, because those plants tend to come in on highly disturbed areas.

Our problem is we live in human time, and we like things "status quo." Speaking purely as a biologist, I would shut down the human-caused system change, which is the winter roads, and I would go in and kill a lot of bison, because that would hasten reversing the changes we have caused.

Bison represent an ecosystem change just as lake trout do...although most people aren't horrified by the bison, because I think we have a notion that with native species, more is better.

Wolves, Humans, and Bison Behavior

YS: Since there's been so much in the news about wolf restoration, the question arises, are wolves likely to exert any influence on the bison?

MM: I don't think so. The view on what wolves might do to bison has been extrapolated from a couple of northern bison populations, simpler systems in which there is very little alternate prey. Wolves, too, are products of their evolutionary history, and they are going to live in the most energy-efficient fashion they can. That doesn't mean that they won't occasionally take a bison. If walking carrion is right out there, wolves will take it if they can, but if there is an easier food source, and elk are numerically and distributionally much more prevalent, then that's what wolves will take primarily. I see bison as perhaps contributing now and then to the welfare of wolves, but I do not see wolves as having much effect on bison.

YS: Isn't there very limited evidence of predation on bison by other animals here—grizzly bears and lions and coyotes?

MM: I heard of one instance when apparently coyotes took a bison yearling, but I think it already had a broken leg and was trapped in downed trees. [*Ed: There has been no documented predation by mountain lions and few reports of grizzly bear predation on Yellowstone bison.*] Any meat eater will take the most energy-efficient, suitable source of food—that's very different from affecting the population. As I think about what the present bison population has been teaching me about this truly nomadic species, always on the move—take a bite, take a step—and I read historical accounts, thousands drowning in the Missouri River and so on, I suspect that a feature of this species is to increase at biological maximum, and then climatic events, not predators, knock them down.

YS: People ask a lot about habituation in the bison, or their "tameness," because bison have become statistically more dangerous to humans in the park than even bears. A lot is made about the number of people who walk right up and practically try and pet one and get gored or something. I remember the first time I was in upper Pelican Valley. I happened to pop over a hill and create a little bison stampede unintentionally, because I didn't know they were there. They were so unused to seeing humans in that area that they just took off running. I remember thinking, "Oh, *wild* bison!"—different from the ones we tend to see down by the roads.

MM: Well, people often mistake habituation for tameness. Habituation appears to have a strong geographic element. If you walk on the sidewalks in Mammoth and mind your own business, unless an elk cow has a brand new calf stashed on the far side of you, they're quite tolerant. They're very habituated to vehicle traffic, to the normal patterns of people use. You're much safer if one moves toward you while you are sitting there than if you violate its space and walk up with your camera and shove it up against the animal's nose. As we have more bison and more tourists, we have an increasing injury rate. It's not because anything has changed with the bison.

Depending on the evolutionary history of the species, some animals are much more tolerant in the open, while others may tolerate a certain distance from humans if escape cover is not too far away. The time of year makes a difference, and whether they have young, and the animal's sex and age. I think of these big bison bulls as kings of the range—if you're that big, it's not very energy efficient to spook at every little thing. What is here that can take one of those guys unless it's dying on its feet—why should it run from anything? But it isn't tame, and that's where tourists get into trouble—that swinging head has 2,000 pounds behind it. I remember the first human fatality caused by a bison in the park—I didn't see the victim, but he had taken a horn dead center and died in about three minutes. All the bull did was a short charge, but a swinging head can do major damage if a horn gets you in soft tissue.

There's a facet of human psychology that I think helps set the stage for some of the interactions. I talked with a psychologist who commented that if an animal will let you approach, you may regard that as a validation that you're a good guy, that you wouldn't dream of hurting the animal, and somehow the animal knows that. My view is that something's happened to human wariness, because even if the animal really were tame, if it weighs 2,000 pounds and it sidesteps, it will squash you.

YS: I've heard you comment that you can really only herd bison where they already want to go.

MM: Absolutely. It is this stolidity that made bison so vulnerable to modern rifles. They were equipped to deal with the direct impingement of, say, the wolf. They're very agile when they want to be, very strong, very quick at kicking. That's why people who have used heel-nipper type cattle dogs have sometimes lost their dogs. Bison don't spend a whole lot of energy running away from things.

Questions for the Future

YS: In the introduction to *Yellowstone and the Biology of Time*, you touch upon the long-term controversy about ungulates and Yellowstone's northern range. But basically you say, here's a hundred sets of photographs—readers should look at them and decide whether the range is unacceptably changed.

MM: We built as large a collection as we could; we thought we had as representative a selection as possible, and did not need to visit every single site that could have been re-photographed. There are many sites for which we'd love to have photographs, but no early photos existed, as far as we know. What you see is what you got. If you can see certain trends, then that should suggest something.

YS: You mention in the book that you are still haunted by some of the old Yellowstone photographs because you couldn't find the locations from which they were taken. Are you going to keep looking?

MM: Well, I don't know— "keep looking" has a time frame too. I don't know if I'll be around long enough. Someday Dave Stradley and I will both hang it up, and that day isn't too far off. But I had hoped, in this last round of re-takes, to take some new photos for somebody else's future. Doug felt the same—he took a photograph looking down Cache Creek, because Cache burned hot in 1988. We've agreed we're going to come back in a hundred years and retake that! ❧

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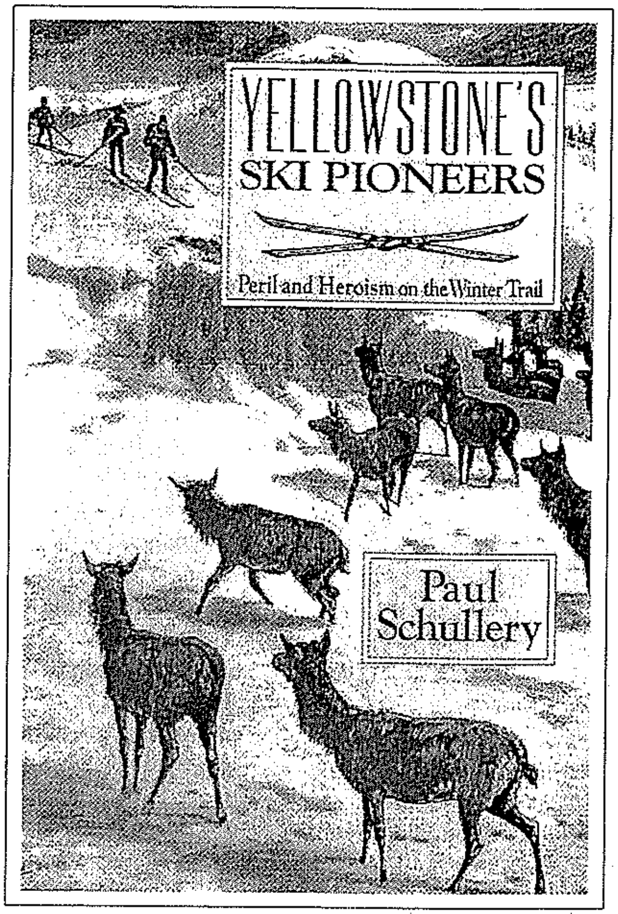
Book Review

Yellowstone's Ski Pioneers: Peril and Heroism on the Winter Trail *by Paul Schullery. High Plains Publishing Company, Worland, Wyoming, 1995, 158 pages. $8.95 (softcover).*



In February 1996, I woke up in the Cold Creek Cabin, a 16-mile ski from the nearest road, pulled on my clothes, and stepped into the night. There was no moon—the night was pitch black, punctuated by the pinpricks of distant stars. The mercury had plummeted to a brutal -40°F. Nothing moved. The deep quiet of the wilderness was broken by an occasional popping sound. I felt sure we were alone, but the popping sounded vaguely like distant rifle fire. I stood, shivering, and listened long enough to realize that I was hearing the sound of xylem in nearby lodgepole pine trees freezing and exploding.

My companions and I had spent the last two days skiing up the Lamar River; the next day, when the temperature warmed up to -25°F, we would set out over Mist Creek Pass into Pelican Valley, continuing a tradition started by the army almost 110 years before: the winter ski patrol. This tradition, as well as other ski adventures and wildlife stories, is chronicled in Paul Schullery's book *Yellowstone's Ski Pioneers: Peril and Heroism on the Winter Trail.*

A keen observer and adroit chronicler of Yellowstone's wildlife, employees, defenders, and destroyers, Schullery has lived and worked in Yellowstone for much of his adult life, including stints as a park naturalist, park historian, and science writer. In *Yellowstone's Ski Pioneers*, he lets the protagonists tell their own stories, then fills in the blanks to help the reader interpret the social climate and attitudes of those times. What emerges is a picture of Yellowstone as a much more isolated, remote, and potentially dangerous place than we know today. In 1872, when the park was established, the nearest town was several days travel away in the winter. Summer visitors were rare, and poachers were the primary winter visitors. Ungulates were slaughtered wholesale by hide hunters and poachers, who often left whole carcasses to rot, typical of the wildlife destruction occurring throughout the American West in this era. General W.E. Strong wrote in 1875:

> One hunter will frequently kill from twenty-five to fifty of these noble animals in a single day. Over four thousand were killed last winter by professional hunters in the Mammoth Springs Basin alone (page 14).

As winterkeepers began to live in the park's interior and travel to Cooke City increased, the winter wonders of Yellowstone found chroniclers following two celebrated trips in 1887. Lieutenant Frederick Schwatka, a veteran of Arctic expeditions and dogsled adventures in Alaska, put together an expedition accompanied by F.J. Haynes, the official photographer of the Northern Pacific Railroad, who took the first known photos of Yellowstone in winter.

Misinformed about winter conditions in the park, Schwatka loaded his men down with heavy equipment which he planned to haul on toboggans pulled by the men and in a wagon. The skis used at that time were described by "Uncle Billy" Hofer as being nine feet long, one inch thick, and weighing about ten pounds. The skier used a seven-foot pine pole to arrest his descents and provide balance.

Even with these difficulties, the plan might have worked, but 1887 brought the hardest winter that many western settlers could remember, with many cattle freezing or starving to death. After leaving Mammoth on January 5, Schwatka's party had to abandon the wagons at Swan Lake Flats. His men struggled with the toboggans for another four miles, camping at Indian Creek. The temperature that night fell to -37°F. The next day was worse: the party made only two miles. Exhausted and ill after reaching the Norris Hotel on the third day, Schwatka rested while his men explored the Norris Geyser Basin. He left with the party for Old Faithful the next day, but made only four miles before giving up and returning to Norris with three of his men.

Haynes refused to quit; with three other men he pushed on to Old Faithful, where they spent five miserable days huddled in a tent waiting out a severe storm. When the storm broke, Haynes took 21 photos of the Upper Geyser Basin. After returning to Norris and travelling to Canyon, Haynes and his party headed for Yancey's Hotel via Mt. Washburn on January 23. Stranded in a blizzard, they dug a snow pit, built a fire, and spent the night joking about their situation and trying to stay warm. The next day was little better; although they had not reached Yancey's by nightfall, they kept going rather than camp in the treeless country north of Mt. Washburn. After reaching the hotel the next afternoon, they spent three days eating weak broth and recovering from their ordeal. As newspapers around the country trumpeted their achievement, Haynes and his crew became heroes. The winter expedition was the beginning of Haynes' long and distinguished association with the park.

Less than a month later, "Uncle Billy" Hofer and a companion began a 225-mile circumnavigation of the park from Gardiner to Old Faithful, along the east side of Shoshone Lake to West Thumb, across Yellowstone Lake to Fishing Bridge, then to Canyon, over Dunraven Pass to Tower, and back to Mammoth. Sponsored by *Forest and Stream* magazine and informed by its editor George Bird Grinnell, Hofer's trip was probably the first serious attempt to survey winter wildlife and conditions inside the park. (Hofer's wilderness travelling skills, wildlife observations, and winter conditions recordings are reported in *Yellowstone Science* 2(4):12-15.)

By 1887, army scouts were making winter trips into the park to protect wildlife from poachers. In 1890, Captain Frazier Boutelle built the first six "snowshoe cabins" for poaching patrols. The forerunners of today's backcountry cabins, 19 of these cabins were scattered around the park by 1900. (None remain; the park's oldest extant cabin, at Buffalo Lake near the west boundary, was built about 1912).

The need for winter ski patrols created a new challenge for the army: teaching soldiers how to ski. Lewis Freeman described the ordeal:

> As each new garrison comes into the park, the early winter witnesses rare sport in the new soldiers learning the use of the ski. They grow as enthusiastic as a lot of children with new sleds. The favorite slide, both for beginners and old hands, is from Capitol Hill... Falls? Of course there are falls, terrific ones at that, but no one seems to mind. Imagine 160 pounds of man, going at the rate of half a mile or more a minute, suddenly dashed to the snow with two stiff, flat, nine-foot inch pieces of ash tied to his feet and ankles as emergency brakes. And they stop him, too. Lucky he is if some erratic slider from above does not ride him down before he can regain his footing. (pages 79-80)

With extreme temperatures, chance of avalanche, and little prospect of rescue, winter patrols were inherently dangerous. By 1907, a "little red book" outlined procedures for safe patrolling:

> No trip will be made on snowshoes by less than two men...wise precaution must be exercised to prevent separation of the party...During the winter duty period, patrolling and scouting will be constantly carried on, and when camps are made they will, if possible, be selected so as to be hidden from poachers who may be in the park. Patrols and scouts will avoid the regular trails as far as possible, and will vary their different trips as much as the character of the country will allow. (page 84)

The first winter patrol casualty occurred in March 1894 when an army private apparently got lost after leaving Riverside (on the Madison River near the west boundary) enroute to Old Faithful for the mail. His remains were found a year and a half later, 10 miles from where he was last seen, and in the wrong direction from where he was headed.

We were reminded again this March of the dangers of wilderness travel during winter. Rick Hutchinson, long-time park geologist, intrepid backcountry traveler, and a friend and colleague, was buried and killed in an avalanche near Heart Lake, along with a visiting associate, Diane Dustman.

One of my favorite chapters in the book is "The Capture of the Notorious Poacher Howell." George Anderson, who became acting superintendent in 1891, was determined to rid the park of poaching even though it carried no serious penalty. After learning that Edgar Howell, a local hunter and poacher, was poaching bison in Pelican Valley, Anderson sent a search party to find and arrest him in 1894. Scout Felix Burgess' story of how he captured Howell, as told to Emerson Hough for a *Forest and Stream* article, is pure backwoods poetry. Less than two weeks later, Rep. John Lacey from Iowa introduced the "Lacey Act" "to protect the birds and animals in Yellowstone National Park, and to punish crimes in said park..." (page 108). It remains one of our most important pieces of legislation for protecting wildlife.

Schullery's book is not only entertaining, but informs our present situation, giving an especially gives a good perspective on bison, political boundaries, and natural regulation policies today. Early army scouts, soldiers, and gamekeepers built corrals, trapped wild bison, and imported domesticated bison to augment a herd that had dropped to between 25 and 50 animals by the late 1890s. Perceptions of wildlife and management policies have shifted radically since that time; the evolution continues as the bison remain at the center of a controversy over free-ranging wildlife.

Yellowstone's Ski Pioneers helps to place the role of present-day park management in perspective on the 125th anniversary of Yellowstone National Park. It interprets our history and provides insights into how and why park policies have evolved. It tells good stories, often coming straight from the men involved. This is a good book with which to curl up on a cold winter night. Consider it a "must read" for anyone interested in wildlife conservation and policy or winter travel in the park.

Tom Olliff has worked in Yellowstone since 1980 and currently serves as the park's resource operations specialist and backcountry coordinator. He has broken trail on numerous ski patrols and recreational ski trips. While somewhat envious of Uncle Billy Hofer's experiences, he enjoys today's smaller skis, lighter equipment, and the comfort of backcountry patrol cabins.

Transition Time for Wolves and the Wolf Project

Two years after the start of a historic restoration effort, at least 45 wolves are freely ranging in and around Yellowstone. Another five wolves remain temporarily penned, and are due to be released later this spring. Nine pairs or family groups are being regularly monitored, while biologists await evidence of more pups being born in April and May. Wolves reside in the Lamar Valley and Blacktail Plateau areas of the northern range, but also wintered in the Thorofare, Pelican Valley, and Heart Lake areas of the park.

In late March, biologists picked up a mortality signal on the alpha male of the Soda Butte pack. One of the original wolves brought from Canada and released in 1995, wolf #13 was noted for his distinctive blue pelage. Though thought to be quite old even when first released, he surprised observers by fathering pups in both 1995 and 1996. After spending the winter with four other wolves in his pack around the Heart Lake Geyser Basin, he died there, probably of natural causes.

Yellowstone's Wolf Project Leader, Mike Phillips, has announced that he will leave the park in June to work for Turner Enterprises, where he will be in charge of endangered species restoration programs on Turner's many properties across the United States. Mike leaves with the project ahead of schedule and under budget; we wish him good luck with his next professional challenge.

A Harsh Winter for Yellowstone Bison

The successful recovery of Yellowstone's bison from near extinction a century ago has come at a price. A pre-winter population of about 3,500 animals was large enough to look for new range beyond the park's boundaries, especially when snow thwarted foraging at higher elevations and increased road grooming for oversnow vehicles encouraged bison emigration. Because some bison carry brucellosis, a bacterial disease that infects many wild and domestic animal species, the U.S. Department of Agriculture (USDA) threatened to revoke the "brucellosis-free" status of Montana's livestock. (See *Yellowstone Science* 3(1):15-16).

A long-range bison management plan jointly prepared by the NPS, the U.S. Forest Service, and the State of Montana, with the cooperation of the USDA Animal Plant Health Inspection Service, is scheduled for public review in mid-1997. An interim plan called for bison entering Montana along the park's north boundary to be either captured and shipped to slaughter or shot. Bison along the west boundary were to be captured and tested; those testing positive would be shipped to slaughter and those testing negative would be released.

Because this winter's heavy snowfall led to bison leaving the park in unprecedented numbers, the consequences of the interim plan have been more drastic than anyone anticipated. Efforts to haze bison back into the park proved ineffective because of the large number of animals present and severe weather conditions, while repeated hazing depleted the bisons' precious energy and fat reserves. As of April 2, 1,080 bison had been taken to slaughter or were shot because they could not be captured or were injured in the capture facility. As a result of the combined effect of management removals and natural winter mortality, the Yellowstone bison population is now estimated to be between 1,200 and 1,500.

Resource Interpreter Norm Bishop Retires

Norman Bishop, who spent the last decade of his career as a Resource Interpreter for Yellowstone's science and resource management programs, retired on February 28, 1997. Norm's career spanned 40 years with the National Park Service, including assignments at Rocky Mountain, Death Valley, and Mount Rainier national parks. His educational efforts to interpret wolves and their natural and cultural roles in greater Yellowstone engendered great popular support for the wolf restoration program.

Northern Range Research Reports Available

Available in May from the Yellowstone Center for Resources are: *Yellowstone's Northern Range: Complexity and Change in a Wildland Ecosystem*, a book on the history of research and management in northern Yellowstone, home to one of the world's largest herds of elk and long the subject of controversy, and *Effects of Grazing by Wild Ungulates in Yellowstone National Park,* which contains 22 technical publications summarizing recent studies that have been peer-reviewed by scientists. Much of the research was completed by scientists from agencies other than the National Park Service, by independent contractors, and by scientists from universities located across the United States.

Grazing effects have concerned scientists and park managers since the 1920s. The issue has been complicated by changing environmental and social conditions, as well as by differences in park management objectives compared to those of wildlife and range managers outside of wildland settings.

Yellowstone's northern range provides ecologists with one of the world's most exciting natural laboratories for studying the processes that shape wildlands and native grazing systems. A summary of the publications regarding the northern range will be featured in the next issue of *Yellowstone Science, 5(3).*