Yellowstone Science

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Ground-Penetrating Radar
A History of Snowmobile Use
Coyote Ecology

Volume 7 Number 2

From the Front Pages to History…

While working on this issue's feature on winter use in Yellowstone, I thought about how today's news becomes routine, and eventually becomes the history that some future scholar like Mike Yochim will footnote.

The plows were warming up to leave headquarters and begin breaking open the roadways into the snowbound interior—"into the park" the locals say, as though the administrative complex at Mammoth Hot Springs is not within Yellowstone's boundaries. It is, of course, and the locals know it. But we also know that the readily accessible (at least by automobile) headquarters of Yellowstone is a different place from the vast majority of park acreage, where the snow comes in November and stays until April…or June…or later…depending on the elevation and the quixotic nature of the weather.

Winter used to be a time of respite for the park's inhabitants. Old-timers recall when all park hotels, restaurants, and stores were boarded up in the autumn. Employees, be they store clerks, bellhops, or seasonal rangers, loaded up their possessions and went back to school (as teachers or students), or migrated to a "sunbelt" park to work for the winter. The few permanent rangers stationed throughout Yellowstone in summer packed up their families and moved back to Mammoth. Except for a few staff or visitors who launched an occasional ski or snowshoe expedition into the snow-covered park interior, geyser eruptions lacked audiences and the wildlife had the place to themselves.

I "wintered in" some years ago, after snowcoaches and rental snowmachines had become a regular means of access. Despite the daily drone of engines, the season was still a period of relative quiet and immense beauty. I watched frost formations on trees and on the backs of bison lying near the thermal features, and saw trout linger at the base of geyser runoff into the Firehole River. I heard ice droplets fall back to the ground from the top of Old Faithful's plume on the coldest days, when I marveled at the 90° contrast between the cold air outside my quarters and the temperature inside (55°!) And I thought then that most people would never experience that harsh, cold beauty unless they came, like I, on a snowmachine.

On the front pages is news that a federal judge upheld the park's decision not to close the groomed interior roads to snowmobiles—at this time. Meanwhile, planners float the idea of plowing the winter road from West Yellowstone to Old Faithful—now the busiest snowmobile route in the park. Along with the growing popularity of winter use has come renewed concern for the impacts to resources, and consideration of opportunities that were once truly out of bounds. While the public debates the type and quality of visitor experiences they want and scientists analyze the effects of machines on the ear, the air, and the snowpack, today's front-page news becomes an added chapter of Yellowstone's long, ever-changing history. SCM

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On the cover: Coyote photo by Carol Polich. Opposite page: Harold Young's Bombardier snowcoach, 1966, NPS photo. Above: Observing coyotes, Y.E.S. photo.

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The Development of Snowmobile Policy in Yellowstone National Park

by Michael J. Yochim

Yellowstone National Park is a spectacular place in winter. Sub-zero temperatures clash with steam from the park's numerous hot springs and geysers to create frosted ghost trees and a winter wonderland. The thermally-warmed open rivers and bare ground shelter wildlife in the hostile winter environment. As temperatures drop, wildlife migrate to the lower elevations along the roads and rivers, making them highly visible to the winter visitor.

For much of the park's early history, the harsh temperatures and high snowfall discouraged humans from visiting during winter. After World War II, however, Americans' interest in winter recreation surged, and their ability to cope with the extreme conditions improved with technological advances. Yellowstone saw these trends as well, and began to allow winter visitors to enter the park on motorized oversnow vehicles beginning in 1949. Since then, visitation has steadily climbed, peaking at 143,000 in the winter of 1993-94. While still a small portion of Yellowstone's annual visitation, winter is now a popular time to visit—so popular that Yellowstone admits more snowmobiles than all other national parks combined.[1]

Yellowstone's winter visitation program has become controversial, with most of the concern focusing on snowmobiles and their associated noise and air pollution, and the possibility of snowmobiles displacing the park's wildlife. Amid the debates over snowmobile use in Yellowstone, surprisingly little information has been known about why Yellowstone's administrators allowed snowmobiles into the park in the first place. For my Master's thesis, I decided to investigate this topic, and to trace the developments in the park's snowmobile policy to the present. I also examined the snowmobile policies of other national parks. This article will summarize these topics, and conclude with a discussion of the story and illustrations it provides to us today. Most of this story is new to historians, not having been researched before.

First Snowmobile Policy: 1940 to 1971

After the Second World War, increased prosperity and leisure time enabled Americans to travel to their national parks in record numbers. In Yellowstone, visitation doubled from its pre-war peak of 500,000 visitors in 1940 to more than one million visitors in 1948. The surge in visitation led business owners and associated politicians in the Cody, Wyoming area to reason that, if Yellowstone were open to automobiles year-round, they would see their profits from tourism revenues spread throughout the year. Consequently, in 1948 they called upon the Yellowstone administrators to plow the park's roads year-round.[2]

Yellowstone's administrators and the Bureau of Public Roads (BPR, now Federal Highways) responded with a report analyzing the costs and feasibility of plowing the park roads in winter. The report concluded that plowing would not be feasible, because the park's road standards were too poor to permit effective plowing, the buildings in the park interior were not winterized, and plowing would be too dangerous.[3]

The report settled the matter for eight years. Meanwhile, snowbound residents of the communities outside the park built the first "snowplanes." Snowplanes were vehicles composed of a two-person cab on three large metal skis with an airplane propeller mounted on the rear that blew around the area's snow-covered roads without ever "taking off."[4] The touring possibilities of the unusual vehicles became obvious; in January 1949, 35 visitors entered the park in 19 snowplanes from West Yellowstone. The superintendent of the park prophetically reported that "it appears that this mode of travel is becoming more popular."[5]

Snowplanes were the only oversnow vehicles in the park until January 1955. That year, Harold Young and Bill Nicholls of West Yellowstone received permission to use the first snowcoaches in the park. Snowcoaches were large vehicles made by the Bombardier Company of Quebec, Canada, capable of carrying 10 people in a heated interior. Calling the snowcoaches a "good tourist gimmick," Young and Nicholls took up to 500 visitors per winter through the park in this manner in the 1950s.[6] AmFac, the park's main concessionaire today, still uses the same or similar vehicles.

In 1955 the National Park Service (NPS) launched its Mission 66 program. Largely a program of development to serve the needs of increasing numbers of visitors to the national parks, Mission 66 also sought to disperse visitation throughout the year, in an effort to take some of the pressure off the parks in summer. In Yellowstone, local politicians used Mission 66's idea to renew their calls for plowing park roads in 1957. In response, Yellowstone's administrators formed a "Snow Survey Committee" to study the matter. On the committee were representatives of Yellowstone and federal and regional highway departments. After traveling around the park observing its traveling conditions, the committee recommended in 1958 that plowing would be "feasible but not practical," citing many of the same reasons as the 1949 BPR report did.[7] This report settled the matter for the next six years.

In 1963 the first visitors on snowmobiles entered the park. Known as Polaris "Snow Travelers," the vehicles were the direct predecessor of modern snowmobiles in that they were a toboggan driven by a motor. Such vehicles became popular very quickly, enabling visitation to jump from about 1,000 oversnow visitors in 1963–64 to more than 5,000 just three winters later.[8]

In January 1964, six senators representing the states on U.S. Highway 20 (which connects with Yellowstone Park's roads) along with Wyoming Governor Clifford P. Hansen called upon the NPS and Department of the Interior to reconsider the decision against plowing park roads.[9] Park administrators embarked upon a third round of cost estimates, visitor use estimates, and debates about policy. The intensity of the debate this time drew NPS Director George Hartzog into the fray. Hartzog organized the Tri-State Commission, a group of high-level NPS officials and regional government representatives. After meeting several times to discuss the feasibility of plowing the roads, the Tri-State Commission meetings culminated in a congressional hearing on the matter in Jackson, Wyoming on August 12, 1967.[10]

Hartzog began the hearing by stating the position of the NPS: first, the form of transportation in winter in Yellowstone should be that which was most appropriate to the park and the park visit; and second, oversnow visitation was, unless shown otherwise, the appropriate means of visiting the park in winter, since oversnow vehicles travel on top of the snow rather than in the trench that plowing would create of the roads in winter. Senator Gale McGee of Wyoming, who chaired the hearing, spent the remainder of it accepting oral and written comments from chambers of commerce in the Yellowstone area and in the state of Wyoming, all of which supported plowing. Chambers from as far away as Logan and Salt Lake City, Utah, and Amarillo, Texas sent statements in support of plowing, believing that plowing the roads through Yellowstone would stimulate traffic on the same highways in their communities.[11]

After the hearing, Yellowstone's administrators gave serious consideration to keeping park roads open from October through the end of December. Superintendent McLaughlin hoped that, by doing so, "most people, particularly the Wyoming Congressional Delegation, will settle down for the next several years and maintain some semblance of peace and quiet."[12] Despite McLaughlin's recommendation to go ahead with this compromise, "the Director's Office…advised there will be an unqualified 'no' on winter road openings in Yellowstone…The basis of this is the restriction on funding levied by Congressional Committees."[13]

Consequently, park administrators spent the following winter admitting oversnow vehicles as before. In March, 1968, though, they convened an all-day meeting at Mammoth Hot Springs to formalize a winter use policy. The policy they discussed and implemented in the next three years would consist of three parts: 1) formally permitting and encouraging visitation to the park's interior by oversnow vehicles instead of automobiles; 2) grooming the oversnow roads to make them more comfortable for travel; and 3) authorizing the park concessionaire to open a lodging facility for overnight use at Old Faithful.[14] Their reasoning for these decisions follows.

Snowplane 1957. Highway maintenance supervisor Charlie Shumate of Colorado at West Thumb Geyser Basin. The propeller is in motion at rear (left). NPS photo.

Early snow groomer 1975. By 1971, the NPS began to groom the roads regularly in order to make travel by over-snow vehicle more comfortable. This is one of their early grooming machines. NPS photo.

Old Faithful Snowlodge 1972. In 1971, the Yellowstone Park Company opened the Snowlodge at Old Faithful to provide overnight accommodations. Note the temporary "Snow Lodge" sign covering the more permanent sign beneath, which probably said "Campers Cabins." In 1973, the company permanently renamed the building "Old Faithful Snowlodge." It was torn down in 1998. NPS photo.

Yellowstone's administrators chose to allow oversnow vehicles rather than automobiles largely because plowing park roads would make them into "snow canyons"—plowed trenches with tall berms of snow on the sides that would be difficult for automobile passengers to see over. They felt that those snow canyons would be obstacles to migrating wildlife and would trap them on the road, making driving hazardous.[15] Furthermore, they felt that plowing the park's roads would have the disadvantages of only serving those who were traveling *through* Yellowstone, and of causing the townspeople of West Yellowstone to suffer economically.[16] They also considered restricting the park to skiers and snowshoers only, but felt that this would have been too exclusive, since few people could ski or snowshoe the long distances necessary to view the park's major attractions.[17] Because "public pressure to open the park gave [them] little choice," they chose to go with oversnow vehicles as a compromise. In this way, the public could view Yellowstone, but the park's administrators could keep the highways from becoming busy throughways.[18]

Oversnow vehicles tend to move the snow over which they travel, creating very bumpy, rough roads. To smooth the roads, the Yellowstone Park Company (YPCo.) had experimented with various means of road grooming, which were all generally ineffective.[19] Park administrators began to investigate better ways of grooming. Using the technical assistance of Midwest snowmobile groups, the NPS purchased the park's first grooming machines, and began grooming the roads by February 1971.[20] Besides making travel more comfortable, grooming the park roads also encouraged snowmobilers to stay on them rather than seeking a smoother surface off road, thereby trampling native vegetation.[21]

Meanwhile, demand had become so great for a place to stay overnight at Old Faithful that some visitors camped out in the only heated building there—the public restroom.[22] After extensive discussion with the NPS, the YPCo. opened the Old Faithful Snowlodge on December 17, 1971, for its first winter season. It chose the "Campers Cabins" building because that was the only hostelry at Old Faithful that was even partly winterized.[23] Open through March 19, 1972, the Snowlodge featured "simple, pleasant and comfortable lodging spiced with hearty western food and beverage and nature's grandest winter display…Single, twin and triple rooms are available. All are convenient to centrally located bath facilities."[24] It was the Campers Cabin building with a new name,[25] featuring 34 dorm rooms without bath occupied in summer by employees. The YPCo. decided against opening all or part of the famous Old Faithful Inn because it would have needed extensive winterizing.[26] (AmFac razed the original Snowlodge in April 1998, replacing it with a more comfortable and architecturally pleasing building.)

Superintendent Anderson and his staff promoted the park's snowmobile program by arranging a visit by Lowell Thomas, a well-known radio commentator of the time. Thomas visited Yellowstone in winter, 1969, and discussed his visit on several subsequent radio broadcasts.[27]

By the end of the 1971–72 season, Yellowstone had responded to the persistent pressure to open the park by encouraging oversnow vehicles as the winter mode of transportation. Maintenance staff provided smooth roads, and the YPCo. provided comfortable lodging and dining facilities at Old Faithful. These efforts to make the park available to the public in winter paid off, for pressure to plow park roads largely disappeared from this point forward. By the end of that winter season, more than 25,000 people had visited the park.[28]

Challenges to the New Snowmobile Policy: 1967–77

The increasing numbers of visitors brought a corresponding increase in snowmobiles—as many as 30,000 in the winter of 1973–74 (three times the number as had entered just five years earlier).[29] With more snowmobiles came more reports from park visitors and staff of problems such as noise, air pollution, and effects on park wildlife. The managers responsible for carrying out the new policy responded to these concerns as best they could while adhering to the policy.

The snowmobiles of the early 1970s were very noisy, sometimes emitting as much as 100 decibels of noise at a distance of 50 feet with a full throttle—a level that would seem as loud as a jet.[30] Complaints from visitors attempting to enjoy the winter silence and from field rangers were common.[31] Superintendent Jack Anderson acknowledged that "everyone pretty well agrees that [snowmobile noise] is a very disturbing factor for those who are attempting to enjoy the peace and quiet of the winter wilderness."[32] However, he felt powerless to improve the situation, since "reduction of noise and air pollution must await mechanical improvements by the manufacturers."[33]

Air pollution from snowmobiles also became a problem, especially at Old Faithful and the West Entrance. Warning park administrators of the air quality problem were some field rangers such as James Fox, who wrote to his supervisor in 1970: "A great deal of exhaust smoke is produced by most snowmobiles…when many machines enter the park in a single day, a foul-smelling blue pall of smoke hangs over the entrance for most of the morning."[34] Adhering to the new policy, Anderson stated (though not in direct response to Fox) that "conditions have not, however, become uncomfortable for breathing" in the park.[35] He again felt helpless to improve the situation, since the technological improvements necessary to clean up snowmobile emissions were out of his control.[36]

Snowmobiles at West Entrance 1972. Snowmobiling in Yellowstone increased exponentially in the 1970s. Here, the man at left is registering at the self-registration station while his friends wait. NPS photo.

Park staff were also concerned that snowmobiles could be displacing and harassing park wildlife and damaging the vegetation. Resource management specialist Edmund J. Bucknall discussed some of the problems in a memorandum to the chief park ranger on March 16, 1970: "The combination of noise and offroad operation of these [oversnow] machines is causing serious disturbance all through the Madison valley winter range…elk are spooking even from the far side of the river at the sound of an approaching snowmobile."[37] The number of research papers from the early 1970s investigating snowmobile effects upon wildlife indicates that Bucknall's concern was well-founded. According to James W. Caslick, who surveyed literature on snowmobile effects upon wildlife, "much of the literature on this topic dates from the 1970s, when snowmobiles were new on the winter scene. There was a flurry of related papers, particularly from the Midwestern states…Reports sometimes conflicted with previous findings, but there was general agreement that winter recreation, particularly snowmobiling, had great potential for negatively impacting wildlife and wildlife habitats."[38]

In response to the complaints of the public and his rangers, Anderson directed park biologist Glen Cole to initiate research into these problems. Cole reported: "My field observations suggested that the elk that used areas near roads became habituated to snowmobiles…Displacements of these animals were mostly confined to the road plus surprisingly short distances."[39] In contrast, Keith Aune, a graduate student at Montana State University, examined the topic in the late 1970s for his master's thesis and concluded that snowmobiles harassed wildlife, displaced them from areas near snowmobile trails, and inhibited their movement across trails.[40]

Based on Cole's findings (Aune's were issued after Anderson retired), Anderson adhered to the new policy, which specified that snowmobiles must remain on the snow-covered roads.[41] It also meant denying permission to the YPCo. to open a snowmobile rental at Old Faithful because that "would, in effect, turn the Old Faithful area into a recreational area with snowmobiling the principal activity and this is not the basic objective in making the Old Faithful area accessible…for public use in the winter."[42] Anderson opened the Old Faithful Visitor Center for its first winter season on January 1, 1971 to provide information to visitors.[43]

Anderson upheld his park's new policy while attending to the concerns associated with rising snowmobile use. Some statements he made in an interview with

Superintendent Anderson snowmobiling in 1972. Anderson personally liked snowmobiling and was out in the park on a regular basis. Here he talks to some park visitors at Old Faithful. NPS photo.

Derrick Crandall of the Snowmobile Safety Certification Committee in 1977, two years after he retired from public service, seem to conflict with his actions as superintendent. In that interview, Anderson labeled the complaints about snowmobile noise "baseless," suggested that those complaining ski another 100 yards to escape the noise, and said, "All it takes is a pair of earplugs to solve that real quick." He also felt that complaints about wildlife harassment were "emotionalism" and "never supported by fact."[44] He said that snowmobiling is "a great experience and a great sport, one of the cleanest types of recreation I know."[45]

Yellowstone's administrators were not alone in struggling with the use of federal lands by off-road vehicles (ORVs), which exploded in the early 1970s. Land managers nationwide struggled with this issue. President Nixon attempted to give them some direction in 1972 with Executive Order (EO) 11644, which established federal policy regarding the use of ORVs on public lands. It clearly specified that snowmobiles were ORVs, and outlined the resources and issues that land managers should consider in allowing ORV use.[46]

Anderson was one of the first park superintendents to respond to the EO. In a decision published in the Federal Register dated May 7, 1974, he designated all of Yellowstone's interior roads as snowmobile routes.[47] One month later, NPS regional director in Denver followed up on the EO with a memorandum suggesting that all Rocky Mountain superintendents should have environmental assessments on snowmobile use prepared for their parks.[48] I could not find a response from Anderson to the regional director in the historical record, nor could I find evidence that he prepared the suggested EA.

Providing an interesting contrast to Yellowstone are the actions of Glacier National Park administrators regarding the executive order. Responding to the regional director's memorandum, Glacier conducted an EA on snowmobile use in 1975. At the time, there were up to 1,300 snowmobiles visiting the mountain park each winter. As part of the EA, Glacier held two public meetings on the matter and gathered written public input. Glacier noted the following problems caused by snowmobiles: wildlife displacement, trampled vegetation, air and noise pollution, conflicts with other park users, the need to groom roads, and the fact that snow compaction caused by snowmobiles would make spring plowing more difficult.[49]

In 1975, Glacier's officials decided to ban snowmobiles from the park, primarily because they disrupted the solitude of the national park in winter: "Over 90% of the comments opposed to snowmobile use related that concern to silence, tranquillity, or in other words, aesthetics. Because aesthetics are an emotion, a feeling, it is impossible to quantify [*sic*]. However, it is a very valid concern, and the National Parks represent, above all other values, an emotion, a feeling, which Americans can obtain only in a handful of other natural scenic places."[50] The officials confirmed their decision with two more hearings and further public comments in 1976-77, and formalized the ban in 1977.[51] It remains in effect today.

Other national parks, including Yosemite, Sequoia/Kings Canyon, and Lassen National Parks, responded to public opinion by eliminating snowmobiles during the same period.[52] In contrast, Rocky Mountain National Park decided to permit snowmobiles on the west side of the park.[53]

Clearly, national park managers have struggled with the issue of snowmobiles. Furthermore, policies on snowmobiles differ among national parks, illustrating that superintendents are not bound by the decisions of their peers. Anderson's post-retirement remarks on this topic are worth noting: "I'm a little upset with some of my fellow superintendents. I sometimes think they are getting lazy when they want to ban snowmobiles simply because they are motor-powered vehicles…they just don't want to get involved because it sets up a debate and … creates work for land managers."[54]

Before retiring in 1975, Anderson received the International Snowmobile Industry Association's first International Award of Merit for his "enlightened leadership and sincere dedication to the improvement of and advancement of snowmobiling in the United States."[55]

Expanding the Snowmobile Program: 1975–82

John Townsley took the superintendency of Yellowstone upon Anderson's retirement and continued promoting the park's winter program. He expanded the NPS winter operation by purchasing more grooming machines and having his staff groom the roads in the evening hours, when falling temperatures would freeze the snow as it was groomed, producing a more durable snow road.[56] To provide for the needs of the increasing numbers of winter visitors, he opened warming huts at Canyon and Madison and expanded interpretive services at the huts.[57]

Townsley authorized the concessioner to expand its involvement in the winter operation as well. The company expanded the capacity of Old Faithful Snowlodge by opening additional cabins and the Snowshoe Lodge, a summertime employee dormitory, for guest use. The company also reopened the Mammoth Hot Springs Hotel for winter use in 1982.[58] The hotel had been open continuously from 1966 to 1970, but the YPCo. closed it in 1970 because the winter season at that time was a pronounced business failure.[59] Both the hotel and the Snowlodge remain open in winter today.

Townsley defended the winter use program from possible shutdown by James Watt, Secretary of the Interior under President Reagan, who wished to save federal funds. After Townsley took him on a tour of the park in December, 1981, Watt decided to keep the park open in winter.[60]

Like his predecessor, Townsley set some limits to the winter program. He denied a stuntman permission to jump a snowmobile over Old Faithful while it was erupting,[61] and banned dogsleds from the park to protect the dogs from snowmobiles.[62] Concerns about air and noise pollution and wildlife impacts were present during Townsley's tenure too.[63] The park's bison evidently began using Yellowstone's hard-packed snowmobile routes to travel upon around 1980. Although he labeled this habit a "strange quirk,"[64] Townsley supported Aune's research into snowmobile effects upon park wildlife.

In recognition for his efforts, Townsley too won the International Award of Merit from the International Snowmobile Industry Association (ISIA) in 1982, shortly before he died. In presenting Townsley with his award, ISIA Chairman M. B. Doyle said "Snowmobilers, local tourism industry leaders and other governmental officials…recognize his personal commitment to bringing persons enjoying a variety of outdoor winter activities into harmony with each other and the park resource they are experiencing."[65]

The First Winter Use Plan: 1983–92

Robert (Bob) Barbee became superintendent of Yellowstone in 1983. During his tenure, winter visitor use doubled from 70,000 persons to 140,000 visitors per winter. To deal with the problems of increasing visitation, Barbee commissioned the first compilation of winter use management guidelines and the park's first *Winter Use Plan*.[66]

As the first step, Barbee and his staff summarized the scattered pieces of Yellowstone's snowmobile policy in the *Existing Winter Use Management Guidelines, Inventory & Needs*. The document, issued in 1989, reflected the concerns at the time about the impacts of winter use on the park and the lack of ongoing research projects aimed at identifying the current and potential impacts of such use.[67]

In 1990, the NPS issued the *Winter Use Plan Environmental Assessment.* A core team of ten persons authored the plan: five from the Denver Service Center, three from Grand Teton National Park, two from Yellowstone, and one from the regional office. The plan made few changes in Yellowstone's winter program, and arguably did not address the concerns raised in the *Existing Winter Use Management Guidelines, Inventory & Needs* issued a year before. For example, Yellowstone administrators did not initiate the research projects suggested in the previous document, perhaps due to a lack of adequate funding.

Yellowstone's administrators themselves did not wholly approve of the *Winter Use Plan*. In a memorandum to a member of the core team, Chief Ranger Dan Sholly questioned the projected winter visitation figures. He felt that the plan was "somewhat generic," and did not have strong language on winter wildlife protection.[68] The *Winter Use Plan* offers little to suggest that Sholly's concerns were addressed. Indeed, in just three years actual Yellowstone winter visitation exceeded the authors' maximum projected increase for the next *ten* years,[69] perhaps because the plan's authors relied upon data from other national parks rather than from Yellowstone itself in projecting the future trends in winter visitation.[70] Also, snowmobile air pollution exceeded the Clean Air Act limits at the West Entrance in 1995,[71] despite the assertion of the authors that such would not happen.[72]

Despite its shortcomings, the *Winter Use Plan* continues to guide the management of Yellowstone in winter. Barbee left Yellowstone in 1994 to assume the regional directorship of Alaska's national parks where, in the late 1990s, he and his staff wrote regulations banning snowmobiles from Denali National Park. As justification for this action, Barbee told me that "we don't want Denali to become another Yellowstone."[73]

A Hard Look at the Problems: 1993–97

Mike Finley became superintendent of

Left: Bison on the road, 1997. By the early 1990s this view was becoming common in Yellowstone; bison using the hardpacked snowmobile roads for travel. This habit has raised concern about the effects of the park's winter program its wildlife. Below: Thousands of snowmobiles, 1997. By the mid-1990s, as many as 140,000 visitors passed through Yellowstone in winter, the majority on snowmobile. Over 75% of the visitors travel to Old Faithful during an average visit; as many as 2,000 snowmobiles will pass through that area per day. Photos by M. Jochim.

Yellowstone when Barbee left in 1994. Soon, Finley and his staff began renewed examination of the impacts of the winter use program.

In 1992-93, administrators in Grand Teton National Park (immediately south of Yellowstone) had opened their park's portion of the Continental Divide Snowmobile Trail, a 240-mile trail in Wyoming. That same winter, visitation in Yellowstone alone surpassed 140,000 persons. Both events tripped an important trigger specified by the 1990 *Winter Use Plan*: the implementation of the Visitor Use Management Planning Process (VUM),[74] which is "a process of identifying goals (or desired futures), looking at existing conditions, identifying discrepancies between the two, and laying out a plan of action to bring the two closer together."[75] The NPS began the VUM Process in Yellowstone in 1993 with Grand Teton and the surrounding national forests. In 1997, these agencies issued the *Winter Visitor Use Management: A Multi-Agency Assessment*, which was a preliminary summary of the issues and concerns related to snowmobile use in Yellowstone and the surrounding area. The document listed noise pollution, air pollution, and wildlife impacts as concerns raised by the public.[76] After analyzing more than 200,000 comments, the agencies expected to issue the final VUM report early in 1999. This document will recommend ways of improving the current situation, but any changes will be at the discretion of each land management agency.[77]

While the federal agencies were busy with the VUM Process, nature intervened with an extraordinary winter in 1996-97, which saw more than 150 percent of normal snowfall in Yellowstone. Compounding the snow was a layer of ice that formed in the snowpack from some rain that fell after Christmas. The park's bison could not break through the ice to reach the grass below and began migrating out of the park (some via the snowmobile roads) in search of more easily obtainable food. Some of the park's bison carry brucellosis, a disease that, if transmitted to cattle, can cause an expectant cow to abort its fetus. To prevent that transmission, along with associated negative economic and political consequences, the state of Montana shot or sent to slaughter most of the bison that left the park—a total of 1,084 by spring, 1997. This represented about a third of the park's herd, was the largest control of bison departing Yellowstone in history, and was one of the largest slaughters of bison anywhere since humans eliminated them from the Great Plains in 1884.[78]

The bison killing led to a lawsuit against the NPS by the Fund for Animals, a wildlife advocacy group. Filed on May 20, 1997, the lawsuit contended that Yellowstone's winter use program was in violation of several laws, including the National Environmental Policy Act (NEPA), the Endangered Species Act, and the NPS Organic Act.[79] The NPS settled out of court with the Fund on September 23, 1997, by agreeing to both consider closing a snowmobile trail in order to evaluate the effects on overwintering bison in the park and also to write a new *Winter Use Plan/Environmental Impact Statement* (EIS).[80]

In January, 1998, Yellowstone administrators announced that they would not close any snowmobile trails, but would institute several research projects to gather baseline data on bison use of groomed roadways. After three years, they would re-evaluate the need to close a road for research purposes.[81] They began the EIS in April, 1998, and should complete it in 2000, if all proceeds as planned.

Conclusion

The history of snowmobiling in Yellowstone illustrates several concerns regarding the management of national parks. First, as with many issues, winter use evolved without much research and with little followup. Park managers were confronted with a new use and had to make a decision on whether or not to allow it without the time or ability to fully research the ramifications of it on Yellowstone. Moreover, they did not have policy direction from above in deciding whether that use was considered appropriate and traditional. Once made, their decision became institutionalized and hard to change. Making significant change in the program today would be difficult at best due to the complexity of the issue and number of economically dependent interest groups.

The legal atmosphere and its effects on park management have changed considerably since Anderson's time. Anderson and his staff had little guidance in deciding to permit snowmobiles either from law or from national park service policy directives. Beginning with the passage of NEPA in 1970, the people of the United States gave increasing legislative guidance to federal land managers. Today's park managers have not only a suite of national environmental laws but also extensive policy direction from the NPS itself to follow and use.

The role of research in national park management has also changed. As Richard Sellars points out in *Preserving Nature in the National Parks* (1997), the NPS did not embrace peer-reviewed research until quite recently.[82] Illustrating this fact in Yellowstone is the dearth of research on snowmobile effects upon the park dating from the 1970's. Today, the climate for research in the national parks is much more supportive and the NPS has many different on-going projects to assess the effects of its winter program upon the park. Still, much research needs to be done.

A decision that was arguably done to protect the park from becoming a busy winter thoroughfare has, in a way unforeseen to the park's managers, enabled its parkways to become even more crowded. The administrators of the 1960s and 1970s recognized that plowing park roads would encourage regional residents to drive through the park rather than around it. Restricting visitation to oversnow vehicles meant that only those who really wanted to see Yellowstone would enter. To encourage such appreciative visitation, administrators promoted the winter program in various ways. Their efforts to stimulate such visitation paid off so well that today's park managers find too many visitors and associated impacts at times. The modern NPS finds itself groping for ways to more adequately control the situation, and perhaps limit visitation.

The history of winter use in both Yellowstone and Glacier illustrates the high level of emotions attached to snowmobile use in national parks. At Glacier, park managers perceived that some concerns were too emotional to be settled by objective research, and that some emotions should be used to direct management within the national parks. Managers in Yellowstone have seen consistent complaints from the public reflecting their concerns and emotions on winter use, and continue to struggle with them.

Ultimately, the story of snowmobile use in Yellowstone National Park may be a good illustration of how visitor preferences change over time. In the 1960s, Yellowstone's visitors seemed to prefer opening the park to access by snowmobile. Practically no opposition to this move occurs in the historical record until after snowmobile visitation was well established. Since then, opposition has been steady or increasing simultaneously with the growth of snowmobile use. Such changing user preferences are difficult for park managers to assess and monitor. As volatile as the preferences may be, it is difficult to predict where the park's winter use program will go in the future. One thing is certain though—the ride promises to be emotional and rocky. ❋

Michael Yochim has worked in Yellowstone National Park for a total of 12 years, both as a tour guide for AmFac Parks and Resorts and as a ranger-naturalist for the National Park Service. He derived this article from his master's thesis research into the history of winter use and the development of snowmobile policy in Yellowstone. The University of Montana conferred upon him the degree of Master of Science in Environmental Studies in 1998.

Michael Yochim.

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Ground Penetrating Radar Studies at Mammoth Hot Springs

by Marvin Speece and Laura Joss

Introduction

The Fort Yellowstone-Mammoth Hot Springs Historic District has long been an area of development within Yellowstone National Park. The park's second superintendent, Philetus W. Norris, selected Mammoth as the permanent park headquarters in 1878 because of "its nearness and accessibility throughout the year, through one of the…main entrances to the park to the nearest permanent settlements of whites and a military post, [because of its] remoteness from routes inviting Indian raids, and [its position as] a proper site for defense therefrom, and [because it provided] for ourselves [and our] saddle and other animals, good pasturage, water, and timber, as well as accessibility to the other prominent points of interest in the Park."[1]

In retrospect, Mammoth has in some ways proved to be an unfortunate choice for park headquarters. For example, the surface rock in the area is a variety of layered limestone called travertine. Because travertine is highly porous and susceptible to dissolution, subsurface cavities are present throughout the area. Collapse features that form when subsurface water weakens overlying travertine are commonly seen at the surface. Moreover, the horizontal travertine beds are cut by numerous steeply dipping fractures. The area features active hot springs with new hot springs forming and some old hot springs becoming inactive. As a result, the area is unstable, and historic buildings are occasionally threatened by the inconstant thermal features and subsidence. For instance, the historic 1907 H.W. Child's Residence, also known as the Executive House, is threatened by the encroachment of the relatively young Opal Terrace hot spring feature.

Throughout Yellowstone National Park's history, the area's unique cultural and natural resources have generated a great deal of research activity by both park and outside researchers. This has resulted in substantial collections of natural resource specimens and cultural resource artifacts being stored in overcrowded facilities and a lack of researcher workspace. Current storage conditions do not meet professional standards, and deficiencies include inadequate environmental controls, security, fire protection, and pest management.

To best serve researchers and the resource collections, the park needs a consolidated research and preservation facility for storage and exhibition of cultural and natural resource collections. The proposed facility, the "Yellowstone Heritage and Research Center," will be approximately 35,000 square feet in size and include storage and exhibit areas, wet and dry laboratories, and researcher workspaces. Mammoth Hot Springs has been targeted as the preferred location so that the facility will be accessible year-round to park staff and visiting researchers.

Given the unstable geology of the area, park staff are concerned about finding a secure site for this facility. Noninvasive subsurface investigations commonly employing one or more geophysical techniques were considered as a preliminary step in surveying potential construction sites at Mammoth Hot Springs. Geophysical techniques can provide images of the subsurface with a minimum of surface

Montana Tech students conduct GPR survey near the Mail Carrier's Cabin. Students pull a sled containing radar antennas. Photos courtesy Marvin A. Speece.

disturbance. In the best case, these images can give sufficient detail to locate subsurface cavities and large-scale fractures or faults. Such information may also help the park staff manage conflicts posed when ever-changing thermal features threaten cultural resources.

The need for geophysical site characterization at Mammoth provided a unique opportunity for a cooperative study involving students and faculty at Montana Tech of the University of Montana, working with the National Park Service.

How Ground Penetrating Radar Works

Of the commonly used geophysical techniques, ground-penetrating radar (GPR) has the greatest resolution. In ideal situations objects in the subsurface with contrasting electrical properties that are separated by only a few centimeters can be distinguished from one another. GPR is the geophysical method of choice whenever sufficient electrical property contrasts exist and high resolution is desired. Moreover, GPR profiles can be quickly displayed and interpreted in the field. Most other geophysical techniques require elaborate post-processing or modeling that can take additional time and thereby delay gratification and increase costs.

In practice, GPR measurements are made by moving transmitting and receiving antennas (1 MHz to 1 GHz) along the ground surface. At a particular position along the surface, the transmitter emits an electromagnetic wave into the ground. When this wave encounters a boundary between materials of differing electrical properties, some of the incident wave energy is reflected back to the surface. The energy returning to the surface is, in turn, recorded at the receiving antenna. The information recorded at one ground position is called a trace. Reflected energy on the trace is observed as an increase in the signal amplitude that occurs at a particular time along the trace.

As the GPR system is moved along the ground surface, traces are recorded at regular intervals. When these traces are displayed side-by-side as a cross section, the size, shape, and depth of a reflecting object can often be determined. Some common features that cause reflections in the subsurface include: 1) changes in rock type, 2) cavities, 3) plastic and metal containers, 4) pipes, 5) changes in porosity, 6) the water table, 7) hydrocarbon plumes, and 8) building foundations.

Unfortunately, the electrical conductivity of the subsurface limits the use of GPR. As conductivity increases, the depth of penetration decreases. In highly conductive, clay-rich soils, the effective depth of penetration of the electromagnetic waves may be less than a meter. Water can also limit the use of GPR. As the salinity or total dissolved solids in water increases, the conductivity of the water increases and severely limits the ground-penetrating capabilities of radar. Local geologic conditions govern which geophysical methods can be used at a given site.

In the Mammoth Hot Springs area, the surface rock is predominantly a hydrothermal variety of layered, porous limestone known as travertine. Limestone typically has low conductivity, making it ideal for radar use. On the other hand, when highly mineralized ground water is

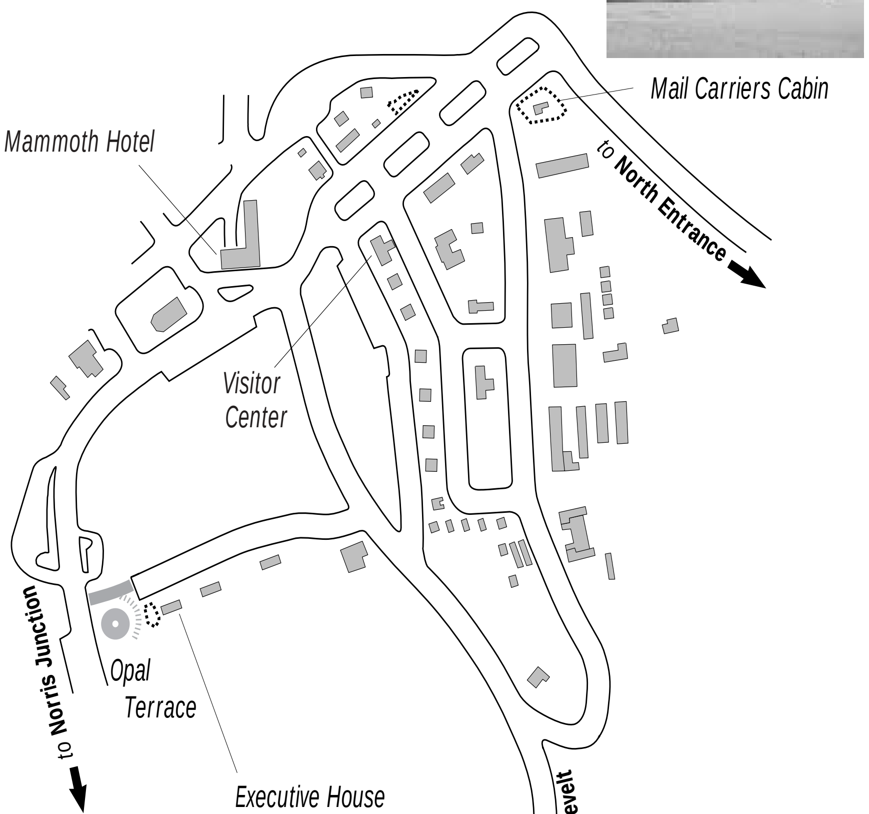
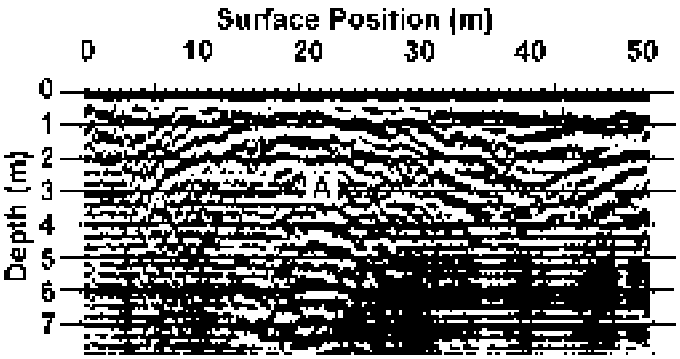


Figure 1. Mammoth Hot Springs area map showing the location of three GPR surveys.



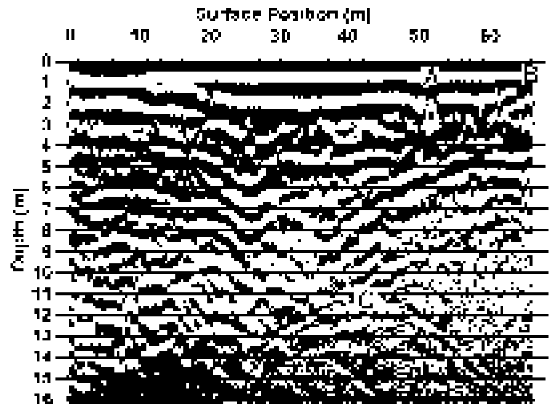


Figure 2 (left). GPR profile collected between Opal Terrace and the Executive House using 200 MHz antennas. The profile direction is approximately south to north and parallel to the earthen retaining wall built to stop the encroachment of the terrace. Depths are approximate and are based on a subsurface wave speed of 160 m/micros that was estimated for travertine. Point ***A*** *near the center of the figure identifies the top of a suspected cavity. Figure 3 (right). GPR profile collected near the 1895 Mail Carrier's Cabin using 100 MHz antennas. The profile direction is south to north. Depths are approximate and are based on a subsurface wave speed of 160 m/micros that was estimated for travertine. Labeled points* ***A*** *and* ***B*** *are at the top of buried pipes. Point* ***C*** *is a the top of a large arcing reflection caused by an overhead transmission line.*

present in the travertine pore space, radar penetration would decrease significantly.

GPR Tests at Mammoth Hot Springs

In May 1997, we conducted GPR tests at several locations in Mammoth: 1) near the 1895 Mail Carrier's Cabin, 2) near the Ice House, and 3) Opal Terrace (Figure 1.) The first two sites were considered as possible locations for the Yellowstone Heritage and Research Center, while the third site was investigated because of concerns about the encroachment of Opal Terrace on the Executive House. These tests consisted of short GPR profiles that were gathered to determine if reasonable penetration depths could be obtained in the area, as well as to see if sufficient electrical property contrasts existed in the subsurface to produce observable reflections. These initial tests showed that penetration depths of over 15 meters were possible, and numerous reflections were observed in the data.

Figure 2 shows a radar profile collected near the base of Opal Terrace between the terrace and the Executive House. The top of a possible subsurface cavity is labeled near the center of the figure. Cavities typically produce strong reverberations in GPR profiles, as demonstrated by the series of reflections that continue until the bottom of the profile (seen beneath the labeled point). Also, note the bowl-shaped feature centered along the top of the profile. This feature may be a former channel that was subsequently filled by layered travertine. This subsurface information will be extremely useful to guide the creation of realistic subsurface models of geology and ground water flow. In turn, the models could be used to help develop contingency plans for protecting the Executive House from continued growth and overflow of the travertine terrace.

The Montana Tech Students' Summer Experience

Field studies are often an integral part of geoscience curricula. At Montana Tech, much of the field experience is gained in a six-week-long summer field camp in which students are exposed to both geological and geophysical field methods. This camp is a required course for both geophysical and geological engineering majors at Montana Tech. Group projects are typically utilized to give students the experience of working with others. Furthermore, projects that combine elements of service to the community with academic learning are sought to enrich the field camp experience.

After the preliminary GPR tests, Yellowstone National Park staff made arrangements to have students in the 1997 Montana Tech summer field course perform a geophysical site assessment of one of the sites under consideration for the Yellowstone Heritage and Research Center, the 1895 Mail Carrier's Cabin. The students had to provide a professional quality report to the park detailing the results of the survey at the end of the field course

In the field, students were organized into task groups that variously surveyed profile lines, collected GPR profiles, and collected background information at the Yellowstone National Park research library. After field data were collected, student teams prepared a report for the

Marvin Speece collects GPR data in the parade grounds near the Ice House, which can be seen in the background.

park. Team tasks needed to prepare the final report included map preparation, profile preparation, survey-data reduction, and narrative writing. Individual tasks were changed at intervals to provide the students with a variety of experiences.

In all, Montana Tech students gathered 35 separate GPR profiles near the Mail Carrier's Cabin. One of these profiles, displayed in Figure 3, shows a wedge of relatively continuous, layered travertine that thins to the north along the profile. The lack of reflections at the base of the layered travertine package could be caused by the boundary between travertine and less reflective volcanic or sedimentary rocks that are likely found underneath the travertine in the area. Alternatively, the lack of reflections could be due to mineralized water. This water has relatively high electrical conductivity which would cause rapid loss in signal strength with depth. Several cultural features—buried pipes and overhead transmission lines—are identified in the figure. No large subsurface cavities are seen in the profile.

The GPR survey at the Mail Carrier's Cabin site detected numerous cultural features such as buried wires and pipes but did not show any large cavities that would preclude building at the site. The study, however, indicated that numerous fractures and small faults are present throughout the site. These fractures may be related to historic subsidence. Partly on the basis of this study, alternate sites are being considered for the proposed facility. A follow-up GPR test near the Ice House indicated that it would be a more secure building site.

Conclusions

Student evaluations of this project were overwhelmingly supportive. Students enjoyed the visit to Yellowstone National Park as well as the opportunity to contribute to a professional quality report that was going to be put to real use. They welcomed the opportunity to practice their public relation skills while interacting with park personnel and visitors. This study provided Yellowstone National Park personnel with information that proved useful for planning purposes for the siting of the proposed facility. Cooperative projects such as this one can provide important learning opportunities for college students while at the same time perform a useful service for the community.

GPR successfully imaged travertine layers in the Mammoth Hot Springs area and detected a possible subsurface cavity near the historic Executive House. GPR is high resolution, easy to use, and noninvasive. Furthermore, it costs much less than a detailed drilling programs. Cooperative studies involving students, faculty, park staff, and the use of GPR are a cost-effective way to evaluate the subsurface and understand the changing thermal features of Yellowstone. ❃

Further Reading

A detailed description of the geology of Mammoth Hot Springs can be found in: Keith E. Barger, 1978, *Geology and Thermal history of Mammoth Hot Springs, Yellowstone National Park, Wyoming*, Geological Survey Bulletin 1444. A copy of the student report, Margaret H. Allen et al., 1997, *Ground-Penetrating Radar Study of the Mail Carrier's Cabin Area, Mammoth Hot Springs, Yellowstone National Park*, is at the Yellowstone National Park research library.

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Marvin A. Speece is associate professor of geophysical engineering at Montana Tech of the University of Montana in Butte. He first visited Yellowstone National Park in 1981 during his undergraduate summer geology field camp. During that visit, Marvin most recalls a long, forced march to the top of Specimen Ridge to look at fossilized tree stumps. He began research in Yellowstone in 1995 with a geophysical study of the Soda Butte Creek drainage, and hopes to keep visiting Yellowstone for research—and pleasure—for many years to come.

Laura E. Joss is Chief of the Branch of Cultural Resources for the park. She received a B.A. in anthropology from Indiana University and an M.A. in museum studies from the Cooperstown graduate program at the State University of New York College at Oneonta. Previously, she was the NPS Rocky Mountain regional curator, and also worked at Glen Canyon National Recreation Area and Mesa Verde National Park. At Yellowstone, Laura enjoys the opportunity to create partnerships between cultural resource management and research disciplines for the mutual benefit of both.

Laura Joss, Marvin Speece, and Stuart Coleman conducting GPR tests. The Mail Carrier's Cabin is in the background.

The Ecological Role of Coyotes on Yellowstone's Northern Range

by Robert L. Crabtree
and Jennifer W. Sheldon

Adolph Murie's pioneering work on the ecology of coyotes (*Canis latrans*) in Yellowstone National Park, published in 1940, was a landmark of predator research in North America. By the late 1980s, biologists had undertaken long-term studies of other ungulate-killing carnivores such as grizzly bears and mountain lions, but not coyotes. In response to the fires of 1988 and in anticipation of gray wolf restoration, we undertook an intensive long-term study of coyotes on the northern range of Yellowstone National Park (YNP). From loose pairs to packs of 10 individuals, the coyote displays many of the behavioral characteristics seen among the 35 species within the family Canidae. Coyotes are an instructive group with which to examine the community structure of carnivores because of their variable social behavior, wide distribution, and ability to thrive in diverse environments.

Carol Polich

History and Background

Coyotes, wolves, and red foxes all occur naturally in the greater Yellowstone ecosystem (GYE) and the northern range of the park. Schullery and Whittlesey (1992), who reviewed historical records of canids prior to 1890, found that while sightings of wolves and fox were common, coyote sightings were rather infrequent. Although this could be in part because coyotes were classified as wolves, several park officials were very adept at distinguishing species, even color morphs of red foxes. The lack of coyote sightings is in sharp contrast to the recorded take of predators from 1906 to 1927, when the last wolves were extirpated from the northern range. While 127 wolves and 134 mountain lions were killed, a staggering 4,352 coyote mortalities were recorded. Could wolves have suppressed coyote numbers? When released from wolf pressure, could coyotes have quickly rebounded?

To address these questions and others regarding fire, weather, prey relations, and potential competitive interactions, an intensive study was needed—one that described and quantified the basic ecological role of coyotes in YNP.

Our Study Begins

We initiated studies of the coyote on Yellowstone's northern range in 1989, six years prior to wolf restoration. Two study areas, the Lamar Valley and Blacktail Plateau, were chosen because of their differential patterns of burn from the 1988

Mark Johnson

Y.E.S.

Left: Jennifer Sheldon returns a coyote pup to its den after capture. Right: Jennifer Sheldon and Bob Crabtree simultaneously radiotrack coyotes and wolves in Lamar Valley.

fires, and because their topography allowed direct observation of coyote behavior in addition to use of fixed station radio-telemetry. Our goal was to maintain one to three radio-tagged adults in all territorial packs in both study areas in order to investigate spatial organization, estimate social class-specific demographic parameters (e.g., survival and reproduction), and enhance behavioral observations. Analysis of territoriality as well as the social and spatial system of coyotes requires identification of all coyotes in a given area (Moorcroft et al. 1999). Adult coyotes were captured with padded, offset, leg-hold traps that had attached tranquilizer tabs and other modifications to minimize injury and capture of non-target species. Coyote abundance was determined from mark-recapture estimates and direct counts (Crabtree et al. 1989).

We collected data on the sex, weight, condition, dentition, presence of scars and unique marks, and description of mammae for each coyote captured. To estimate age, we extracted the vestigial first premolar from an anaesthetized lower jaw. Blood samples were taken for serological analysis and DNA fingerprinting. Each adult coyote was ear-marked and fitted with a radio collar (functional for three to four years) that weighed less than 3 percent of each coyote's body weight. The proportion of breeding females in the population was estimated from activity and movement data during whelping. Litter size was determined from den counts and by counting embryos from female carcasses. Pups were hand-captured at dens when 9 to 12 weeks old and surgically implanted with intraperitoneal radio-transmitters to allow estimates of early pup mortality, dispersal, and social interactions. Pups were intensively monitored during the summer months, the period of highest neonatal mortality, and later followed for as long as they were on the study area.

Both marked and unmarked coyotes were intensively observed in the Lamar study area with the aid of spotting scopes and radiotelemetry. Behavioral data (Gese et al. 1996a) were recorded on a hand-held computer and locational data was mapped. Behavioral time budgets were developed from systematic observations made from hillsides located throughout the Lamar Valley. In the Blacktail study area, radio-tagged coyotes were intensively radiotracked but were not readily observed because of the undulating topography. Pack size was determined by repeateds counts of known adults during winter. Effective group size (or social cohesiveness) was determined from the number of adult coyotes seen traveling together during morning transects.

Estimates of the annual biomass in take of various prey species by coyotes were primarily based on scat analysis. Scats were collected from predetermined transects in both the Lamar and Blacktail areas during winter, spring, summer, and fall collection periods, and seasonal estimates of the fresh weight of prey consumed took into consideration the different rates at which different types of prey are digested by the coyote. A concurrent study of small mammal communities done from 1990 to 1994 provided estimates of availability and overall predation rates on small mammal prey.

Prior to the restoration of wolves we captured and radiotagged 67 adult coyotes and 62 pups between the fall of 1989 and spring of 1993. Adults were monitored seasonally for a total of more than 200 coyote-years. An additional 37 adult coyotes without collars were monitored in the Lamar Valley. The natural distinguishing marks of their pelage made individual identification and observation a viable study method.

The Social System of Coyotes

Coyotes exhibit a well-defined social system similar to that of gray wolves. Coyote packs on the northern range averaged six adults each during the winters of 1990–95, before wolves were reintroduced (Fig. 1). In 1993, the Bison Peak pack in the Lamar Valley included 10 adults plus a double litter, with two mothers producing a total of 12 pups. Coyote packs this large had not previously been described; however, nearly all other field studies have been conducted on coyote populations subjected to substantial levels of human exploitation, which signifi-

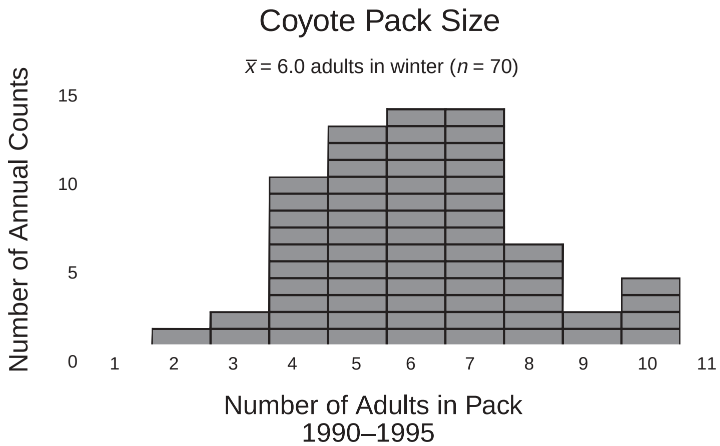

Figure 1. Prior to wolf reintroduction, coyote packs on the northern range had an estimated average of six adults each.

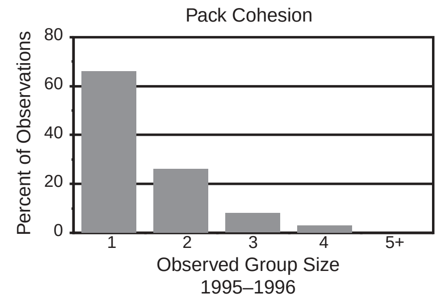

Figure 2. Unlike wolves, coyote pack members often travel alone.

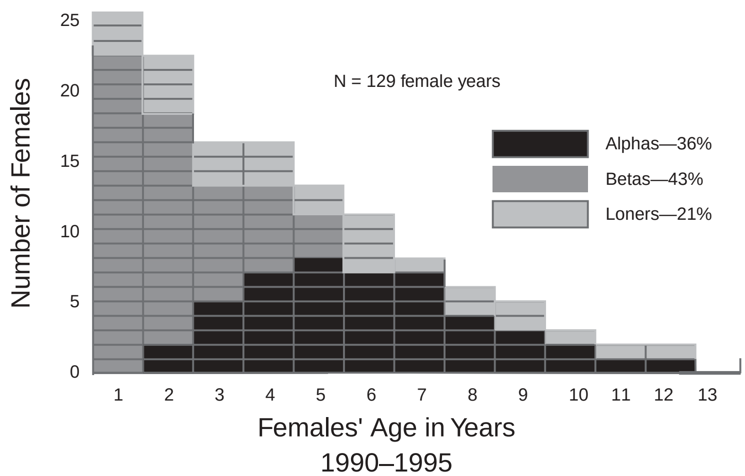

Figure 3. Estimated age distribution of female coyotes on the northern range.

cantly lowers pack size, and this has biased assumptions made about coyote demography and social behavior. The reason for such large packs in Yellowstone is related to the abundant prey (rodents and carcasses) and the fact the Yellowstone coyotes are protected from hunting and trapping. Research in Yellowstone and other protected areas (Crabtree 1989) has resulted in the coyote being viewed as a social canid similar to other medium and large-sized canids elsewhere in the world (Sheldon 1992).

Similar to gray wolves, coyotes live in territorial packs that consist of a dominant "alpha" breeding pair and subordinates, or "betas"—pups born in the current or previous years. Of the 104 adult coyotes we monitored, 88 percent belonged to packs; 30 percent were alphas and 58 percent were betas. Some betas were considered "slouches" because they did not help raise their younger siblings at the den. And although coyote pack members occupy the same territory and socialize often, they rarely travel all together. We found that 65 percent of our coyote observations on the northern range were of single coyotes (Fig. 2).

The remaining 12 percent of the coyotes residing in our study area were loners that did not belong to a pack and occupied the periphery of or spaces between territories. More than 85 percent of the loners were generally considered "nomads," usually young coyotes who had low site fidelity and ranged over large areas from 50 to 300 km^2, presumably in search of a mate and a territorial vacancy. The other loners, considered "solitary residents," were either "floaters" or former alphas. The floaters tended to be younger, age 1 to 3 years, showed weak fidelity to an area, and ranged over a larger area than the former alphas; they spent substantial time on the periphery of several territories and were suspected of being outcasts of one of the adjacent territories. Former alphas were age 3.5 to 11.5 years, and often had head and facial scars.

Reproduction

The average age of the coyotes we captured (excluding pups in the fall) was 3.8 years, the oldest average age yet reported in a field study. Even though females are physiologically capable of breeding by 10 months of age, especially in hunted or trapped populations, we found that with few exceptions, only the alphas (about 36 percent of the females in the study population, Fig. 3) successfully reproduced. Female coyotes have one estrous period each year, and the alphas generally mate in early February. In lightly exploited or unexploited areas like Yellowstone, females attain alpha status and

Carol Polich

initiate reproduction at 2 to 5 years of age. We found that the probability of a successful litter decreased starting around age seven. Although they failed to reproduce 14 percent of the time and sometimes lost entire litters shortly after birth, older alpha females still defended their territories and retained their alpha status.

Pregnant females begin to prepare for birth in late March and typically excavate two or three den sites originally dug by badgers. Alpha males are very attentive at this time and will bring food to their pregnant mates. Birth, or "whelping," occurs in early April, when females spend the first week almost entirely underground, frequently nursing and grooming their pups. Other pack members guard the den site from enemies—bears, eagles, wolves, and other coyote packs. The pups are nursed exclusively by their mother until about mid-May, when they first emerge from their dens. At this time, the alpha male and beta pack members increase their guarding behavior and begin to regurgitate food for the pups.

Prior to wolf restoration, den emergence counts in late May averaged 4.4 pups per territory (Fig.4). However, indirect evidence suggested that approximately one pup per litter was lost in the first month after birth, resulting in an estimated litter size of 5.4 pups per territory at birth. Average annual litter size per territory varied greatly, from 2.6 pups per territory in 1994 to 6.9 pups in 1992. This is the greatest variation yet reported in a coyote population not affected by human exploitation. The sex ratio of pups, determined in June at the time of capture, was 34 males to 28 females.

Similar to wolves, coyote packs occasionally produce a double litter. We have observed this five times in Yellowstone and estimate that double litters occur about 5 percent of the time. In one case, an 11-year-old alpha female had seven pups together with her daughter, a 2-year-old beta who had a litter of five pups. All pups were communally nursed and reared. The beta had been a den helper the previous year and appeared closely associated with her alpha mother.

When Hatier (1995) examined the role of helping behavior in 1992 and 1993, she found that in larger packs—those with more betas—more food was brought to the den and the breeding alpha pair spent significantly less time guarding it. Although an increase in the number of feedings (presumably because there were more betas) was significantly correlated with larger litter size, the overall pack size was not positively correlated with litter size or litter survival. Hatier suggested that these data support the contention that betas were tolerated by the alphas because they relieved the stress of reproduction (feeding and guarding) and because there were abundant food resources to support them.

Pup Survival

High neonatal pup mortality was observed from mid-June through mid-August each year. The summer survival rate, estimated from 62 radio-tagged pups captured each June 1990-1993, averaged 30 percent. The fall survival rate was much higher—85 percent of the pups that survived the summer were still alive in the fall. Thus, given the average litter size of 4.4 pups emerging from the den, the average overall population productivity was only 1.5 pups surviving per pack per year.

The principal causes of pup mortality were disease and starvation, which occurred immediately after pup weaning in July and August. Examination of 18 pups recovered shortly after death revealed acute enteritis, a condition associated with an active parvovirus infection. Live parvovirus was cultured from tissue samples taken from one pup just after its death, which was associated with extended periods during which the maximum daily temperature reached 85° F or higher. Although the cause of death could not be determined for another 11 pups recovered at various stages of decomposition, all but one were found in or near water or a moist, shaded area, as were all of the 18 pups examined shortly after death. Pups infected with parvovirus become severely dehydrated and travel to water or wet shaded areas. Based on disease investigations by veterinarian Mark Johnson, and given the highly infectious nature of parvovirus, we suspect that all pups in an affected litter become infected; only the strongest (probably dominant) pups survive.

During the pre-wolf period (1990–1995), if a coyote pup survived for four months, its chances of becoming a mature adult were good. The overall annual survival rate for adult coyotes on the northern range was 91 percent and did not differ significantly between years. The

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Coyote pups first emerge from dens in mid-May when five-weeks old.

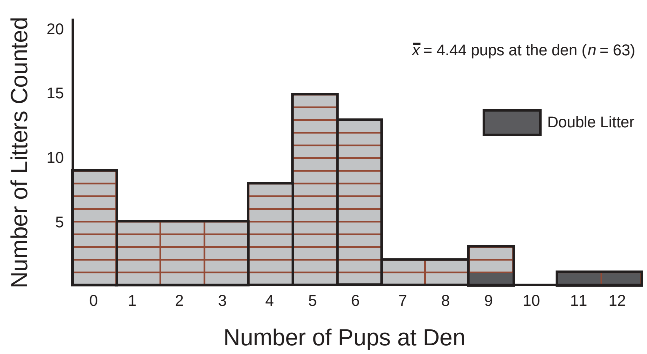

Figure 4. Estimated litter size when pups emerged from den, 1990–1995. Litter size is highly variable on the northern range.

causes of 12 adult mortalities were: mountain lions (4); vehicle (4); and unknown but natural causes (4).

Population Density and Territory Size

Coyotes inhabit all vegetation communities below 8,000' in the GYE except for areas of contiguous deep snow and steep rocky areas. The estimated density of adult coyotes on the northern range averaged 0.45 per km². In the open shrub-steppe and mesic grasslands of the GYE, coyotes can reach densities exceeding 1.0 per km². This estimate is based on both a direct count and an indirect estimate using a method developed by Crabtree (1989) that utilizes the ratio of marked to unmarked scats collected on transects. However, across much of the forested habitat of the GYE, densities range from 0.1 to 0.4 coyotes per km².

The coyote territories we identified on the northern range prior to wolf reintroduction (Fig. 5) were contiguous, non-overlapping areas of 7 to 12 km² (mean = 10.1). Coyotes defended their territories by vocalization, physical presence, and scent-marking (urine and feces). Observations of scent-marking and territorial defense indicated relatively little if any overlap between groups. Territory size and shape are a function of many factors including prey availability, coyote pack size, and the presence of neighboring packs.

The boundaries of territories in the Lamar Valley and Blacktail Plateau areas were extremely stable from 1990 to 1995. Only four boundary shifts occurred over 93 territory-years, and none lasted more than one year. Two of the shifts involved territorial reductions associated with loss of an alpha; the new territorial area still included over 50 percent of the original area. The other two shifts appeared to be associated with access to prime vole habitat when vole numbers were high. Five of seven coyote denning areas found by Robinson and Cummings (1951) on the northern range in 1946–49 were in the same location in 1990–93.

These data, combined with the slow turnover of alpha pairs residing in a territory (average = 6 years) and the consistency of their diet more than 50 years (Table 1), suggest that coyotes invaded suitable habitats vacated by extirpated gray wolves and that the location and number of their territories remained stable until wolves returned in 1995.

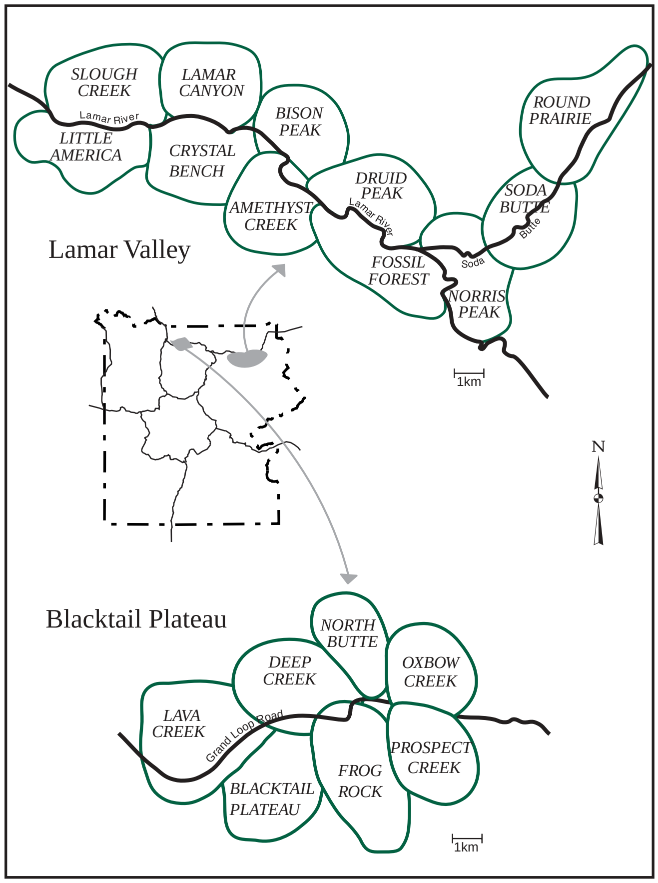

Figure 5. Location of coyote territories in the two study areas on the northern range prior to wolf reintroduction (1990–1995).

Overall dispersal rates in Yellowstone were low compared to other studies. The mean annual dispersal rate was 22 percent for pups and 16 percent for pack members (only subordinate betas dispersed). Movement of radio-tagged juveniles in Yellowstone indicated that some juveniles dispersed in fall or early winter but returned to their natal territories later in the winter or in the spring before whelping. Delayed dispersal may have been the result of habitat saturation—no territorial vacancies were available for dispersing juveniles.

Food Habits

The two most important coyote food items in our study areas were microtines (voles) and carcasses, mostly elk (Fig. 6). Nearly 50 percent of the coyotes' annual biomass intake came from small mammals. In the seven non-winter months, voles, pocket gophers, ground squirrels, and snowshoe hares made up 41, 25, 3, and 4 percent of prey biomass consumed, respectively, compared to, an estimated 26 percent during the five winter months

Table 1. Coyote food habits.

Prey Species	% of coyote diet Murie 1940	% of coyote diet This study 1995
Microtus spp.	42.4	41.3
Pocket gopher	27.0	24.5
Ground squirrel	0.6	3.0
Snowshoe hare	4.3	4.4
Elk	20.3	21.2

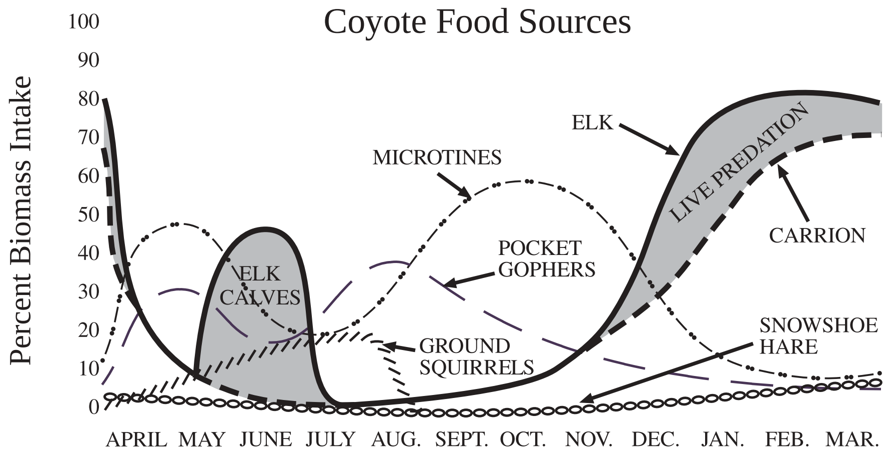

Figure 6. The two most important coyote food sources are microtines (voles) and elk carrion (1990–1995).

from all small mammal prey, mostly voles. Voles were primarily utilized from the early spring snowmelt period until early to mid-winter, after which dense snow prevented coyotes from capturing them (Gese et al. 1996a).

About 45 percent of the coyotes' annual biomass intake came from ungulates. During the five winter months, an estimated 74 percent came from elk, primarily carrion. Carcasses were used only from mid to late winter, except in habitats where coyotes could displace mountain lions from their ungulate kills (Murphy 1998). In the non-winter months, elk (calves and carrion) made up 21 percent of prey biomass consumed.

Prior to wolf reintroduction, coyotes were the major elk predator on the northern range, killing an estimated 1,276 elk annually (Table 2). The coyote population accomplished this not by specialization, but by sheer numbers (n = 450). They also exhibited a propensity for killing, mostly young neonates in June (an estimated 750 annually). A major impetus for this is the availability of prey during May, June, and July when coyote pups are growing rapidly. In Yellowstone, we commonly found elk calf remains at coyote den sites. Coyotes may also inflict heavy predation (>80%) on radio-tagged antelope fawns (D. Scott 1994, pers. commun.).

Coyotes usually kill ungulates that are weak, impaired, domesticated, or starving, but occasionally can kill healthy adult ungulates, even elk. We recorded 26 coyote predation attempts in the Lamar Valley from 1990 to 1995, and detailed observations of nine of these attempts on both adult and younger (<5 months) deer and elk during the winter were reported by Gese and Grothe (1995). Successful attacks were related to deeper snow, and nearly all attacks were led by the alpha male. Two or three adults participated, while the remainder of the pack watched or was absent (mean pack size was 6.7 adults), yet most pack members fed on both preyed upon and winter-killed ungulates (S. Grothe, unpubl. data).

Although coyotes are capable of killing healthy adult elk during winter, Gese and Grothe found that they seldom do so. In comparison, mountain lions—specialized obligate ungulate predators—kill around 600 elk (and only 35 neonates) on the northern range each year (Murphy 1998). Grizzlies kill an estimated 750 neonates and a few adults (B. Blanchard, pers. commun.)

Ecological Relationships Between Coyotes and Prey Species

Despite major differences in carcass and vole biomass during the 1990–95 period, there was little change in coyote numbers, which varied between 42 and 58 individuals among the seven packs intensively monitored in the Lamar Valley. But individual pack sizes did correspond to prey abundance.

Analysis on a per territory basis in the Lamar Valley revealed vole biomass to be a significant predictor of coyote pack size (r^2 = 0.34, p = 0.035) and a factor affecting litter size. In wet years, vole biomass is very low in the extensive mesic grasslands due to the effect of flooding on reproducing adults (Johnson and Crabtree 1999). In dry years, vole biomass is relatively high in these dense grass floodplain habitats but low in upland grasslands. Although the relationship between annual litter size and vole populations was marginally significant (p = 0.07), packs that had low vole numbers due to flooding had significantly lower litter sizes (p = 0.02).

Table 2. Yellowstone ungulate predators.

		Elk Population						
Species	Estimated Number	Neonate Calves	Yearlings	Adults Winter	Adults Non-Winter	Total	Biomass	Per Capita Kill Rate
Mountain Lion (a)	17	35	313	70	193	611	76,150	36
Grizzly Bear (b)	60	750 (b)	0	0	Few	750	13,500	13
Coyote (c)	450	750 (b)	360–626	20–35	0	1,276	66,760	3

(a) Kerry Murphy, Hornocker Wildlife Institute.
(b) Francis Singer, Biological Resources Division, USGS.
(c) This study, projected estimates.

Table 3. Short-term (4 and 5 years after) and predicted long-term (11 to 50 years) effects of the 1988 fires on small mammal prey abundance on the northern range of Yellowstone National Park, Wyoming.

Species	Burned Sagebrush Short-term	Burned Forest Long-term	Short-term	Long-term
Uinta ground squirrel	18x increase	Increase	—	—-
No. pocket gopher	4x increase	Increase	2x increase	Increase
Microtus spp.	4x increase	Increase	Slight increase	Unchanged
Red-backed vole	—	—	3x increase	Increase
Sorex spp.	14x increase	Increase	3x increase	Increase
Snowshoe hare	—	—	Decrease	Major increase

Carcass availability was primarily a function of winter severity and had a profound influence on coyote demography. The number of winter-killed elk in a territory was a significant predictor of the pack's litter size the following spring ($p = 0.015$). Furthermore, in severe winters, larger packs took advantage of all the available carrion and had both larger litters and higher pup survival rates (Crabtree and Varley 1999).

As previously stated, the number, size, configuration, and location of territories were relatively constant. In a habitat-saturated area like the northern range, there was little if any room to adjust territory size in relation to the availability and abundance of prey. Rather, adjustments to varying prey abundance came in the form of changes in litter size, pack size, and dispersal within the confines of stationary territories.

We detected no effects of elk seasonal movements on coyote behavior or population demography. Mule deer occurred at such low densities that any changes in their numbers would be undetectable. However, no significant effects of mule deer would be expected because coyotes rarely utilize them as a prey source; their remains were not observed in the examination of over 500 coyote scats.

Fire Impacts on Coyotes

After the 1988 fires, the portion of burned area in the 12 coyote territories examined ranged from 0 to 52 percent, providing a gradient of burn levels with which to study burn effects on coyotes. Demographic factors like pack and litter size were not significantly affected by burn level. However, coyotes may have benefited indirectly from the fires by having an increased prey base. Several important small mammal prey species (voles and ground squirrels) were more abundant in burned than in unburned habitats during 1992 and 1993 (Table 3). Because the numbers of voles, and possibly ground squirrels, were significantly related to coyote pack size and probably litter size, we can infer that the 1998 fires were advantageous to the coyote population.

Pack Size and Population Regulation

For the years prior to wolf colonization (1990–95), we divided the data on coyote prey abundance into two fairly distinct categories for analysis: years when food was abundant (1991, 1992, and 1994 in the Blacktail Plateau only, where floods did not affect vole numbers), and years when food levels were low (1990, 1993, 1994 in the Lamar Valley due to floods, and 1995). In good food years, carrying capacity within the coyote territory exceeded pack size and the number of adult pack members contributed directly to litter size and pup survival. However, because virtually all food consumed by a pack came from within its territory, in low food years the packs may have exceeded territorial carrying capacity, and pack size was negatively correlated with both litter size and pup survival.

The evolution of packs, or sociality, has been attributed to the increased foraging efficiency made possible by pack membership, but this relationship remains unclear. We found no empirical evidence that larger coyote groups have a larger per capita food intake, thus improving fitness. In fact, single individuals and

Jennifer Sheldon

The Druid coyote pack feeds on an elk carcass. Alpha female 620 (left) was killed by the Druid wolves on November 25, 1999.

Monty Dewald

Druid female wolf 42 chases Little America alpha female coyote 440. She escaped after being bitten.

groups of two coyotes commonly killed both deer and elk in Yellowstone (Gese and Grothe 1995), and dominant coyotes tended to monopolize feeding time on both preyed-upon and winter-killed ungulate carcasses (Gese et al. 1996b). Defense of the carcass appeared to be primarily the role of the dominant alpha male.

Coyote populations are regulated by factors other than prey abundance: territoriality, dominance hierarchy (exclusive breeding by the alpha pair), shortened breeding tenure, subordinate dispersal, delayed dispersal, reproductive failure, double-littering, and early and late summer pup mortality. Most studies indicate direct or indirect evidence of intraspecific competition, especially in unexploited and habitat-saturated populations, as evidenced by low pup weights, scarring, reproductive failure, frequent territorial disputes, and high pup mortality, including the probable loss of entire litters shortly after birth. The abundance and availability of prey is certainly a major limiting factor, but the extent to which it is involved in population regulation remains uncertain.

The Return of Wolves: Changing the Coyotes' World?

Prior to wolf restoration, between 85 and 90 percent of the northern range coyote population existed in packs and average pack size was high. The extirpation of gray wolves probably permitted higher coyote population densities, and coyotes at least partially slid into the niche left vacant. This could account for two key findings of this study: coyotes were a major elk predator, and they consumed a very high percentage of the available small mammal prey, probably to the detriment of other small mammal predators.

Since the restoration of gray wolves in 1995, the ecological role of the coyote has already shifted numerically, functionally, and behaviorally. The gray wolf is a much larger animal—the average adult weight of the males brought from Canada was 111 pounds, and for the females, 94 pounds, while adult coyotes examined on the northern range have weighed an average of about 30 pounds for males and 26 pounds for females. So far, gray wolves have inflicted heavy mortality on coyotes (Crabtree and Sheldon 1996), killing from 25 to 33 percent of the coyote population each winter, especially in the wolves' core-use areas. In over 200 coyote-wolf interactions observed since 1995, we have witnessed wolves killing coyotes 23 times. The sex and age structure of both these coyotes and others that were probably killed by wolves, suggests that wolf killing is opportunistic, with a possible bias toward younger coyotes. Of the 34 coyote carcasses we recovered, 20 were fairly intact (scavengers hadn't yet fed on them) and close examination revealed that the deaths had been caused by severe bites to the chest area resulting in broken ribs and internal bleeding. All but one death occurred in relation to scavenging behavior at wolf-killed elk carcasses.

When the wolves were released in 1995, the Lamar Valley was populated by 80 coyotes in 12 packs with an average pack size of 6; by 1998, the count had dropped to 36 coyotes in 9 packs with an average pack size of 3.8. Based on this data, it appears that the killing of coyotes by wolves during the winters of 1996–97 and 1997–98 resulted in a 50 percent reduction in coyote numbers and significantly reduced pack size on the northern range, without subsequent recolonization of traditional coyote territories. Coyote packs in this core area of wolf territories either disappeared or were in a constant state of social and spatial chaos. In 1998, only one pack of three coyotes and a handful of transients occupied the core area of the Druid wolf pack, along lower Soda Butte Creek where it joins the Lamar River. Before wolves, there had been four packs totaling about 30 coyotes.

But there seems to be safety in numbers. Prior to wolf restoration, coyotes normally traveled singly or occasionally in groups of two or three; now they are now much more cohesive and tend to travel with most of their pack—we have observed traveling groups as large as nine. Packs on the fringe of wolf territories, which are fairing better, number from six to ten individuals and have experienced little mortality, yet they are close enough to effectively scavenge wolf kills.

When coyotes outnumber a single wolf or pair of wolves, the tables can turn. Coyotes have chased and even attacked individual wolves and wolf pups. When a pack of three or more coyotes encounter a single wolf feeding on kill, the coyotes may occasionally harass the wolf and chase it off. When coyote and wolf groups of similar size (3 to 6 animals) encounter each other, they may watch each other closely and sometimes engage in a battle. Occasionally groups of wolves will chase groups of coyotes; we have witnessed a lot of growling and occasional nipping, but no serious contact or death.

At least six coyote dens were partially excavated by wolves, and the coyotes responded by denning in or under large rocks and moving their dens away from areas frequented by wolves. Placing dens farther from preferred foraging areas could increase the effort required of adult pack members to feed the pups. However, this negative effect is being offset; some of the surviving coyote packs are smaller in size and are producing, on average, heavier pups with higher survival rates.

These changes could have major ripple effects on both the coyotes' competitors and their prey species. Fighting, killing, chasing, and relegation to inferior habitats has been clearly demonstrated between coyotes and wolves (Crabtree and Sheldon, in press). Yet wolves, coyotes, and even red foxes continue to coexist in the Northern Rockies. We believe that the coyote's behavioral plasticity and demographic resiliency to exploitation is an evolutionary product of coexisting with competing species, mainly the gray wolf. Since wolves have returned to Yellowstone, coyote populations have become wiser and more wary. They certainly will survive, and will very likely continue to outnumber wolves. We believe that conservation science can learn important lessons from long-term studies of a successful, ubiquitous species like the coyote in unexploited populations such as exist on Yellowstone's northern range. We hope to continue our studies post-wolf to provide such understanding.

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Jennifer Sheldon is currently a research fellow and lead project biologist of Y.E.S.'s Coyote Ecology Project. She is also a Ph.D. student at Montana State University, where she is examining the effects of gray wolves on coyote demography and social behavior. She received her M.S. degree at Colorado State University studying canid behavior. In 1992, she published the book, Wild Dogs: The Natural History of the Nondomestic Canidae.

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Yellowstone Author Receives Stegner Award

Marsha Karle

Paul Schullery, a writer who lives and works in Yellowstone National Park, was recently awarded the prestigious Wallace Stegner Award from the University of Colorado's Center of the American West. The award recognizes an individual or individuals who have made a sustained contribution to the cultural identity of the American West through literature, art, history, or lore. Schullery is the author, co-author, or editor of 28 books, including *The Bears of Yellowstone*, *Mountain Time*, *Searching for Yellowstone: Ecology and Wonder in the Last Wilderness*, *American Fly Fishing: A History*, and *Royal Coachman: The Lore and Legends of Fly Fishing*. At various times since 1972, Schullery has worked in the park as a ranger-naturalist, archivist-historian, chief of cultural resources, and senior editor. He is also the former executive director of the American Museum of Fly Fishing in Manchester, Vermont. Schullery is an affiliate professor of history at Montana State University and an adjunct professor of American Studies at the University of Wyoming.

Park to Clean with "Green" Products

Yellowstone is apparently the first park in the country to adopt a new policy to replace existing cleaning and janitorial products used by park and concessioner personnel with environmentally preferable products. In August 1998, the Environmental Protection Agency hired a consulting firm from Jackson Hole, Wyoming, to assess the park's present line of cleaning products. This firm was instrumental in the helping other customers, including the Signal Mountain Lodge Company in Grand Teton National Park and the city of Santa Monica, California, convert to "green" products. The firm concluded that the products used in Yellowstone ranged from some with slightly toxic ingredients to those with potentially significant health hazards. Park concession operations were included in the assessment.

In September of 1998, the park removed cleaning products used in the Old Faithful and Mammoth areas and began to test the use of green janitorial products. Custodial staff were pleased with the results, and with the fact that employee health hazards have dramatically decreased. In January 1999 the park decided to proceed with a parkwide product conversion. The new products will also save the park money and reduce source pollution. Park managers hope that other parks and businesses will convert to the use of greener products.

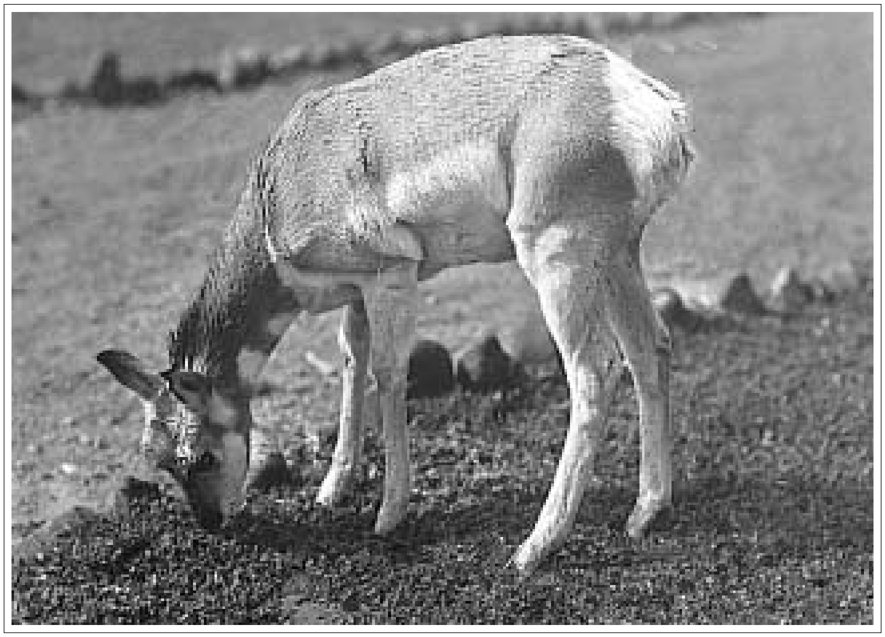
Oral History Project Underway

Two cultural resources assistants are working on an oral history of ungulate management in Yellowstone. They will interview former park employees who worked with and helped plan this major part of the park's wildlife management program. Through the 1960s, park rangers spent a considerable amount of time feeding, herding, and rounding up elk, bison, and pronghorn for transport to other lands. Park staff also participated in direct reductions of the herds to meet management objectives of the day. Since many of the animals determined to be "surplus" to the park's needs were shipped to Indian reservations, project personnel also hope to interview some American Indian representatives from affiliated tribes that hunted ungulates in the Yellowstone area in the past.

Bioprospecting Agreement on Hold

A recent decision by a federal judge presents a temporary setback for Yellowstone's bioprospecting agreement with Diversa, Inc. The agreement, the first of its kind in the NPS, was designed

Left: Elk being released from trucks at Crow agency, Montana, in 1938. Below: Elk on feed ground at Lower Slough Creek in 1926. NPS photos.



Young pronghorn. NPS photo.

to allow the park to recoup some financial benefit from the potentially valuable commercial products that result from research sampling in Yellowstone—an activity that requires only that collectors obtain a free permit to conduct their studies. The plaintiffs, Edmunds Institute, Alliance for the Wild Rockies, International Center for Technology Assessment, and Phil Knight, had charged that the park failed to conduct an environmental assessment and solicit public input on the effects of the agreement; they also sought to reveal the financial details of the bioprospecting agreement. The government contended that research data collection had negligible environmental effect and granting research permits were a routine activity categorically excluded from further environmental compliance. Their position was also that the financial details of the agreement are protected by law. As a result of the court decision, the park expects to prepare an environmental assessment on bioprospecting and continue with attempts to ensure that taxpayers and park resources receive a more direct benefit from research sampling done in Yellowstone.

Pronghorn Numbers Remain Low

On March 25, 1999, Yellowstone National Park biologists conducting the annual aerial census of the northern Yellowstone pronghorn herd counted 204, compared to 231 observed in the April 1998 survey. The spring count, conducted under the auspices of the Northern Yellowstone Cooperative Wildlife Working Group, provides a minimum population estimate for the herd. Pronghorn numbers have declined from a high of 591 in 1991 to between 200 and 250 each year since 1995.

The cause of the population's decline is unknown, but its small size puts the pronghorn herd at risk. In February, 30 adult female pronghorn between Mammoth and Gardiner were collared for a three-year study conducted by the park with the University of Idaho to assess reproductive rates, nutritional condition, survivorship, and causes of mortality. Helicopter Capture Services, a private company specializing in wildlife captures, captured the animals using netguns. The pronghorn were fitted with radio-collars, and samples were taken for genetic testing, disease screening, and nutritional analysis. The radio-collared does will be located daily in the spring to determine fawning dates and litter sizes. Fawns of collared does will be hand-captured and marked to determine survival rates.

Other research projects are being considered to provide information about the factors limiting this population. The northern Yellowstone pronghorn herd summers primarily within the park and winters between Mammoth Hot Springs and Corwin Springs, Montana. Once part of a larger population extending north along the Yellowstone River valley to Livingston, Montana, the herd has been isolated since the 1920s, when pronghorns were almost extirpated through hunting north of the park.

Author, Long-time Geyser Gazer Dies

Park staff were saddened by the news that John S. Rinehart, scientist and author of *A Guide to Geyser Gazing*, died April 9, 1999, in Santa Fe, New Mexico. Rinehart, a physicist who received his Ph.D. from the State University of Iowa, received a Presidential Certificate of Merit for his development of the proximity fuse during World War II. He also devoted much time to the study of geysers and donated many important materials on this topic to the Yellowstone National Park archives. He is survived by his wife, Marion, who resides at El Castillo, 250 E. Alameda, Apt. 111, Sante Fe, New Mexico 875001.