YELLOWSTONE SCIENCE

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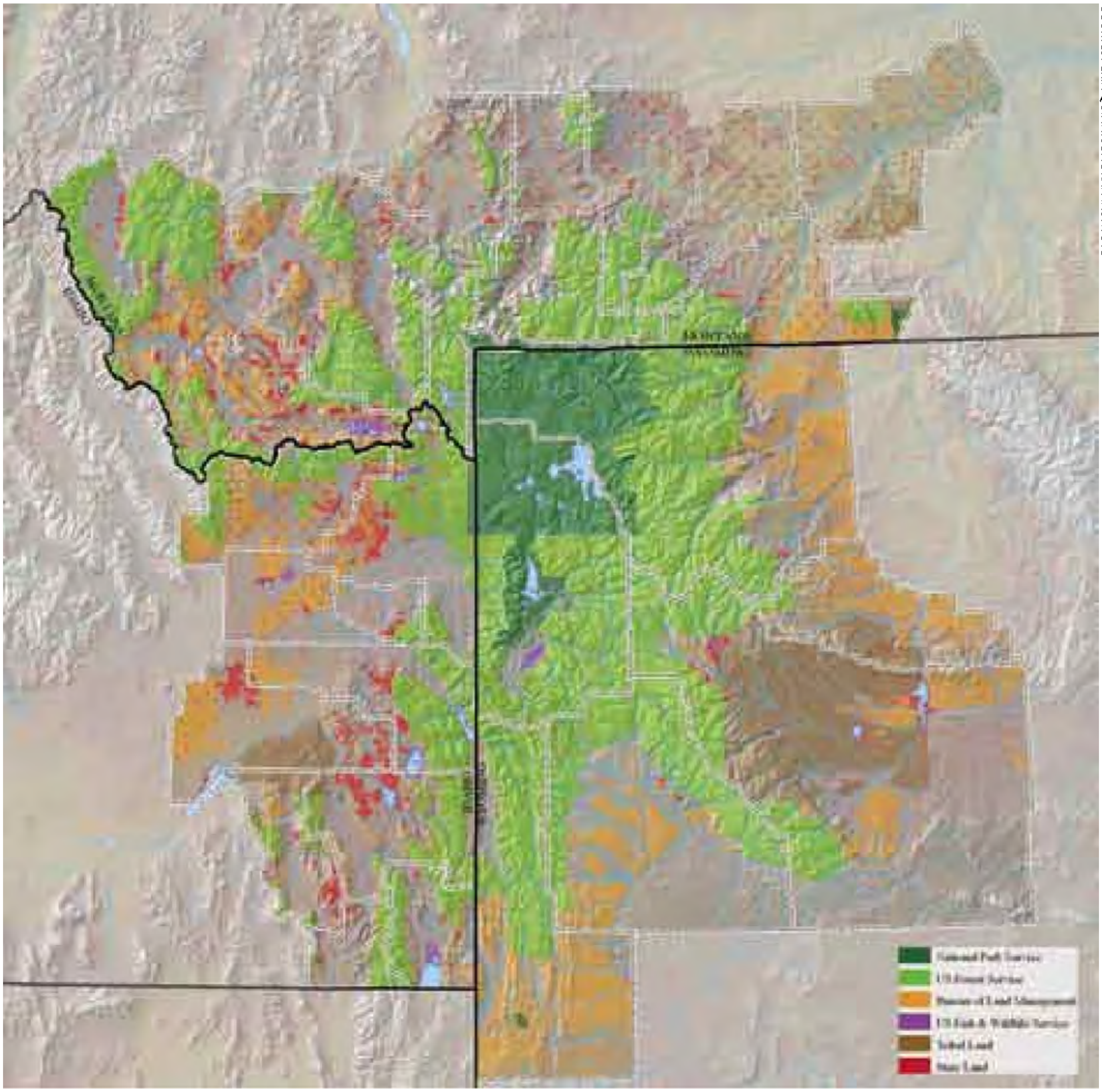
The Next West

Groomed Roads and Bison: The Gates Report

Thermophilic Fungi



COURTESY ERIN QUINN/SONORAN INSTITUTE

Marking Change

Yellowstone's 8th Biennial Scientific Conference on the Greater Yellowstone Ecosystem, *Greater Yellowstone Public Lands: A Century of Discovery, Hard Lessons, and Bright Prospects,* took place in October 2005. The conference was a thought-provoking and often inspiring opportunity for participants to discuss conservation in the twenty-first century. Dr. Charles R. Preston of the Buffalo Bill Historical Center in Cody, Wyoming, served as the conference's Program Committee Chair, and in this issue of *Yellowstone Science* he examines some of the changes taking place in the Greater Yellowstone Ecosystem (GYE). His article explores how people can work together to retain this area's natural amenities and the quality of life it offers, and why quick action is needed. Successful conservation efforts in the GYE will have to cross political boundaries. Mary Ann Franke's article delves into the findings of a new research report commissioned by park managers to determine the effects of road grooming in the park on bison movements. Also in this issue, we commemorate the life of U.S. Geological Survey scientist Francis J. Singer, two new books on wildlife conservation in the GYE are reviewed, and Joan Henson reports on fungi that may prove useful in the bioremediation of metal-contaminated soils. Change is often exciting, but brings new challenges with it. These are both exciting and challenging times to be involved in conservation in the Yellowstone area.

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Tami Blackford
Editor and Graphic Designer

Alice Wondrak Biel
Associate Editor

Virginia Warner
Photo Editor

Mary Ann Franke
Assistant Editor

Artcraft Printers, Inc.
Bozeman, Montana
Printer

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Submissions are welcome from all investigators conducting formal research in the Yellowstone area. To submit proposals for articles, to subscribe, or to send a letter to the editor, please write to the following address: Editor, *Yellowstone Science*, P.O. Box 168, Yellowstone National Park, WY 82190. You may also email: Tami_Blackford@nps.gov.

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on the cover

Clockwise from top right: grizzly bear, NPS/Jim Peaco; trumpeter swans, Erik Hendrickson; cyclists, NPS; sheep in the Beartooth Mountains, NPS.

NPS/JIM PEACO

Construction along the Yellowstone River north of Yellowstone National Park.

FEATURES

DEPARTMENTS

NEWS & NOTES


NPS/JIM PEACO

Yellowstone Grizzlies Proposed for Delisting

The U.S. Fish and Wildlife Service has proposed to remove the Yellowstone grizzly bear population from the list of threatened and endangered species. When the species was listed in 1975, only 220–320 bears remained in the ecosystem, and these animals were jeopardized by loss of habitat and high mortality from conflict with humans. Since the mid-1990s, the Yellowstone population has grown at a rate of 4–7% per year. Grizzlies have occupied 48% more habitat since they were listed, and biologists have sighted bears more than 60 miles from what was once thought to be the outer limits of their range.

The recovery of grizzly bears in the Yellowstone ecosystem is the result of intensive scientific research, state and federal cooperation to manage habitat and limit mortality, and the implementation of regulatory protections over more than three decades. However, biologists believe the Yellowstone area grizzly population and other remaining grizzly bear populations in the lower 48 states and Canada are markedly separate from each other, with no evidence of interaction with other populations.

The proposal to delist the Yellowstone population of grizzly bears was published in the Federal Register on November 17. The proposal can be found at <http://mountain-prairie.fws.gov/species/mammals/grizzly/yellowstone.htm>. The public can submit comments on the proposal to: Grizzly Bear Recovery Coordinator, U.S. Fish and Wildlife Service, University Hall 309, University of Montana, Missoula, Montana 59812. Comments can also be sent by electronic mail to FW6_grizzly_yellowstone@fws.gov. Comments must be received by February 15, 2006.

Montana Bison Hunt Begins

On November 15, 2005, a bison hunt began on State of Montana lands adjacent to Yellowstone National Park (YNP) for the first time since 1991, when the Montana legislature discontinued the hunt due to extensive negative publicity. The Montana Fish, Wildlife and Parks Commission approved the sale of 25 either-sex bison licenses for use between November 15 and January 15, 2006; and 25 either-sex licenses for use between January 16 and February 15, 2006. Sixteen of those licenses were allotted to Montana's American Indian tribes, and 10 licenses were awarded to the hunters drawn for last season's proposed hunt. About 6,000 Montanans and 200 nonresidents applied for the remaining 24 licenses. On October 11, 24 Montana residents were chosen.

The hunt, which is administered by Montana Fish, Wildlife and Parks (MTFWP), was carefully developed to: 1) provide opportunities for a "fair-chase" hunt; 2) provide for long-term conservation of the bison population; and 3) be consistent and compatible with the Interagency Bison Management Plan, which, it should be noted, does not require any cooperating agency to reduce the bison population in order to manage the risk of brucellosis transmission. The YNP bison population has grown to 4,900 animals, the highest recorded in recent years.

Hunters are able to pursue bison on more than 460,000 acres, or nearly 720 square miles of wildlife habitat available for bison near West Yellowstone and Gardiner. Bison hunters are required to attend special orientation sessions devoted to the unique aspects of hunting bison.

Draft *National Park Service Management Policies* Released for Public Review

On October 18, the National Park Service (NPS) released the much-anticipated proposed update of *NPS Management Policies*—the document that provides park managers with policy guidance to achieve the NPS mission to preserve park resources while providing for their enjoyment by present and future generations—for public comment.

NPS Management Policies has been reviewed and updated several times in the past, most recently in 2001. Among other things, the revised management policies provide new definitions of "unacceptable impacts" to resources and "appropriate uses" of parks; provide more flexibility and tools to park managers and recognize that each park has unique needs; recognize new challenges facing the NPS, such as Homeland Security; and provide guidance in response to changing recreation uses and technology.

To review and comment on the document, visit <http://nps.gov/waso>. An "official comparison" of the old and new policies is also available at <www.nps.gov/policy/mp/comparison.pdf>. There will be a 120-day public review and comment period for the proposed management policies; comments are due by February 18, 2006. Comments can also be submitted via e-mail to waso_policy@nps.gov or via surface mail to Bernard Fagan, National Park Service, Office of Policy-Room 7252, Main Interior Building, 1849 C Street, NW, Washington, D.C. 20240. For further information, contact Bernard Fagan at (202) 208-7456, or via e-mail at waso_policy@nps.gov.

Yellowstone Receives Propane Bottle Recycler

Yellowstone National Park can now recycle all small propane cylinders, thanks to the recent acquisition of a Propane Bottle Recycler (PBR). The PBR is the first of its kind, and was inspired by the realization that an estimated 3,000 cylinders, used by visitors to fuel such things as camp stoves, lanterns, and heaters, are annually discarded in the park. The cylinders were previously discarded into trash receptacles, returned to visitor centers, or left in campgrounds.

At the request of Yellowstone staff, WWW Industries of Billings, Montana, designed and manufactured the PBR, which is a mobile unit whose generator is fueled by the same propane that is extracted from the bottles and used to power the entire unit. The bottles are then punctured and flattened into scrap metal that can be redeemed as recycled steel. The unit is designed to process more than 1,000 cylinders daily. This innovation was developed and purchased through contributions by the Yellowstone Park Foundation, Grand Teton Lodge Company, Signal Mountain Lodge Company, Xanterra Parks & Resorts, Yellowstone General Stores (Delaware North Parks Services), Worthington Cylinders, Mountain States Environmental, REI, Amerigas, WWW Industries, and Grand Teton and Yellowstone national parks.

The PBR was developed to recycle one-pound propane cylinders, but can also handle smaller or larger cylinders. In addition, the PBR can recycle cylinders containing other gases such as isobutene and mat gas. Prior to the PBR development, it would have cost Yellowstone \$3.00–\$4.00 to recycle each discarded cylinder at an outside facility, for a total expense of approximately \$9,000–\$12,000 annually. Additionally, the refilling of one-pound propane cylinders is prohibited by law.

Currently, Yellowstone has propane cylinder recycling bins located at all major campgrounds throughout the park, as well as at all general stores. The unit will be made available to a host of public and private entities throughout the Greater Yellowstone Area, and will demonstrate how this national issue may be resolved.

NPS/JIM PEACO

An empty, crushed steel canister.

According to statistics compiled by WWW Industries, the U.S. alone consumes an estimated 40 million, one-pound propane bottles every year, occupying approximately 3.3 million cubic feet of space in landfills every year. The amount of steel from these discarded bottles could produce approximately 8,000 automobiles annually.

State and Federal Agencies Complete Five-Year Review of Bison Management Plan

A partnership of state and federal agencies (National Park Service, USDA Forest Service, USDA Animal and Plant Health Inspection Service, Montana Department of Livestock, and Montana Fish, Wildlife and Parks) that manage bison in and around Yellowstone National Park recently completed a five-year status review of the Interagency Bison Management Plan (IBMP), implemented in December 2000.

The review looked at the accomplishments to date and evaluated them against the adaptive management procedures outlined in the IBMP. As required by the IBMP, the review was done to determine if the goals of the IBMP are being met, evaluate the status of the objectives outlined in Step 1 of the plan over the first five years of operations, determine if those tasks have been completed, and assess whether the agencies can progress to the next step as outlined in the IBMP. Step 1 encompasses a set of 14 tasks, including cooperation among the five agencies, maintenance of spatial and temporal separation between cattle and bison, protection of private property, and conservation of wild, free-ranging bison.

A report on the status review confirms that the agencies are effectively working together and have met the main goals of the IBMP to keep bison and cattle separated, protect private property, and manage the bison population in a way that protects both Yellowstone's wild and free-roaming bison population and Montana's brucellosis-free status. The agencies are also cooperatively monitoring bison abundance and distribution, research has documented that the RB51 vaccine satisfies safety criteria for vaccination of eligible bison, and this has begun.

However, the report determined that the agencies are not yet ready to move to Step 2 of the IBMP. All 14 tasks in Step 1 must be completed before moving to Step 2. In addition, Step 2 in the West IBMP Management Area (IBMPMA) will begin when a safe and effective remote delivery mechanism is available and the state of Montana is in a position to implement a remote vaccination program there. Step 2 in the northern IBMPMA begins when cattle no longer graze private lands outside Yellowstone National Park on portions of lands known as the Royal Teton Ranch (RTR) in Zone 2 during the winter and when a bison management plan has been developed by the agencies in cooperation with RTR. The five state and federal agencies will continue to work together to accomplish the remaining Step 1 objectives, implement the basic goals of the IBMP, and focus on key adaptive management elements that will improve the agencies' ability to meet those goals.

Passages — Francis J. Singer

by Zack Bowen, Juliette Wilson, and Kate Schoenecker (USGS–Fort Collins Science Center), John Varley and Kerry Murphy (Yellowstone National Park)

NPS/DOUGLAS SMITH

Francis Singer, left, studying willows with park staff and researchers.

Francis J. Singer, 1949–2005

On September 21, 2005, Yellowstone National Park (YNP) lost a valued colleague and friend, Francis J. Singer of the U.S. Geological Survey (USGS)'s Fort Collins Science Center. Dr. Singer had just received his 30-year pin for federal service and was completing work in Yellowstone when the colon cancer he bravely fought for five years prevailed.

For the past 30 years, Dr. Singer dedicated his career to research for the Department of the Interior, primarily the National Park Service (NPS), in the field of ungulate ecology. His research spanned an array of topics, including the ecology and management of wild boar in the Smoky Mountains, causes for decline in the Denali caribou herd, effects of sport hunting on Dall sheep, resolution of human–ungulate conflicts, evaluation of the natural regulation of ungulates, studies of plant–ungulate interactions and ecological carrying capacity of elk in Rocky Mountain National Park, restoration of bighorn sheep in 15 national park units, and leadership of the USGS's Wild Horse and Burro Research Program. Dr. Singer was a prolific writer, known for spending hours at the library writing reports in longhand. Scores of published reports describe his work on 10 species of wild ungulates, as well as raptors, black bears, grizzlies, and wolves.

Dr. Singer built his career by accepting challenging positions in the states of Montana, Wyoming, Alaska, Tennessee, North Carolina, and Colorado; he worked with more than 24 different superintendents and numerous managers and directors in different bureaus. His work in all of these positions had consistent themes, including high-profile species, complex questions, contentious issues, difficult physical environments, and a commitment to providing the best possible products for public land managers.

Dr. Singer was responsible for initiating and conducting one of the largest research programs to date on plant–ungulate interactions. This work has helped guide management decisions, highlighted the concept of ecological carrying capacity, and advanced the science of ungulate–ecosystem interactions.

Dr. Singer's work on natural regulation of ungulates in Yellowstone, beginning in 1985, dealt with one of the most contentious management issues in the NPS. This effort exemplified his approach of bringing together world-class scientists and using an interdisciplinary team approach to work on complex and challenging questions. Frank, as his Yellowstone colleagues knew him, facilitated research by others such as Sam McNaughton and Douglas Frank. The collective work of Dr. Singer and these other scientists formed the basis of the National Academy of Science review, *Ecological Dynamics on Yellowstone's Northern Range*. This was an objective, national look at natural regulation and ungulate populations, and the related effects on woody vegetation, soils, and streams.

Frank had a profound effect on our understanding of science in Yellowstone. He taught park managers the importance of manipulative research (as opposed to the predominate "observational" variety) and that peer review is vital from the inception of a project through to its end. The importance, quality, and volume of his Yellowstone work on grazing, fire, and wolves earned him the NPS Director's Award for Science.

As Chief of the Herbivore–Ecosystem Interactions Project, Dr. Singer brought leadership and effective management that has been instrumental in facilitating the achievements of many fellow scientists. His legacy can be seen in real contributions to science, improved management of ungulates on public lands, the accomplishments of those he has mentored, and the success of the Fort Collins Science Center. Throughout his career, Dr. Singer's selfless dedication, analytical capabilities, and commitment to high standards for himself and others earned the respect of those around him and made a real and lasting contribution to our understanding of some of the most visible natural resources in North America.

YS

Saving the Charmed Goose

Reconciling Human Demands with Inherent Limitations in the Greater Yellowstone Ecosystem

Charles R. Preston

NPS

EARLY ONE MORNING, a poor farmer arose to gather eggs from his coop. He was astonished to find that one of his geese had laid an egg of solid gold. He rushed back to his house, egg in hand, to share the good news with his family. For many weeks, the farmer gathered one gold egg each day from the charmed goose. The farmer and his family were soon able to pay off all debts and begin to accumulate some wealth. But as the farmer grew wealthier, he also grew greedy and impatient. He imagined a great cache of gold inside the goose, and decided to sacrifice the goose and extract all the riches inside at once. When he sacrificed the goose, however, he found no gold inside—only the raw materials and internal, complex, "goosey" system to produce eggs of gold. He spent the rest of his increasingly impoverished life trying to duplicate the gold-producing system of the late goose, to no avail.

This slightly embellished version of the classic Aesop tale holds at least two important lessons. First, we can easily destroy the very thing we most treasure by failing to understand it and to respect its integrity and inherent limitations. Second, it may be quite impossible to duplicate or restore a complex system once it has been destroyed or compromised. Often lost in the "cloud" of this tale is the silver lining of implied promise—that if we learn to respect the integrity and inherent limitations of a resource, then we may benefit from its bounty well into the future.

While the lessons and implied promise of Aesop's tale may have universal relevance in space and time, I believe that they are especially pertinent to the Greater Yellowstone Ecosystem (GYE) in these early years of the twenty-first century. Beyond its symbolic meaning to people throughout the world, the GYE supports globally significant biological, geological, and cultural resources, and provides substantial opportunities for economic, scientific, recreational, aesthetic, and spiritual fulfillment for residents and visitors alike. This remarkable place holds great value for people with diverse backgrounds and interests. Yet, our numbers and activities are presenting increasing threats to its integrity and identity as we begin this new millennium. It is not too late to forge a comprehensive strategy that will preserve the integrity and uniqueness of this region for future generations, but we must move quickly, decisively, and collaboratively to do so—casting aside dogma, traditional ideological differences, and rear-view mirrors along the way. Just as the GYE served as the grand stage for creation of the global model of early conservation when Yellowstone National Park (YNP) was established as the world's first national park in 1872, the region is now in a position to showcase the development of a more robust conservation paradigm for the new millennium.

It is not too late to forge a comprehensive strategy that will preserve the integrity and uniqueness of this region for future generations, but we must move quickly, decisively, and collaboratively to do so.

An Overview of the Greater Yellowstone Ecosystem and Its Significance

The Greater Yellowstone Ecosystem construct was initially developed to delineate a contiguous area representing critical grizzly bear habitat and range in the Yellowstone area (e.g., Craighead 1977, Craighead 1979, Craighead 1980). Subsequently, it has been defined, redefined, refined, and described by various authors (e.g., Clark and Zaunbrecher 1987, Craighead 1991, Glick et al. 1991, Patten 1991, Harting and Glick 1994, Reading et al. 1994, Hansen et al. 2002) to provide a logical context for their analyses and comments concerning ecological, human demographic, and policy topics. Here, I am using the expanded GYE definition of Hansen et al. (2002), to include the 20 contiguous counties in Wyoming, Montana, and Idaho surrounding Yellowstone National Park. This definition incorporates the high plains surrounding a largely mountainous landscape, populated by just fewer than 360,000 human residents as of the 2000 U.S. census (Hansen et al. 2002). The region also plays host to more than 3 million visitors annually. The GYE encompasses all of Yellowstone and Grand Teton national parks, the John D. Rockefeller, Jr., Memorial Parkway, six national forests, three national wildlife refuges, two Indian reservations, some lands managed by the Bureau of Land Management, and substantial state, county, municipal, and privately-owned lands. Of the federally administered public lands, roughly 2.5 million hectares lie in national forest wilderness areas or national park wilderness zones, and roughly 2.5 million hectares are located in non-wilderness areas. The bulk of national forest lands outside of wilderness areas are managed for wildlife habitat, watershed integrity, and multiple human uses, including motorized transportation and recreation, grazing, logging, and mining. Most of the state and private lands, except those with established conservation easements, are available for a wide variety of uses, including business and residential development.

The headwaters of three major river systems, the Green, Snake, and Yellowstone, originate within the GYE. These rivers and other waterways in the region provide habitat for native cutthroat trout, river otters, bald eagles, ospreys, alder and cottonwood trees, and other native aquatic/riparian fauna and flora, exceptional angling and other recreational experiences for residents and visitors, and water for agriculture, cities, and towns along the drainage corridors.

The nucleus of the GYE is Yellowstone National Park. It is revered the world over as a showpiece for wildlands conservation—a place where human industry and convenience are generally secondary to preservation of native wildlife and natural processes. It is a place set aside for people to visit and enjoy a vignette of wild America. It became the world's first national park in 1872, was declared a biosphere reserve in 1976, and was added to the World Heritage List in 1978. Yellowstone National Park (YNP) includes the world's most diverse and intact collection of geothermal features, connected to an underground network of waterways that reaches out into the GYE far beyond national park boundaries. The space now occupied by YNP has been used and influenced by people of various cultures for at least 10,000 years, and it continues to be influenced by our activities today. Nonetheless, it remains the core of the last large, virtually intact ecosystem in the northern temperate zone of the earth. With the controversial restoration of the gray wolf to YNP in 1995, this system is unique in the lower 48 United States, because it again contains a complete complement of the prominent wildlife species that lived here when Euro-Americans first explored North America.

But YNP is not a closed system, and even combined with the adjacent protected lands of the John D. Rockefeller, Jr., Memorial Parkway and Grand Teton National Park, it cannot contain nor indefinitely sustain viable populations of some of its most prominent wildlife species. These include mule deer, trumpeter swans, bald eagles, Yellowstone cutthroat trout, and especially bison, pronghorn, elk, grizzly bears, and gray wolves. These species depend to some extent on the public and private lands surrounding the national parks, and therefore depend on the tolerance and willingness of humans living on the edge of Yellowstone and Grand Teton national parks to share multiple-use public lands and private lands with them. General Philip H. Sheridan was among the first to publicly acknowledge that YNP was not adequate to support its wildlife when he expressed his opinion, in 1882, that the park should be expanded significantly to the east and south, in part to accommodate the needs of migrating elk and other ungulates (Haines 1996). Thus, the modern concept of a Greater Yellowstone Ecosystem traces its roots back to the nineteenth century, and the ecological aptness of the concept has subsequently been reinforced through scientific inquiry (e.g., Craighead et al. 1995).

The dominant human culture and economy in the GYE outside the national parks revolved around agriculture, logging, mining, and energy development through much of the twentieth century. Each of these ventures carries the potential for ecological harm as well as economic benefit. Farming fragments and replaces native habitat with cultivated monocultures, alters natural waterways through irrigation, and may introduce chemical pesticides into soil, groundwater, and open waterways. Poorly-managed livestock grazing can degrade natural habitats and lead to conflicts with native predators and ungulates. Timber harvesting reduces habitat for some wildlife species (while often improving habitat for others), may increase soil erosion and siltation of waterways, and often promotes habitat-fragmenting roads. Hard-rock mining and energy development may also promote road construction and interruption of wildlife migratory corridors, substantially alter habitats, and may introduce toxins into the ecosystem. Even when these activities are conducted outside the national park reserves, they exert some effects on the wildlife, ecological system, and aesthetic characteristics that the parks share with the rest of the GYE. The overall impact of these activities on wildlife, water and air quality, scenery, and other natural resources in the GYE depends on their location, intensity, and the manner in which they are conducted. These activities and the "Old West" cultural values and attitudes generally associated with them are often viewed as impediments to long-term conservation. Today, however, large mammal diversity and abundance in the GYE are greater than they were at the beginning of the twentieth century, and the region remains rich in other natural amenities (e.g., clean air and water, vast expanses of open spaces and exceptional scenic beauty, opportunities for solitude away from human-caused light and noise pollution) and high-quality outdoor recreational opportunities (e.g., backcountry camping, horseback riding, hiking, fishing, hunting, wildlife watching) that have disappeared or been severely compromised through much of the rest of the lower 48 United States. As we press forward into the twenty-first century, however, gathering forces of the "New West" are clashing and paradoxically combining with the dwindling but still powerful forces of the Old West to profoundly challenge the natural amenities, quality of life, and long-term economic health of the GYE.

Old West Meets New West

Historically, human population densities have been sparse in much of western North America, including the GYE, leaving large, unbroken tracts of undeveloped rangeland and other open spaces (Wilkinson 1993, Glick and Clark 1998, Power 1998). But settlement patterns are dramatically changing the landscape in the New West. Traditional lifestyles and economies built around extractive industries and agriculture are giving way in many parts of the GYE to more "footloose" lifestyles and economies built around service and technology (Power 1991, Rasker and Glick 1994). It is largely the quest for unimpaired scenic beauty, wildlife, clean air and water, and outdoor recreational opportunities that have helped fuel recent human population and economic growth through much of the Rocky Mountain West, but especially in the GYE (e.g., Rasker and Hansen 2000). These same natural amenities were also cited in a survey of business owners in the northern portion of the GYE as hooks that keep local residents from leaving (Johnson and Rasker 1995).

Rasker and Hansen (2000) and Hansen et al. (2002) critically examined human population growth and economic changes in the New West, in general, and in the GYE in particular. They identified the mountain West, with a growth rate of 25.4%, as the fastest growing region of the United States during the last decade of the twentieth century. Although urban centers, such

NPS/JIM PEACO

The northern portion of the park, both within and outside park boundaries, supports important winter range for many species of ungulates.

as Denver and Salt Lake City, have grown substantially, rural areas have also experienced significant growth. In a detailed analysis of cultural changes occurring between 1997 and 2002 in the 20 counties of the GYE in Wyoming, Montana, and Idaho, Hansen et al. (2002) found that human population size increased by 55%. The five fastest-growing counties they studied increased by a dramatic 107%.

Population growth in the GYE has been accompanied by a steady economic shift from traditional, largely extractive industries to a diverse array of technology-based businesses, producer services, and non-labor (i.e., investments, retirement) income sources. Hansen et al. (2002) reported that while timber, ranching, farming, oil, gas, and mining accounted for 19% of the total personal income in the Greater Yellowstone region in 1970, these industries accounted for only 6% of the region's total personal income by 1995. This trend away from traditional economic sectors was especially pronounced in the five fastest-growing counties in the GYE. In general, the most robust, fastest-growing economies in the region (e.g., Teton County, Idaho; Teton County, Wyoming; and Gallatin County, Montana) have been buoyed by non-traditional sources of income, such as professional and service industries, and money earned from past investments, pensions, and other retirement benefits.

The population growth and economic changes that have occurred in recent decades in the GYE carry profound implications for land use and conservation.

The population growth and economic changes that have occurred in recent decades in the GYE carry profound implications for land use and conservation. Many of the new residents who have relocated to the GYE specifically cite scenery, proximity to wilderness, and outdoor recreation as important influences in their choice of a place to live and work (Johnson and Rasker 1995). Increasing numbers of newcomers want to live nearer to open spaces and public lands, in close proximity to hunting, fishing, and wildlife-watching opportunities. Many of these newcomers readily identify themselves as conservationists, support land use planning regulations, and profess a holistic philosophy of ecosystem management. As a consequence of their lifestyles and growing numbers, however, urban expansion at the edges of municipalities has increased significantly, and rural residential development has increased more than 400% since 1970 in the Montana and Wyoming portions of the GYE region alone (Hansen et al. 2002). This expansion has come largely at the expense of agricultural and other open spaces providing scenic vistas and resources for wildlife. Exurban expansion also increases the spread of invasive, noxious weeds, the year-round presence of hikers and other recreationists in important wildlife habitat, and may alter more wide-reaching ecological processes, such as natural wildfire regimes. Thus, the urban and exurban sprawl characterizing the socioeconomic transition from the Old West to the New West (Riebsame et al. 1997) is degrading the very natural amenities that initially inspired much of the population and economic growth. Hansen et al. (2002) argue that if this trend continues, it will not only compromise natural ecosystem function and many prominent wildlife species, such as the grizzly bear, but could impede future economic growth in the GYE as well.

While some communities in the GYE are undergoing rapid population as well as cultural and economic change representative of the New West, the region continues to be dominated by strong utilitarian, dominionistic, and libertarian values and attitudes typical of the Old West (Reading et al. 1994). These attitudes tend to breed skepticism or outright hostility toward conservation initiatives such as human use restrictions on public lands, attempts to guide or limit private land use and exurban sprawl through planning and zoning regulations, and regulations favoring restoration or recovery of threatened and endangered species. In some cases, the anti-conservation sentiment is driven by the belief that the region's economy still depends on agriculture and the extraction of timber, minerals, and oil and gas resources, and that development of these commodities is the lifeblood and highest and best use of public lands for the economic well-being of rural people (Rasker et al. 2004). This has been described by Power (1991) as the "view through the rearview mirror." In other cases, the anti-conservation sentiment is more philosophical, driven by a strong belief that personal freedoms of local people are paramount, and that conservation initiatives are nothing more than conspiratorial schemes to expand the powers of the federal government, limit people's access to public lands, restrict landowner's property rights, and destroy the traditional western way of life (see Hennelly 1992).

Recently, opposition to the restoration and continued presence of the gray wolf to the GYE has provided a rallying platform for many local residents who feel frustrated and alienated by what they perceive as an attack on their western

CHARLES R. PRESTON

Current logging operation in the Shoshone National Forest.

culture and values. Wilson (1997) has posited that the wolf is merely a symbol of a much broader cultural clash between elements of the Old West and New West over access to social power, the nature and extent of private property rights, and the appropriate relationship between humans and nature (i.e., anthropocentric/dominionistic vs. biocentric/holistic). While much of the ongoing conflict surrounding the restoration and management of the gray wolf to the GYE is rooted in philosophical ground, the concerns of some local stockgrowers and hunting outfitters stem from what they view as a very concrete threat to their individual livelihoods.

Similar philosophical and pragmatic debate swirls around grizzly bear management in the GYE. The recent, heated controversies surrounding large predator management in the GYE accentuate the importance of private and multiple-use lands to the region's megafauna, as well as the importance of local residents' perceptions and attitudes to long-term wildlife conservation. Unfortunately, the rhetoric surrounding large predator conservation and management has served to polarize people into pro- and anti-conservation camps, based in part on Old West–New West affinities. Many people and community leaders in the region have tended to develop their positions on predator management, planning and zoning regulations, or other important GYE conservation issues by choosing an ideological camp instead of examining facts in evidence in the context of a clear goal or vision for a sustainable GYE future. By its nature, this approach highlights the differences in extreme viewpoints among GYE residents rather than identifying common ground. It also emphasizes worst-fear scenarios, rather than addressing legitimate concerns in a critical manner. Worst of all, the public dialogue in GYE communities rarely addresses the most significant single reality that underlies all of the surface issues. Simply stated, there are inherent limitations to the number of people and the sum impact of our activities that the GYE can support without losing the ecological integrity and natural amenities that make this place unique and drive its modern economy. Once we acknowledge this reality, we must decide if the ecological integrity and natural amenities of the GYE are worth saving. If the answer is yes, then we can start from common ground to blend the best of the Old West and New West and create a Next West vision for the GYE.

Creating a Common Vision Across Boundaries

The mosaic of public and private land ownership, varied management mandates, and diversity of stakeholder perceptions and attitudes has created conflicting ideas about GYE land use. Consequently, the lack of a shared, clearly articulated vision for the GYE, together with a swelling human population and exurban sprawl, are producing increasingly fragmented landscapes with impaired ecological function. As habitats become more compromised, we can expect an increase in human–wildlife conflicts and even greater threats to biodiversity integrity and natural amenities in the GYE. Many have argued that the best way to address those threats is to implement a more coordinated, holistic, landscape or ecosystem-level approach to managing land use in the region (e.g., Craighead 1979, Clark and Zaunbrecher 1987, Berger 1991, Glick and Clark 1998). Reading et al. (1994) recognized the importance of the attitudes of people living in the GYE to creating a shared vision and coordinated management approach to the region, and found that the majority of people they surveyed were supportive of coordinated management to conserve natural amenities in the region. However, most respondents were unwilling to include private and state lands in management plans. The authors attributed this unwillingness to traditional Old West concerns about governmental control and economic issues. Most GYE residents in the study seemed to see ecosystem management as a threat to their control over public and private land use. They believed that the economic and social health of local communities depended on continued resource extraction, and feared that oil and gas development and timber harvesting would be substantially or moderately limited by ecosystem management policies.


BARBARA O'GRADY

People are drawn to the GYE for its scenic beauty, wildlife, clean air and water, and recreational opportunities.

Holistic, ecosystem management of the GYE is further complicated by the jumble of state, federal, and tribal agencies, county commissions, planning and zoning boards, and other entities that are charged with administering various components of the GYE. Some laws and regulations, such as the Endangered Species Act, legally require uniform, cross-boundary stewardship in some cases, but are often difficult to monitor and enforce. Furthermore, government regulations without incentives tend to engender great resentment among landowners, recreationists, and others who cling steadfastly to the primacy of private property rights and individual freedoms in virtually all circumstances. Glick and Clark (1998) have suggested that cross-boundary, whole-ecosystem stewardship of the GYE will require fundamental changes in resource law, administration and policy, and economic policies and tax incentives. They further argued that success in whole-ecosystem management must involve active participation by all stakeholders, and would thus require some, perhaps all stakeholders to relinquish a modicum of traditional control.

It seems clear that to sustain the ecological integrity and unique suite of natural amenities of the GYE into the future, the entire region must be managed with deliberate hands guided by a common vision. The vision must be constructed purposely with contributions from all stakeholders to accommodate the essential needs of each to the extent possible. But if the overarching goal is to sustain the natural amenities and ecological integrity of the GYE, then the vision of how to achieve that goal must be created with the understanding that there are inherent limitations to the number of people and the sum impact of our activities that the region can support without losing the critical amenities and integrity desired.

If the overarching goal is to sustain the natural amenities and ecological integrity of the GYE, then the vision of how to achieve that goal must be created with the understanding that there are inherent limitations to the number of people and the sum impact of our activities that the region can support without losing the critical amenities and integrity desired.

The idea of creating a common vision for conservation of the GYE is not new. In 1985, the National Park Service and U.S. Forest Service initiated a six-year planning effort to develop an integrated, interagency ecosystem management strategy for the region. At the end of the day, however, the resulting "Vision" document was not widely embraced, and did not attain many of its objectives. In addition to some logical flaws in its foundation (see Lichtman and Clark 1994), the Vision was undermined and eventually vanquished by a well-organized, traditional Old West alliance of local government officials and agriculture, extractive industry, and motorized recreation advocates who portrayed the Vision as a substantial threat to personal property rights and individual freedoms of local residents. Many local residents and policymakers felt left out of the Vision, and viewed it as a tool of the federal government and extreme environmental preservationists to block access to public lands and limit use of private lands. The reluctance of some ecosystem management advocates to embrace the participation of private landowners and local communities in land use planning lent credence to the objections of anti-Vision forces. The success of the anti-Vision alliance demonstrated the strength and continuing influence of Old West ideology in local communities in the GYE, and the intensity of distrust between these forces and ecosystem management advocates. But the Vision exercise also served to provide lessons to help build a more inclusive and robust vision for holistic GYE management.

The most important lesson was that any successful attempt to create a broad-scale, cross-boundary management vision for the GYE must actively involve all major stakeholders, especially local landowners and residents. It is also critical that ecosystem management goals, objectives, and strategies be founded in sound science that is broadly shared in public as well as scientific forums. Recent history with gray wolf management and other GYE issues has demonstrated that ideologically-based dogma, fear, and even hysteria can dominate public rhetoric and policymaking when scientific data are lacking or are not clearly and widely disseminated. Even when scientific information is widely and effectively disseminated, there always will be some vocal, ideological extremists on either side of an issue trying to command a following to influence policy. But informed public dialogue tends to marginalize the voice of extreme ideologues, especially when ideology does not best serve the interests of the majority of people.

In recent years, several community-based ecosystem management efforts have emerged to address local land use issues in the GYE. Glick and Clark (1998) highlighted four of these (i.e., the Beaverhead County Partnership, Madison Range Landscape Assessment and Adaptive Management Project, Henry's Fork Watershed Council, and Greater Yellowstone Coalition Stewardship Program) as potential prototypes showing promise for resolving cross-boundary conflicts. The authors identified five important components that these initiatives share: a) collection and dissemination of sound data; b) creation of public forums for open dialogue; c) active involvement of local stakeholders; d) articulation of concrete management goals; and e) ongoing evaluation and flexibility to deal with feedback and changing circumstances. These and other local initiatives have set the stage for broader programs aimed at creating and implementing a common vision for holistic management across the GYE—a vision that explicitly integrates the economic realities of the New West.

For example, the National Parks Conservation Association has embarked on an ambitious Gateway to Yellowstone program to build public awareness of the economic value of Yellowstone National Park and the natural amenities of the GYE to the health and vitality of gateway community economies and cultural identities. The goal of Gateway to Yellowstone is to expand the base of public support for conservation of GYE landscapes and wildlife by finding common ground among diverse stakeholders and building alliances among non-traditional constituencies (Tim Stevens, personal communication). Another non-governmental organization, the Yellowstone Business Partnership, is an organization of businesses in 25 counties in and around the GYE. This organization is dedicated to working with gateway and other local communities throughout the three-state GYE to encourage and support economic growth in ways that take advantage of and support long-term conservation of wildlife and other natural assets in the region.

Exurban Sprawl: "It won't happen here"

Arguably, the single greatest threat to the ecological integrity, natural assets, and western cultural identity of the GYE is continued exurban sprawl driven by shifting, New West demographic and economic trends. It is increasingly difficult for ranchers and other major landowners to reject lucrative financial offers to sell their open lands for development. Yet these private, open rangelands are critical to conserving wildlife, preserving scenic landscapes, and maintaining traditional western lifestyles. While communities like Jackson, Wyoming, and Bozeman, Montana, have been grappling with rapid population growth and exurban sprawl for several years, many residents in other communities in the GYE were convinced that "it won't happen here."

That conviction was shaken for one previously slow-growing community in 2004–2005, when a large, gated residential community was proposed for development. The development, called Copperleaf, is slated to replace a large hayfield and sagebrush–steppe bench encompassing a portion of the Shoshone River drainage 25 miles east of Cody, Wyoming, along the route to the east gate of Yellowstone National Park. The site is located in critical winter range of deer and elk, and is heavily used by hundreds of these ungulates between October and April each year. It is also located in a particularly scenic corridor, just a few miles west of the Shoshone National Forest boundary. The proposed development has been met with passionate and widespread opposition from county residents, including the voices of some property rights advocates who had previously opposed more stringent planning and zoning regulations for Park County, Wyoming.

Some local residents have expressed opposition to the Copperleaf development on the grounds that it would diminish wildlife habitat and the scenic beauty of the area, while others argue that the development would change the cultural character of the area. Still others point out that the high costs of providing and maintaining infrastructure for exurban development would probably surpass tax revenues (see Alternative Energy Resource Organization 1996, Coyne 2003). The most compelling concerns for many, however, have focused on the availability of fundamental, limited resources, for example, water. Final approval for Copperleaf is pending the results of multiple appeals and legal actions, but the proposed site plan was tentatively approved by a county government generally sympathetic to development and Old West property rights arguments.

Whether or not Copperleaf moves ahead with development plans, the issue seems to have galvanized Park County citizens to think more deliberately and pragmatically, rather than ideologically, about land use in the future. Copperleaf advocates have correctly pointed out that more poorly planned, environmentally damaging Park County developments have been approved in the past with far less opposition than Copperleaf has faced. But open spaces are vanishing, and priorities may be changing in this part of the GYE. In the wake of Copperleaf, some Park County residents have even suggested a "No New Footprints" campaign whereby county governments would stem the loss of natural assets to new home construction by providing incentives for people to purchase previously occupied homes rather than add new footprints to exurban areas.

The recent proliferation of land trust authorities and other organizations concerned with conserving open spaces for wildlife and agriculture testify to the recognition of land use planning as key to the future of the GYE. The Nature Conservancy has long promoted landscape-scale conservation, and pioneered the concept of conservation easements in the


CHARLES R. PRESTON

Elk frequently forage and rest during winter in this pasture now destined for residential development between Cody, Wyoming, and Yellowstone National Park.

GYE and elsewhere. Many western sportsmen and ranchers recognize the need for landscape conservation and even conservation easements, but are uncomfortable with some aspects of The Nature Conservancy options, largely due to perceived philosophical and/or economic considerations. Organizations such as the Greater Yellowstone Coalition, Rocky Mountain Elk Foundation, and the Wyoming Stockgrowers Agricultural Land Trust offer alternative means for landowners to conserve open lands for continued natural, cultural, and economic values. Collectively, these programs offer a broad suite of options to assist landowners interested in preventing all or some of their property from being subdivided and developed.

The Importance of a Well-Informed Public

As Glick and Clark (1998), Preston (2004), and others have pointed out, good conservation decisions supporting a common vision for the GYE will depend largely on a well-informed and engaged local population. Unfortunately, GYE communities tend to be isolated, with limited access to objective centers of information and forums for public discourse. An environment without these resources tends to foster public opinion and local policy decisions founded in dogma rather than on a critical review of information. Museums and cultural institutions are in a unique position to provide credible information to public audiences and replace dogma with information. Collections, research, and informal science education through exhibits and programs will always be the cornerstones of natural science museums, but I have argued to a variety of audiences (e.g., Preston 1999, Preston et al. 2002, Preston 2004) that one critical role for natural science museums in the new millennium is to provide an objective, public forum for the dissemination of information and diverse perspectives on contemporary conservation issues. Museums are also in a position to explore public perspectives on issues to better understand how people form opinions and how to communicate most effectively with the public.

Museums and cultural institutions are in a unique position to provide credible information to public audiences and replace dogma with information.


BUFFALO BILL HISTORICAL CENTER

This grizzly bear exhibit is part of the Draper Museum's *Greater Yellowstone Adventure*.

For example, before we unveiled our *Greater Yellowstone Adventure* exhibits in the Draper Museum of Natural History in 2002, we conducted an extensive, front-end survey of potential visitors representing local communities and our national audience. We found that we needed to employ different interpretive approaches to communicate effectively with each of these audiences, largely due to their differing perspectives on conservation issues in the GYE (Preston et al. 2002). Local audiences were far more suspect of information without attribution, and feared that local concerns about issues like wolf restoration would be ignored or trivialized. We took this information into account when developing exhibits, and were able to successfully communicate with local audiences by highlighting diverse perspectives on wolves in the GYE alongside the presentation of authoritative information (Randi Korn and Associates 2003).

We continue to assess audiences' attitudes toward contentious issues by soliciting and displaying written comments from our visitors. This has both helped us to understand the interests and existing knowledge base of our audiences and broadened the perspectives of many of our visitors who may not have been exposed to the ideas of people who think differently from themselves. The ongoing dialogue we have established with museum visitors helps us to develop topics and approaches for educational programming in our galleries, classrooms, lecture halls, and field sites. When hosting informational forums on contentious conservation issues such as managing free-roaming horses, human–grizzly conflicts, or wildfires, we have found that it is important to include the voices of different stakeholders with the stated goal of finding common ground. Our approach has been to build program partnerships with agencies, organizations, institutions, and private landowners who may often talk about one another, but rarely talk to one another in a managed environment. For our part, we make it clear that it is not the role of our institution to advocate for a particular policy position, but rather to advocate for the best information possible and a dialogue that is based in critical thinking. We have found that participants and audiences often express pleasant surprise at how broad the common ground is on most issues. Our hope is that by creating this kind of environment, we can foster civil public discourse that will reveal innovative, collaborative solutions to important conservation issues in the GYE. In this way, our institution can move beyond its more traditional role of documenting and interpreting the past, to help shape the future of our region. Although not every community in the GYE has a museum, many have public institutions that can and do serve as a source of objective information and a forum for pubic discussion. These community-based institutions can play a crucial role in identifying issues important to their constituents and in shaping an ecologically, culturally, and economically sustainable future for the GYE. The effectiveness of these museums and other community-based information centers in promoting critical thinking and providing a common base of information throughout the GYE can be enhanced if we create shared program networks so that lectures, conferences, and even exhibits can be presented simultaneously or serially. The Draper Museum of Natural History and our parent institution, the Buffalo Bill Historical Center, are beginning to explore opportunities for shared programming among GYE centers of informal learning.

Blending the Best of Old West and New West to Create the Next West

The Greater Yellowstone Ecosystem is a place like no other in the world. It is the last place where we can possibly observe wild bison, elk, pronghorn, mule deer, moose, grizzly bears, black bears, gray wolves, cougars, bald and golden eagles, and trumpeter swans in the same field of view and argue about what role they should play in our lives and how they should be managed. One can avoid these controversies by living almost anyplace else in the world. It is a place of spectacular landscapes and true wilderness, where one can still escape human-caused noise and nighttime lights. In terms of native biodiversity, the GYE is healthier in many respects today than it was 100 years ago—healthier in some respects than it was 10 years ago. Yet the GYE and its natural assets are facing substantial threats from the combination of New West population growth/exurban sprawl and Old West ideology based in resource extraction and "anything goes" attitudes toward property rights and individual freedoms. With increasing human population and cultural diversity in the GYE and throughout the West, it is important to recognize that individual freedoms of one stakeholder often conflict with the individual freedoms of other stakeholders. For example, the freedom for one person to operate a motorized off-road vehicle in a given place and time may conflict with the equally valued freedom of another person to access and enjoy the same place and time without engine noise and exhaust. To share and conserve the natural assets of the GYE, it is critical that we explicitly acknowledge the legitimacy of varied and sometimes incompatible personal freedoms in an ever-shrinking space. Only by identifying and legitimizing such conflicts can we begin to identify opportunities to resolve them in a manner consistent with sustainable use of the limited resources. The natural assets of the GYE carry significant value for members of both Old West and New West cultures, but these assets are not unlimited. They and the systems that created and support them must be understood, conserved, and nurtured if they are to provide the same value to future generations. Residents of local communities stand to benefit the most from the natural assets of the GYE and should bear the greatest responsibility for its stewardship.

As unlikely as it sometimes seems in the heat of lightning-rod controversies such as gray wolf restoration and management, the best chance for a future GYE as beautiful and diverse in wilderness, rangelands, wildlife, and recreational opportunities as it is today depends on forces from the Old West and New West working together toward a common vision of sustainable use of natural assets in the Next West. Creating and implementing that vision requires people of passion and commitment working from a common base of sound information. Let the vocal pretenders and the dogma fall by the wayside. To work together, we will have to sift through our traditional allegiances and prejudices, set aside our team colors and distrust for one another, and deal with the real and considerable challenges before us. To be effective, we should remember the five elements of successful cross-boundary conflict resolution articulated by Glick and Clark (1998) (*see sidebar*). Gateway communities in the GYE have an opportunity to lead the way,

Five Elements of Successful Cross-Boundary Conflict Resolution (Glick and Clark 1998)

1. The collection and dissemination of good data before undertaking major management actions;
2. The creation of forums or mechanisms for civic dialog where information can be discussed and used in a constructive manner;
3. The decision to give stakeholders a voice on resource management issues and an opportunity to play a greater role in management decisions;
4. Identification of a set of shared management goals; and
5. Continual evaluation and modification to reflect changing conditions.

encouraging cross-boundary stewardship by teaming with federal and state agencies, commodities producers, private landowners, and other stakeholders in constructive, proactive partnerships that proceed with sound information, well-defined goals and objectives, and flexibility to deal with changing circumstances. In this way, we will create the future, rather than grudgingly allow it to happen to us. It is a test of our collective wisdom and good intentions, with the future of the Greater Yellowstone Ecosystem—one of the last charmed geese on our planet—in our hands.

COURTESY OF AUTHOR

Dr. Charles R. Preston is Chief Curator of the five museums of the Buffalo Bill Historical Center and the Founding Curator-in-Charge of the Draper Museum of Natural History. The innovative, 55,000 square-foot Draper Museum opened in 2002, as part of the Buffalo Bill Historical Center complex, in Cody, Wyoming. The Draper has become a model for a new genre of immersive natural science museums focused on the integration of humans and nature near globally important conservation areas, such as Yellowstone National Park. Prior to his current appointment, Preston was Chairman of the Department of Zoology at the Denver Museum of Natural History, and before that Associate Professor of Biological Sciences and Wildlife Management at the University of Arkansas at Little Rock. He has authored three books and more than 60 technical and popular book chapters and articles. His most recent book, *Golden Eagle: Sovereign of the Skies,* with photographer Gary Leppart, was released in May 2004.

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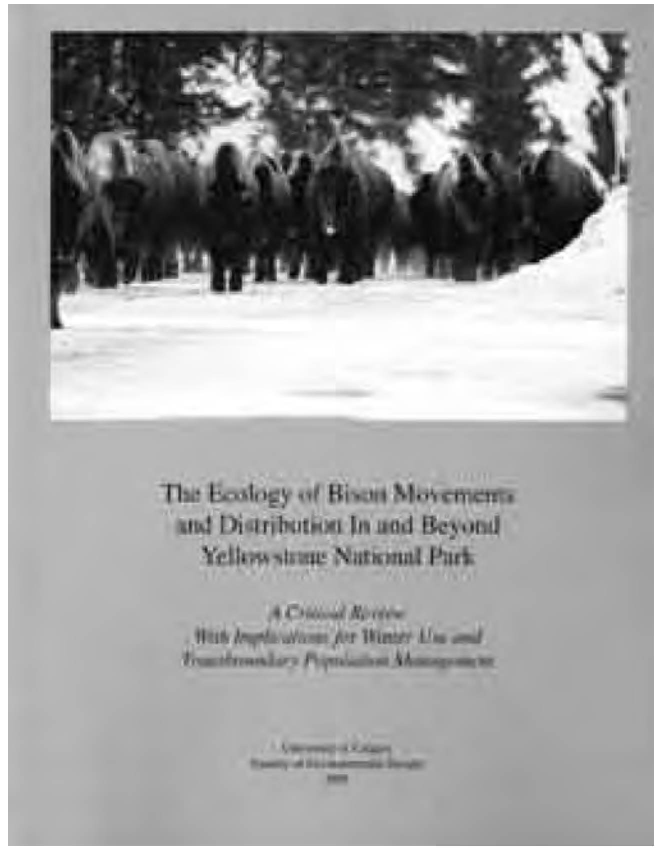
Do Groomed Roads Increase Bison Mileage?

A new analysis sheds light on an old controversy

Mary Ann Franke



THE PUBLIC DEBATE ABOUT WINTER USE in Yellowstone National Park reflects a wide range of values and views about what the park's priorities should be. Opinions differ on whether recreational snowmobiling belongs in national parks at all, as well as on whether it is acceptable if certain restrictions regarding numbers, exhaust, and noise are enforced. People are also concerned about the options available for experiencing the park in winter and the impacts of winter use policy on gateway communities, visitor and employee safety, and wildlife.

The first lawsuit over winter use in Yellowstone claimed that the National Park Service had not adequately investigated whether grooming roads for oversnow use might adversely affect bison. After hundreds of bison trying to leave the park were killed in 1997, The Fund for Animals sued the National Park Service on behalf of what it believed to be the best interests of wild bison. However, opinions on bison use of groomed roads may also be colored by other human interests in the winter use controversy. For example, the BlueRibbon Coalition, a motorized recreation advocacy group, claimed in 1999 that "with groomed trails to help conserve precious body fat and energy stores, the bison population is thriving in Yellowstone these days." The BlueRibbon Coalition pointed to a presumed decline in "wintertime deaths by slow, painful starvation" and ignored the increase in sudden deaths at the slaughterhouse. "Oddly, The Fund For Animals and other environmental extremists seem to see this boon to winter survival as a bad thing," they said (BlueRibbon Coalition, 1999).

The public confusion is partly due to an absence of scientific consensus on how, if at all, road grooming has affected the bison population's size, distribution, and movement within and out of the park. To obtain an independent perspective, the National Park Service enlisted Dr. Cormack Gates, a respected Canadian wildlife biologist who is on the Faculty of Environmental Design at the University of Calgary. Familiar with the ways of bison but removed from the politics of Yellowstone, Gates chairs the International Union for Conservation of Nature and Natural Resources/Special Survival Commission Bison Specialist Group (North America), as well as the Canadian National Wood Bison Recovery Team. In April 2005, after a thorough study of the relevant research and discussions with people knowledgeable about various facets of the issue, Gates delivered a 313-page report to Yellowstone managers. Before looking at a summary of the report's analysis and recommendations, some background on how Yellowstone reached the point where such a report was necessary may be helpful.

Background: Bison and Winter Roads in Yellowstone

Occasional plowing of the road along the north side of the park from Gardiner to Cooke City, Montana, began in the late 1930s and became routine by the 1960s. Snowcoaches began packing the snow on ungroomed roads in the park's interior in 1955, and snowmobiles first entered the park in 1963. As a compromise with neighboring communities that wanted all of the park's roads to be plowed for wheeled vehicles, the National Park Service (NPS) began to groom roads in the park's interior for oversnow use in the winter of 1970–71.

By the early 1990s, Meagher was seeing evidence that roads groomed for oversnow use were affecting bison movements in the park's interior, where much more snow accumulates than on the northern range (Meagher 1993). Although the Gates Report indicates that a mixed group of 24 bison broke trail in deep snow through the Pelican Valley–Hayden Valley corridor in 1956, Meagher documented that when bison from Pelican Valley began moving westward more routinely in the winters of the 1980s, more bison began moving from Hayden Valley into Firehole Valley, and went there earlier in the winter. She maintains that it was this "domino effect" that eventually moved bison further west to Madison Junction and beyond the park's west boundary, as well as northward out of the park. Meagher also proposed that if bison's use of groomed roads had furthered this range expansion, it also may have contributed to the growth in the bison population by enabling more bison to use "energy-efficient linkages" between foraging sites, in turn allowing more bison to survive the winter and give birth to healthy calves in the spring (Taper et al. 2000). The winter bison count for 1988–89 exceeded 3,000 for the first time in the park's history.

History, scientific data, and experience suggest that the extent and route of bison winter movements are affected by factors that can vary substantially from year to year, including population size, forage availability, snow conditions, energy costs, and learned behavior.

Winter road grooming in Yellowstone happened to begin just a few years after the NPS ceased periodically reducing the park's elk and bison herds as a means of addressing concerns about "overgrazing." The halt to bison captures also eliminated the opportunity to test the Lamar Valley bison herd for exposure to brucellosis, which was likely introduced in the park by livestock early in the twentieth century. In 1968, a total of 418 bison were counted in Yellowstone, 70 of them in Lamar Valley. But as the Lamar Valley herd grew, its winter range extended to lower-elevation areas westward and northward toward the park boundary. This was not a new phenomenon; bison have probably been leaving the Yellowstone Plateau for various reasons for millennia. During the severe winter of 1942–43, more than 700 bison from Lamar Valley traveled the Yellowstone River corridor toward Gardiner, and about 130 bison left the park. Most returned within 10 days, but one bison reached a ranch 44 miles north of the park. What changed in the 1980s, as observed by former Yellowstone National Park biologist Mary Meagher, was that more bison were traveling out of Lamar Valley in more winters. When a large movement occurred during the winter of 1982–83, the plowed road from Tower Junction to Gardiner, rather than the topographic route along the Yellowstone River, was their primary path (Meagher 1989).

During the winter of 1984–85, Montana state personnel shot 88 bison that crossed the park's northern boundary because of concerns about property damage and the possibility that they could transmit brucellosis to livestock. The NPS tried constructing barricades across both the road and the Yellowstone River corridor, but the bison adapted by using other routes and detouring across steep terrain or traveling along tributary drainages. Meagher proposed that the "relatively easy and energy-efficient travel [on the plowed road] probably facilitated learning and a rapid increase in numbers" (Meagher 1989).

Bison Exit, Snowmobiles Enter

In 1989, the NPS, the U.S. Forest Service, and the state of Montana began what would turn out to be 11 years of negotiations to develop an Environmental Impact Statement (EIS) for controlling bison movements at the park boundary. The following year, the NPS issued an environmental assessment of winter use in response to the increasing number of snowmobiles that were entering Yellowstone. The resulting plan, which also included Grand Teton National Park and the John D. Rockefeller, Jr., Memorial Parkway, was largely concerned with how snowmobile use affected visitor experience. The possible effects of snowmobiling on wild animals' ability to survive the winter had long been questioned and the subject of some research, but the effects of road grooming on bison and other wildlife did not become a primary focus of the winter use controversy until 1997, when The Fund for Animals sued the NPS for its alleged failure to evaluate the possible consequences. To settle the lawsuit, the NPS agreed to prepare an EIS on winter use for the three park units. The NPS also agreed to decide by December 1, 2000, whether to close a road segment to human winter use on an experimental basis and to make the decision based on the monitoring of wildlife movements. However, the NPS later decided to defer any experimental road closure indefinitely because "further research [on bison movements without a road closure] was necessary before closing a road would provide useful research information" (Sacklin et al. 2000).

Since then, researchers have walked hundreds of miles observing bison winter travel in Yellowstone. Two biologists from Montana State University, Dan Bjornlie and Robert Garrott, found that bison travel both on and off the road from Old Faithful to Norris was lowest during the snowmobile season and then peaked in April, after plowing started and melting snow began to expose scattered patches of forage. Based on data collected during the winters of 1997–98 and 1998–99 in the Firehole–Madison–Norris area, most bison travel occurred on trails previously broken by bison, along stream banks, or through geothermal areas, so only a small portion of it required the animals to move snow. Winter travel between the Hayden and Firehole valleys was largely accomplished on a 19-km trail over Mary Mountain that the bison maintained by traveling it frequently in both directions. For travel west of Mary Mountain, bison were most likely to use the road in places where the constricted topography offered little choice, as in the canyons of the Madison and Firehole rivers. But Bjornlie and Garrott's conclusion that "grooming roads during winter does not have a major influence on bison ecology" was dismissed as "flawed" by The Fund for Animals, because the data covered only the two relatively mild winters that followed the major bison herd reduction in 1997 (Bjornlie and Garrott 2001; The Fund for Animals 2000).

Yellowstone staff have also collected information on bison use of groomed roads. By 2004, they had seven winters' worth of data, but no evidence that conflicted with Bjornlie and Garrott's findings, and no winter of bison movement like that of 1996–97. When the National Research Council considered the available evidence for its 1998 study, *Brucellosis in the Greater Yellowstone Area*, the authors concluded that grooming had not had any "substantial influence" on bison population size, and pointed out that by the early 1980s the growing population had reached a density that could have pushed bison into new habitat even without groomed roads. Meagher has observed that, instead of breaking into smaller groups to forage at small patches, bison will "maintain group social bonds" if possible by moving to a foraging area where they can remain together (Meagher 2002).

Although The Fund for Animals and others who want an end to road grooming in the park have used her research to support their case, Meagher has acknowledged that her data on bison population changes from 1970 through 1997 did not prove cause and effect (Meagher 2002). History, scientific data, and experience suggest that the extent and route of bison winter movements are affected by factors that can vary substantially from year to year, including population size, forage availability, snow conditions, energy costs, and learned behavior. Drawing definitive conclusions from an experimental road closure on whether grooming is a significant factor may therefore be difficult. Another complication is that even if road grooming "facilitated" the bison's use of new winter ranges, they might continue to use those routes and maintain a trail through accumulating snowpack without the help of grooming. As the National Research Council report suggested, "now that locations of other habitat areas are known to the herd, it is unlikely that discontinuance of snow grooming will prevent their movements."

ALICE WONDRAK BIEL

A bison at Mud Volcano in 2002.

The Need for a Comprehensive Study

The Record of Decision signed for the 2000 winter use EIS called for recreational snowmobiling in Yellowstone and Grand Teton national parks and the John D. Rockefeller, Jr., Memorial Parkway to be phased out by the winter of 2003–04. The preferred alternative allowed grooming roads for snowcoaches, while stating that "it is unknown if and to what extent beneficial effects [of road grooming] outweigh negative effects on bison movement." The International Snowmobile Manufacturers' Association (ISMA) then sued, alleging that preparation of the

EIS had failed to satisfy the requirements of the National Environmental Policy Act. The U.S. Department of the Interior negotiated a settlement with ISMA under which the NPS completed another EIS in 2003. The 2003 Record of Decision designated an alternative that allowed snowmobiles but set daily entry limits and requirements for the use of "best available technology" and commercial guides. This plan was rejected on December 16, 2003, when U.S. District Judge Emmet Sullivan in Washington, D.C., ruled on another lawsuit filed by The Fund for Animals. He also criticized the NPS's failure to consider an alternative without road grooming in the EIS, and ordered the agency to re-examine how road grooming affects bison and other wildlife. Asked to reopen ISMA's lawsuit, U.S. District Judge Clarence Brimmer in Cheyenne, Wyoming, vacated the 2000 decision in October 2004. This led to the adoption of a temporary winter use plan and the preparation of another EIS, scheduled for completion in 2007.

In response to the Washington, D.C., court ruling and to improve understanding of the issue, the NPS also commissioned an in-depth analysis of the available evidence on how road grooming may be affecting the bison population in Yellowstone for use in the next EIS. Cormack Gates prepared the resulting report, "The Ecology of Bison Movements and Distribution in and Beyond Yellowstone National Park: A Critical Review with Implications for Winter Use and Transboundary Population Management," with the help of co-investigator Brad Stelfox, also on the faculty at the University of Calgary, and three colleagues: Tyler Muhly, Tom Chowns, and Robert Hudson. It was released to the public in June 2005. It is colloquially referred to as "the Gates Report."

"More bison use more space."

"The ecological, social, legal, and political complexities" of the question of how winter road grooming affects park wildlife required "an interdisciplinary approach involving the integration of social and natural sciences concepts and methods," the Gates Report explains. The assessment included a review of published and unpublished information on what has been learned about ungulate movement ecology in Yellowstone and other locations, interviews with 34 "key informants" familiar with the ecological and social aspects of the controversy, and development of a computerized bison distribution model that can be used to simulate the results of various mid-winter scenarios. In addition, Gates invited 27 environmental and animal rights organizations and interested individuals to a workshop to review the concepts on which the assessment and model were based and share their own knowledge and perspectives on bison movements and ecology. Represented organizations included the Buffalo Field Campaign, the Greater Yellowstone Coalition, and the Humane Society of the United States. However, some organizations, including The Fund for Animals (which became part of the Humane Society in November 2004), declined to attend.

Some Key Findings from the Gates Report

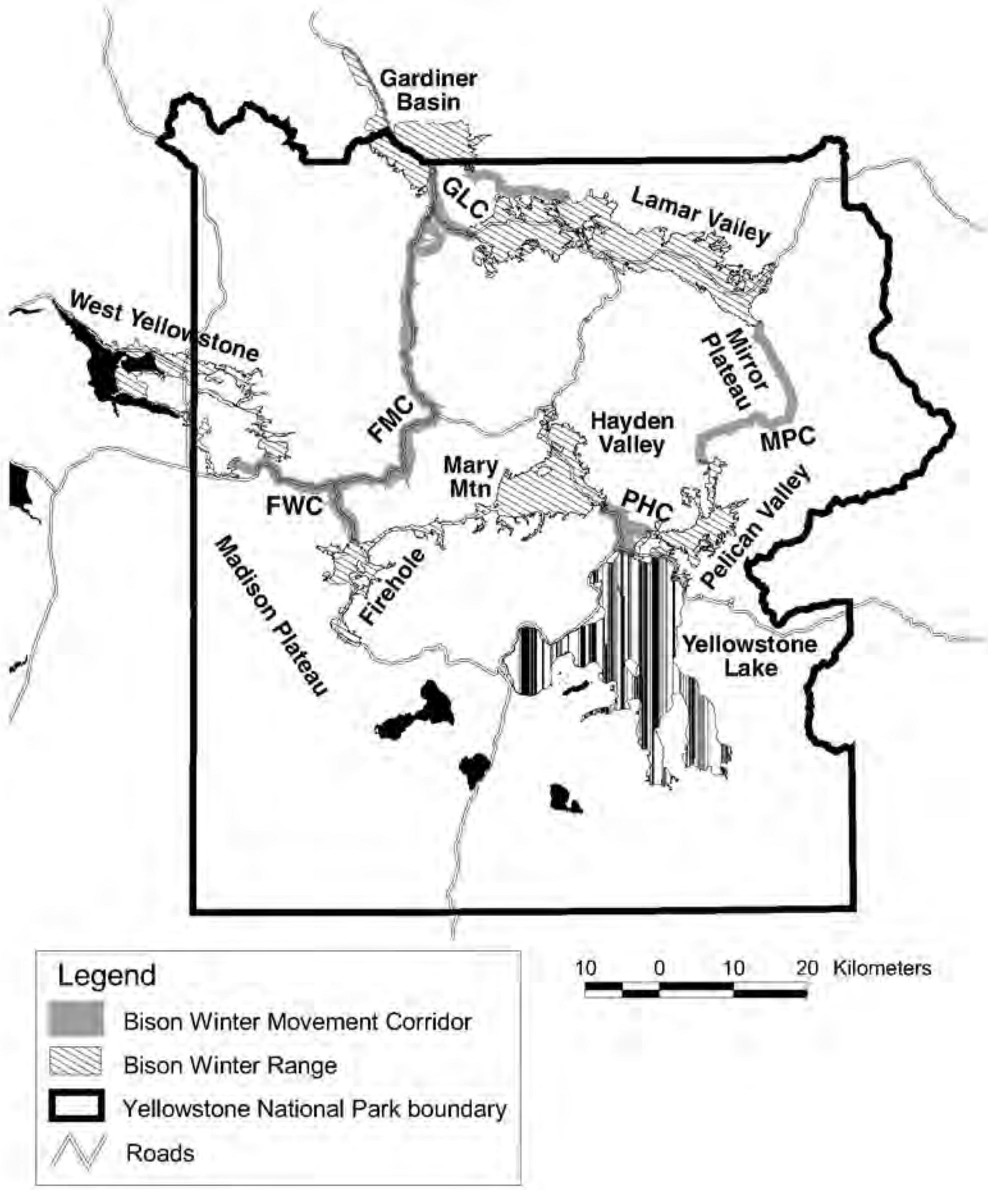
- **The key drivers of bison distribution and winter movements** in Yellowstone are bison population density and snow conditions.
- **When local bison density reaches a certain threshold,** bison will move to find new foraging patches and maintain pathways between patches.
- **The plausible explanation for changes in winter bison distribution** is a range expansion that enabled local bison density to remain relatively constant as the population increased.
- **Without road grooming, migration from the central to northern range would likely not have developed**. Bison travel through the Gibbon Canyon might be deterred by mid-winter snow cover and steep terrain if there were no road grooming or snow compaction by oversnow vehicles.
- **Other groomed roads facilitate bison travel within and between foraging areas**, but range expansion would have occurred regardless in response to population growth.
- **No evidence indicates that groomed roads have affected population growth** relative to what would have happened in the absence of road grooming.
- **Wolf predation on bison** on the northern range will not increase to a significant level as long as elk remain relatively abundant there compared to bison, but it could begin to affect bison numbers on the central ranges, where bison are already a significant component of wolves' winter diet.

Summary: The Gates Report

Bison Population Dynamics

As the Gates Report points out, the population dynamics of ungulate species in Yellowstone occur on a spatial scale larger than the park itself, and on a historical time scale during which both environmental changes and human activities have left their mark. By one estimate, about three-quarters of bison, elk, and pronghorn migration routes in the Greater Yellowstone Area have been eliminated during the last century as a result of an increasing human presence (Berger 2004). But all of the region's ungulate species continue to move from one seasonal range to another, and most of these animals travel some distance on this seasonal basis in response to changes in forage quality and availability.

When ungulate culling practices ended in 1967, the bison in Yellowstone were considered to be grouped in three herds based on their primary winter ranges. Although they mingled during the summer rut, the herds generally remained apart in winter. Since then, the herds have continued to be most widely dispersed in late winter. By mid-July most are congregated in three rutting areas: the largest in Hayden Valley, the second-largest in the eastern Lamar Valley, and a small aggregation on the Mirror Plateau and Cache/Calfee Ridge. But as the Mary Mountain and Pelican Valley herds increased, their winter distributions spread and eventually coalesced. Consequently, bison in the park are now usually referred to as just two herds or "subpopulations"—the northern and the central—and some interchange may occur between them during the winter.



Bison winter ranges and movement corridors. FMC: Firehole-to-Mammoth corridor; FWC: Firehole-to-West Yellowstone corridor; GLC: Gardiner basin-to-Lamar Valley corridor; MPC: Mirror Plateau corridor; PHC: Pelican Valley-to-Hayden Valley corridor.

The Gates Report describes Yellowstone as having five bison winter ranges that are connected by five primary corridors. The northern herd uses Lamar Valley and the Gardiner basin, while the much larger central herd uses Pelican Valley, the Mary Mountain area, the West Yellowstone area, and the Gardiner basin. Bison habitat extends continuously from Lamar Valley to the Gardiner basin, but these areas were considered separately for purposes of this study to distinguish between bison movement in and outside the park. A "corridor" is defined as the principal pathway used by groups of bison cows and calves when traveling between two ranges. However, bison rarely use the Mirror Plateau corridor from Lamar Valley to Pelican Valley during the winter because of deep snow, steep terrain, and the long distance between the ranges.

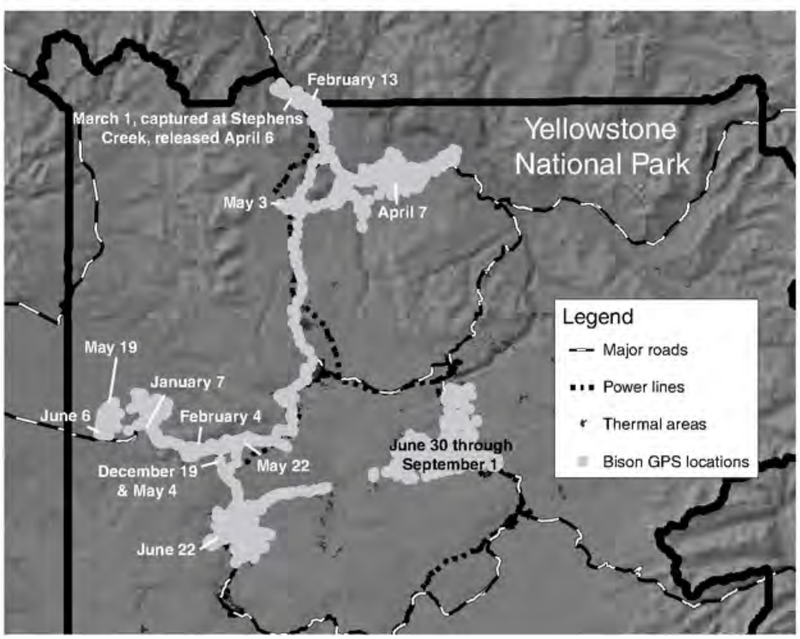
Both the northern and central ranges contain large tracts of continuous grassland and meadows that are connected by corridors through forested areas with patches of foraging habitat. However, environmental differences between the ranges result in differences in bison ecology. In both northern and central Yellowstone, the elevation decreases from east to west, but only on the northern range is this descent accompanied by a significant decline in snow cover. This creates a natural migration corridor from the upper Lamar Valley to the Gardiner basin, where a precipitation shadow causes drier conditions. The central ranges, in contrast, usually accumulate much deeper and longer-lasting snow, except in geothermally-influenced areas. The warmth generated by the thermal features may allow a longer growing season and reduce snow cover. In addition, snow melt and spring greenup occur earlier in the West Yellowstone area than in Hayden and Pelican valleys (Despain 1990).

"All models are wrong, but some models are useful."

The Gates Report concluded that bison move toward the park boundaries in winter "in response to forage limitation" in the park that may result from a combination of factors, including previous summer precipitation, snowpack characteristics, and grazing pressure by bison and elk. As the bison population has increased, therefore, so has the extent of its movements and the likelihood that a group of bison will look for forage beyond the park boundary. "Exploratory movements by mature bulls, which subsequently establish annual migration paths to and from peripheral ranges, likely precede range expansion by cow/juvenile groups," states the report. "More bison use more space," Gates puts it more simply.

Since monitoring of female bison with radio collars began in 2002, park staff have tracked some bison that move from Hayden Valley toward both the west and the north boundaries in the same year. However, range expansion cannot entirely compensate for population growth, because "high quality foraging patches are limited in overall area, are patchily distributed and depleted first, forcing bison to shift to poorer quality patches as [bison] density increases." The likely responses to increased bison density, according to the Gates Report, are "decreased fecundity and increased juvenile mortality," reducing the rate of population growth.

Bison appear to travel on roads in winter where it is convenient, that is, where the roads are aligned with corridors that bison would be expected to use because of terrain, habitat features, and bison behavior. Consistent with this hypothesis, the Gates Report notes, bison rarely use the road segments from Canyon to Norris, East Entrance to Sylvan Pass, South Entrance to Old Faithful, or the western half of the groomed road between Seven Mile Bridge and West Yellowstone. As for a reduction in natural winter mortality that might result from bison use of groomed roads, the Gates Report could find in the available population data no "detectable" change in the growth rate of the Pelican Valley herd after grooming began.



GPS locations of a five-year-old female bison from the central subpopulation between December 2003 and September 2004. Rick Wallen, Yellowstone bison biologist, believes that this extent of northward and westward movement may now be typical of up to one-third of the central herd.

Developing a Bison Distribution Model

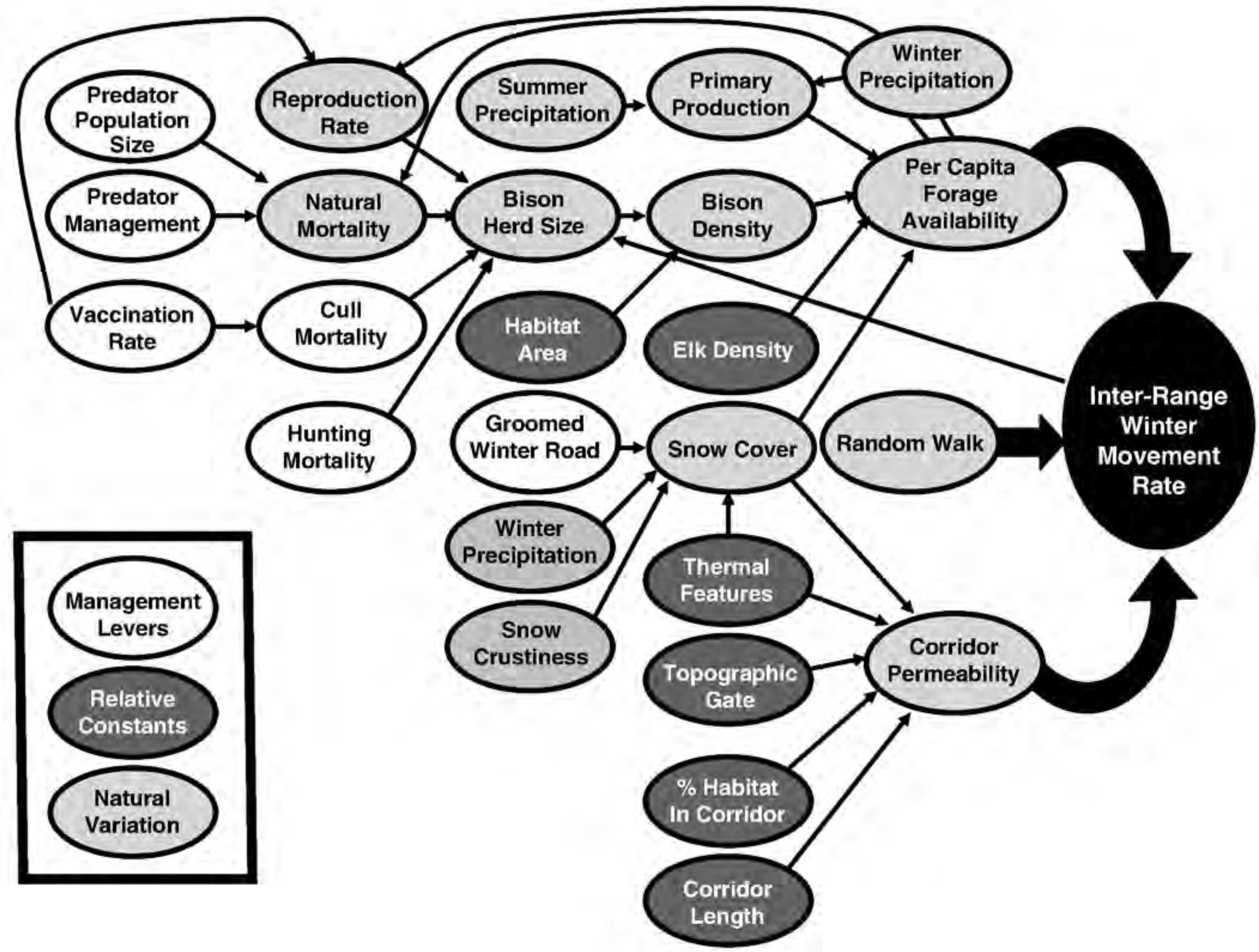
Computer-based models are increasingly used to explore the structure of ecological systems, how their components interact, and how changes to one component may affect the others. The process of closely analyzing these relationships can be as valuable as the resulting model. As Mark Boyce has written,

> *We can clarify our understanding of ecological processes by developing a model of the system in question. In fact, one might argue that the system cannot be clearly understood until we develop an explicit model. And as our understanding of the ecosystem improves, so, too, our models will need to be constantly refined. . . . Any mathematical model of an ecological system is a heuristic tool, and is necessarily a simplification. But simplification does not invalidate ecological models. Indeed, simplification is needed to make the system comprehensible. One hopes to incorporate major limiting factors or driving forces in the system so that the model mimics reality (Boyce 1991).*

Although the complexity of ecosystems makes predictions difficult, models can be used to gauge the range of possible outcomes and compare the relative impact of different natural or human-induced changes. As part of their analysis, Gates and his colleagues developed a Yellowstone National Park Bison Distribution Model that can simulate the effects of various ecological scenarios and management actions on bison population size and movement in midwinter. Because of the limitations of the data and the imprecise assumptions upon which models are based, the report explains, "models cannot be 'right' in a predictive sense, but rather should strive to be 'reasonable' in their structure, assumptions, and relationships." As Gates puts it more bluntly, "All models are wrong, but some models are useful."

To develop a model that would be useful in examining the relationship between bison movement and multiple variables, Gates began by creating a graphic representation called the "Impact Hypothesis Diagram" (IHD). It illustrates how the components in the system interact with each other. "Each arrow connecting variables in the IHD is described as a mathematical relationship derived with the key informants or based on empirical relationships taken from the literature."

Existing data were used to delineate the variability in summer and winter precipitation, forage production, and bison use of ranges and movement corridors. To limit the variability of possible environmental conditions that the model would have to take into consideration, however, it was specifically designed to simulate mid-February in Yellowstone. For example, "per capita forage availability" is the amount of forage available per bison in mid-February, which is assumed to depend on three key variables: precipitation during the previous summer, snowpack characteristics, and grazing pressure by bison and elk. The "permeability" of each movement corridor to migrating bison in mid-February was assumed to depend on five variables: prevalence of thermal features, topography, habitat characteristics, corridor length, and mid-February snow conditions (which would depend partly on whether the road is groomed). At workshops conducted by Gates and Stelfox, groups of key informants ranked the importance of each variable, making



This diagram was used as the basis for the Yellowstone National Park Bison Distribution Model. The variables are color-coded to indicate those that are treated as constants in the model, those that can be simulated as random variables, and those that can be controlled by management decisions. Although "Elk Density" does vary over time, it was treated as a constant in this model to simplify the variables used in the simulations. The "Random Walk" variable refers to inter-range bison movement that is unrelated to forage availability or bison density; it was estimated to account for 10% of the total bison movement in the park.

it possible to rate the permeability of each corridor with and without road grooming during a 100-year simulation during which precipitation varies randomly within a historical range.

Four models were developed from the five workshop groups. (Two of the models were so much alike that they were combined.) Three of these four models produced similar results when simulations were done; they were used to construct a "majority average model." The model based on the constraints set by Group 4 (Mary Meagher's group) differed from the majority model primarily because Group 4 believed that bison would be unwilling to move through snow that had a snow water equivalent (SWE) of more than 10 cm. (This is approximately equal to one meter of snow, but varies depending on the density of the snowpack: the denser the snowpack, the higher the SWE. From 1949 to 2002, the average SWE in the park interior was about 20 cm compared to 7.5 cm on the northern range.) In the majority model, the threshold that would halt bison movement was set at 19 cm. The majority model therefore rated the bison movement corridors as more "permeable" than did the Group 4 model at a given level of SWE.

In non-road grooming scenarios using the Group 4 model, in many winters bison movement would only occur through the Gardiner basin-to-Lamar Valley corridor. Using the majority model, however, bison would be able to maintain a trench through the snow in three of the four most heavily used corridors even without road grooming. The exception is the Firehole-to-Mammoth corridor, which was thought to be relatively impermeable in many winters if the road was not groomed. "The calculated migration of Central Range bison to the Northern Range would likely not have developed in the absence of the groomed road between Madison Junction and Mammoth," the report states. ("Calculated migration" is movement by animals to a destination already known to them.) The Firehole-to-Mammoth corridor was considered an exception because of its length and the particular challenge presented by the Gibbon Canyon. According to the Gates Report, "The road segment through the Gibbon Canyon is the single area in the park where snow cover in combination with steep terrain may deter bison movements in the absence of grooming and snow compaction by over snow vehicles." Most of the key informants thought that bison would be unable to push through the snowpack that could accumulate on an ungroomed road in the 6-km length of Gibbon Canyon. However, now that the northern range destination is known to the bison, some key informants (including Mary Meagher) believed that if bison began packing a trail through the Gibbon Canyon early in the season, they could maintain a trail there in the absence of road grooming despite additional snow, as bison do over Mary Mountain. Another possibility suggested by some informants is that bison might be able to navigate along the geothermally influenced Gibbon River, where less snow accumulates. A power line

> The debate about road grooming is moot now. The Pelican bison were key to the changes in population distribution and numbers. Their land-use patterns were shaped by winter severity and the geothermal survival factor. This unique "bison ecosystem" has been altered irrevocably over the past two decades.
>
> —*Mary Meagher, September 17, 2005*


NPS

This bison near Giant Geyser shows how the animals usually use their massive heads rather than their feet to dig below the snow for forage.

located about one kilometer east of the road could provide an alternative route, but otherwise the areas surrounding the canyon are too steep and heavily forested to allow bison travel.

How much snow does it take to stop a bison? The answer may depend on factors such as terrain; the bison's condition, age, and sex; and the distance to a previously used foraging area. In addition to depth and density of the snowpack, the hardness of an icy crust on the snowpack can affect bison movements by making it difficult or impossible for bison to reach the forage that may be present below.

Although a groomed corridor was rated more permeable than the same corridor without grooming in all models, the increase in permeability was larger in interior corridors than for boundary corridors. This suggests that road grooming may have a greater influence on bison movement between interior ranges than between interior and boundary ranges. Simulations using the majority model showed no difference in the number of bison culled at the park boundary when comparing road grooming to non-road grooming scenarios over the long term. However, it appeared that road grooming might reduce the periodic large bison exoduses that occur in some years by distributing bison movements out of the park more evenly from year to year. Natural winter mortality was higher in the road grooming than non-road grooming scenarios in simulations using the majority model. This difference may be attributed to the greater movement between ranges that occurs with road grooming, which could increase the "probability that higher bison densities may occur on any given winter range," and that forage there would be insufficient.

The snow conditions under which bison will move was the only variable on which the key informants expressed a significant difference of opinion, but development of the model exposed other gaps in what is known about Yellowstone bison ecology. Additional research is needed in these areas to refine the model and improve the accuracy of the assumptions used to run the simulations. Uncertainties include the extent of the interchange between the northern and central bison herds and the ability of wolves to affect bison abundance and distribution in the park. Even in those components of the model on which considerable data were available, small changes in the mathematical relationships built into the model can produce large changes in the resulting simulations.

Recommendations from the Gates Report

Monitoring and Science

1. Yellowstone National Park should implement an internally funded bison population monitoring program that collects and manages data on population size, vital rates, and winter distribution in the long term.
2. Yellowstone National Park should define a minimum viable bison population for the northern range.
3. Yellowstone National Park should encourage and coordinate research focused on reducing key uncertainties over a full range of densities as the population fluctuates in response to environmental stochasticity or management actions.
4. An adaptive management experiment should be designed to test permeability of the Firehole-to-Mammoth corridor under variable snow conditions, with a specific focus on the road section between the Madison Administrative Area and Norris Junction.
5. Yellowstone National Park should install a SNOTEL or snow course station in the Pelican Valley, monitor snow conditions in the Pelican–Hayden corridor, and re-evaluate the two existing snow models.

Management Structures and Processes

6. Engage the U.S. Institute for Environmental Conflict Resolution in an independent situation assessment that includes advice on designing an integrated agency and public planning strategy to represent the common interest.
7. The Yellowstone Center for Resources should play a lead role among agencies and researchers in coordinating data sharing, research, and monitoring of bison and other research relevant to bison ecology and management, by developing a stable collaborative science and management framework.
8. Develop or refine appropriate systems models and other decision support tools to help agencies and other stakeholders to understand key uncertainties and system properties, and to evaluate outcomes of management scenarios defined through value-based decision processes.
9. The National Park Service should increase its support for the appropriate agencies to secure agreements for key winter range for bison and other wildlife adjacent to the park in the northern range.

Recommendations for Monitoring, Research, and Management Process

The Gates Report makes nine recommendations, five of which pertain to additional research and monitoring of bison. Given the large extent of the migration from the park's interior toward the north boundary in some years, and the possibility of lethal management actions for those bison that cross the boundary, the Gates Report recommends conducting a management experiment "to test the hypothesis that the Central population's movement to the Northern Range is possible [in mid-winter] only with grooming of the snowpack on the road, in particular in the Gibbon Canyon." Such an experiment should be designed to "test the effectiveness of unaltered snowpack as a barrier to winter movements between the Central and Northern Ranges in relation to varying environmental conditions including forage production, winter severity, and population size." The report also notes other gaps in the data available to make bison management decisions, and recommends that these be addressed through systematic research, for example, on the ability of bison to move through or forage in snow under the variety of circumstances present in Yellowstone.

"On its own scientific knowledge is insufficient for making effective decisions."

The other four recommendations "are offered to improve the process of creating broadly supported management policy and actions." They go beyond the science of bison ecology to the means by which the National Park Service makes decisions about bison management in conjunction with other government agencies. "It was understood from the outset that one of the central causes of ongoing conflict was not a lack of knowledge but a lack of policy process by which people and institutions can be constructively engaged in integrative decision-making using the best available science," the Gates Report notes. "The role of science in supporting high quality decisions cannot be overemphasized, but on its own scientific knowledge is insufficient for making effective decisions. Establishing the organizational structures and processes to link science to value-based decision-making is perhaps more challenging than conducting research."

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COURTESY OF AUTHOR

Mary Ann Franke began writing and editing for the National Park Service in 1991. She has spent 10 summers and one January in Yellowstone, but migrates to Sedona, Arizona, each fall in response to the shortening days and increasing snowpack.

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Fungi in Yellowstone's Geothermal Soils and Plants

Joan Henson, Regina Redman, Rusty Rodriguez, and Richard Stout

JENNIFER WHIPPLE

Hot springs panic grass is often found in Yellowstone's geothermal areas.

DESPITE TEMPERATURES of 70°C (158°F), acidic pH, toxic levels of heavy metals, and low organic matter content, geothermally heated soils in Yellowstone National Park harbor many species of fungi. Some of these fungi secrete enzymes that may be of commercial interest, because they may be more heat-resistant than enzymes from cooler soils. In addition, fungi growing in geothermal areas tolerate relatively high concentrations of heavy metals, a trait that may be exploited for bioremediation of metal-contaminated soils. For example, areas around metal smelters, such as the abandoned one located near Anaconda, Montana, lost their vegetation because of toxic heavy metals precipitating from the smelting process. Toxic topsoil can become aerosolized by wind, and metal-tolerant fungi, with their network of filamentous cells, could stabilize the topsoil or remove metals from the soil by absorption processes.

Fungi inhabiting harsh geothermal soils may also colonize and live inside (endophytically) the sparse vegetation found there. A plant often found on hot ground in Yellowstone's geothermal areas is hot springs panic grass (*Dichanthelium lanuginosum*). This grass serves as a host for the fungal endophyte *Curvularia protuberata*. Laboratory experiments support the idea that this fungus and this plant are mutualistic with regard to heat tolerance, that is, they are more thermotolerant together than they are alone. Together, the endophytic fungus and its host plant could also be useful for remediating contaminated soils.

Living organisms differ greatly in their ability to adapt to high temperatures. This is nicely summarized in Thomas D. Brock's classic booklet, *Life at High Temperatures*, which can be found at visitor centers throughout Yellowstone National Park. In the latest edition of this booklet is a table showing that

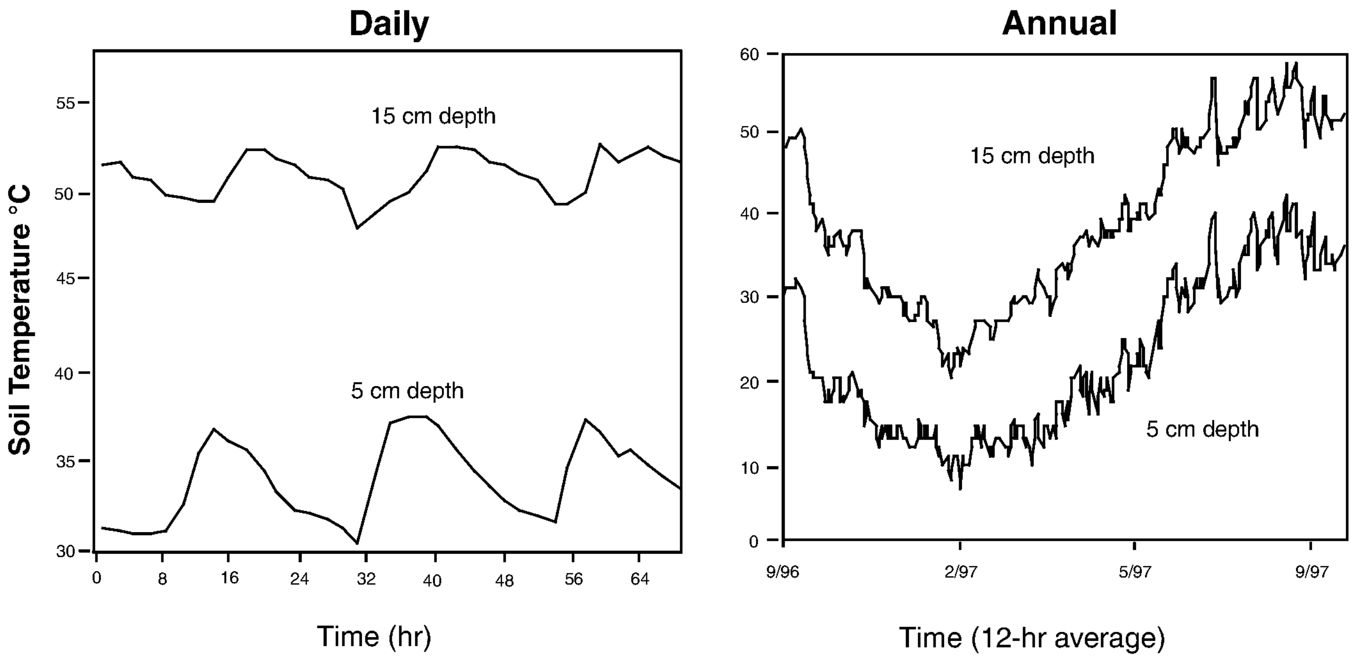


Figure 1. Diurnal cycle of soil temperature at Amphitheater Springs site 1a. Data were collected hourly from thermocouple probes positioned at 5 and 15 cm under the soil surface. Temperatures from one of the warmer mesocosms (a bigger core, ~15 cm wide and 40 cm deep, which can be repeatedly sampled) over a 72-hr period (left) and over an entire year (right) are shown.

Mesocosm/Core	Associated Plants	Initial pH Range	Initial Temperature 5 cm	Initial Temperature 15 cm	Annual Temperature Range (°C) 5 cm	Annual Temperature Range (°C) 15 cm
Mesocosm 31	*D. lanuginosum*	4.5–7.5	31°	46°	5–44°	19–56°
Mesocosm 32	*D. lanuginosum*	4.4–6.3	35	50	2–44	12–58
Mesocosm 33	*D. lanuginosum*	4.7–5.4	24	36	1–38	11–45
Cores 36A–D	*D. lanuginosum*	4.6–4.9	34	41	9–34	14–41
Cores 37A–C[a]	mixed grasses	6.1–6.3	22	19	<0[b]–22	<0[b]–14
Cores 4A–D	*D. lanuginosum*	3.9–4.5	42	56	10–42	18–56
Cores 6A–D	*D. lanuginosum*	4.2–5.0	28	38	11–30	18–38
Cores 8A–D	*D. lanuginosum*	4.3–4.9	27	33	8–30	15–33
Cores 11A–D	decaying log	2.7–4.0	98	107	55–98	91–107
Cores 13A–D	*D. lanuginosum*	4.2–4.7	43	47	8–43	14–47
Cores 25A–D	*D. lanuginosum*	3.9–4.2	20	23	2–24	10–24
Cores 27A–D[a]	lodgepole pine	ND	9	7	ND	
Core 28D[a]	mixed grasses	ND	12	10	ND	
Core 29A[a]	sagebrush	ND	12	11	ND	
Core 34	*D. lanuginosum*	4.2–4.4	3	8[b]	3–29	8–32
Core 35	*D. lanuginosum*	5.1–5.2	32	47	10–32	18–42

Ambient air temperature at Amphitheater Springs ranged from –36.1°C in January 1997 to 31.7°C in August 1997.
A=5 cm, B=10 cm, C=15 cm, D=20 cm. Where A–D is not noted, samples were only taken at 5 and 15 cm depth.
While soil samples were taken at up to four different depths, temperature was measured only at 5 cm and 15 cm.
[a] Non-geothermal cores
[b] Frozen ground, temperatures not recorded

Table 1. Temperature and pH ranges of selected soil mesocosm/core samples from site 1a near Amphitheater Springs in Yellowstone National Park (ND = not determined).

prokaryotes (*Eubacteria* and *Archaea*) are much more heat-tolerant than eukaryotic organisms such as plants and fungi. Fungi are considered thermophilic if they grow between 20 and 60°C (about 70–140°F). Indeed, in the 1970s, Professor Brock and colleague M.R. Tansey were the first to report that some fungal species could be isolated from geothermal features.

Our objectives in this study were 1) to identify and characterize fungi isolated from both geothermal soils in Yellowstone National Park (YNP) and the plants growing there and 2) to describe the natural habitats of these fungi. A rationale for pursuing this research is that fungal isolates from geothermal soils may secrete useful thermotolerant enzymes because they are adapted to unusually hot soil environments. These fungi may be useful in the bioremediation of metal-contaminated soil or water because they are sometimes found in geothermal soils containing high levels of metals such as iron and lead. In addition, they offer an opportunity to gain insight into cellular mechanisms of both thermotolerance and thermoresistance utilized by higher (eukaryotic) organisms.

Geothermal soils and site characterization. Our investigations were mainly conducted in the Amphitheater Springs area of YNP (44.80°N/110.72°W), approximately 20 miles south of Mammoth Hot Springs. At this field site (1a), we collected 37 cores where the geothermally-heated soil temperatures ranged from 3 to 107°C. Soil temperature was measured in several thermal areas, and all thermal soils tested showed diurnal fluctuations in soil temperatures that were recorded by a datalogger with temperature probes at 5 and 15 cm (Fig. 1). In almost all geothermally-heated soil cores, the lowest temperature occurred at the 5-cm depth and the highest at the 15-cm depth (Table 1), a situation that was reversed in non-geothermal soils, which ranged from 9 to 19°C at 5–15 cm depths. Each core was sampled at 5, 10, 15, and 20 cm depth. All geothermal soils tested had low organic carbon (OC) levels (Table 2) and most geothermal cores were acidic (pH 2.7 to 5.8). Geothermal soils are acidic because of sulfuric acid produced by oxidation sulfides such as hydrogen sulfide (H_2S) and pyrite (FeS_2). This

Soil Analyses of Amphitheater Springs Cores 1–10

Site/ Core	Soil Depth (cm)	OC %	P µg/g	Pb µg/g	Fe µg/g	S µg/g	SO4 µg/g
1a-1	5.0	4.6	455	7.0	13,199	8,800	107.4
	10.0	3.0	375	3.3	13,173	7,100	64.0
	15.0	2.5	385	5.1	12,214	7,600	35.2
	20.0	2.2	375	5.7	13,255	8,500	40.2
1a-2	5.0	31.9	395	4.9	11,917	58,100	2445.6
	10.0	2.5	365	4.9	13,449	15,100	595.2
	15.0	2.2	375	3.5	13,121	12,900	523.8
	20.0	2.1	419	6.0	13,269	15,400	447.8
1a-3	5.0	5.9	565	8.4	10,146	18,500	114.1
	10.0	2.7	435	6.9	12,551	15,500	100.0
	15.0	3.9	655	7.3	15,175	15,600	206.0
	20.0	2.3	410	6.1	7,635	59,700	212.4
1a-4	5.0	9.5	540	17.9	13,959	13,000	23.8
	10.0	3.5	368	8.2	16,871	8,100	38.7
	15.0	2.3	250	3.6	14,818	9,500	27.6
	20.0	2.2	250	3.9	14,645	13,100	27.8
1a-5	5.0	16.1	725	19.3	4,082	11,400	31.9
	10.0	3.2	564	19.6	1,123	5,700	8.4
	15.0	3.9	528	15.9	3,065	5,600	6.0
	20.0	18.4	610	19.8	4,642	12,700	33.3
1a-6	5.0	4.5	322	7.4	7,737	42,000	23.0
	10.0	2.7	326	3.9	4,959	3,800	21.6
	15.0	2.7	410	4.1	2,639	3,600	38.8
	20.0	3.2	526	3.5	2,210	42,000	71.8
1a-7	5.0	8.2	593	14.0	12,035	12,500	53.5
	10.0	6.2	590	18.1	11,004	16,500	97.7
	15.0	3.0	401	6.9	9,932	4,900	121.1
	20.0	2.1	301	4.3	6,935	7,300	119.4
1a-8	5.0	15.8	685	12.8	3,946	12,900	52.2
	10.0	3.7	523	5.8	2,705	9,700	52.3
	15.0	3.2	506	5.9	4,878	14,200	50.6
	20.0	3.1	515	4.0	4,115	12,900	57.4
1a-9	5.0	10.4	660	15.2	4,145	13,700	275.8
	10.0	4.2	436	12.0	4,600	9,200	90.5
	15.0	1.7	243	10.2	3,603	64,000	6.7
	20.0	0.6	94	6.4	1,002	2,700	8.4
1a-10	5.0	3.9	302	11.6	2,993	9,500	254.7
	10.0	2.0	199	14.6	2,684	11,000	47.4
	15.0	1.3	142	18.0	1,926	3,900	21.8

Table 2. Analyses of organic carbon (OC), phosphorus (P), lead (Pb), iron (Fe), total sulfur (S), and sulphate (SO_4) in selected geothermal soil cores from site 1a near Amphitheater Springs.

acidity increases soil metal content by dissolving metal ions and transporting them to the surface soil. Many of our thermal soil samples had elevated levels of phosphorus, lead, iron, and/or sulfur (Table 2). For comparison, non-geothermal soils typically have greater than 12% OC and less than 5 µg/g lead, 500 µg/g sulfur, and 100 µg/g iron.

With regard to vegetation cover at these sites, the geothermally-heated soils displayed low plant diversity, with hot springs panic grass (*D. lanuginosum*) typically the predominant flowering plant species (Fig. 2).

Culturable thermotolerant and thermophilic fungi. Fungi were cultured from two areas that had significant temperature variation between and within soil core samples (Table 1). Sixteen fungal species were cultured and screened to determine optimal temperature and pH for growth (Table 3). *Acremonium alabamense* and *Scolecobasidium sp.* were the only true thermophilic isolates, because they grew at 55°C and failed to grow at 25°C and 20°C, respectively. Six other species (*Absidia cylindrospora, Aspergillus fumigatus, Aspergillus niger, Penicillium sp. 1, P. sp. 3,* and *P. sp. 4*) exhibited thermotolerant profiles; although they were unable to grow at 55°C, they could grow when shifted to 35°C after exposure to 55°C for one week. All other fungi reported in this study were not thermotolerant or thermophilic.

We also collected samples near individual plants or several feet away from *D. lanuginosum* plants, the roots of which can tolerate sustained temperatures of 50°C (Fig. 2). The number of culturable fungi was 10–100 times less in soils that were devoid of plants, which suggests that plants provide nutrients and/or shelter for the fungi.

Extracellular enzyme activity and metal tolerance. All fungal species tested exhibited some level of extracellular protease and/or cellulase activity, with the exceptions of *Scolecobasidium sp.* and *Sporothrix sp.* (Table 3). Hot springs panic grass and other plants in geothermal soils likely provide nutrients in root exudates for soil fungi. However, the fungi may also

Genus/Species	Optimal pH[1]	Optimal temperature[2]	Classification with temp. range[3]	Extracellular proteases	Extracellular cellulase
Absidia cylindrospora	5.0–6.0 (4.2)	35 (18°)	TT (20–45°)	+ (pH7–8)[4]	–
Acremonium alabamense	5.0 (3.9)	45 (44)	TP (30–55)	+ (pH5–8)	+ (pH6–8)
Acremonium ochraceum	6.0 (3.6)	25–35 (55)	M (20–45)	ND	ND
Aspergillus fumigatus	4.0 (5.8)	35 (68)	TT (20–50)	–	+ (pH6)[4]
Aspergillus niger	5.0 (4.0)	35 (20)	TT (20–45)	+ (pH7–8)	+ (pH8)
Chaetomium erraticum	6.0 (3.5)	35 (52)	M (20–45)	–	+ (pH6–7)
Cunninghamella elegans	5.0 (4.8)	35 (21)	M (20–45)	+ (pH7)	–
Penicillium piceum	5.0 (4.8)	35 (28)	M (20–45)	–	+ (pH8)
Penicillium sp. 1	5.0 (4.8)	35 (50)	TT (20–45)	+ (pH5–7)	+ (pH8)
Penicillium sp. 3	5.0 (4.8)	35 (40)	TT (20–40)	+ (pH5–7)	–
Penicillium sp. 4	4.0 (4.2)	35 (19)	TT (20–45)	+ (pH5)	+ (pH7)
Penicillium sp. 7	5.0 (4.5)	25 (21)	M (20–45)	+ (pH5–7)	+ (pH8)
Penicillium sp. 8	6.0 (4.7)	35 (68)	M (20–45)	ND	ND
Scolecobasidium sp.	6.0 (4.7)	45 (21)	TP (25–55)	–	–
Sporothrix sp.	6.0 (4.2)	35 (27)	M (20–45)	–	–
Torula sp.	5.0 (4.7)	35 (26)	M (20–45)	ND	ND

[1] pH of soil in parentheses
[2] temperature (°C) of soil sample in parentheses
[3] M=mesophile (maximal growth below 50°C and can grow above 0°C), TP=thermophile (doesn't grow at 20°C and has an optimal temperature at or above 50°C), TT=thermotolerant (temperatures=0°C)
[4] pH secreted
ND=not determined

Table 3. Optimal pH, growth temperatures, and extracellular enzyme production of fungal soil isolates. Proteases are enzymes that break down protein, and cellulases are enzymes that break down cellulose.

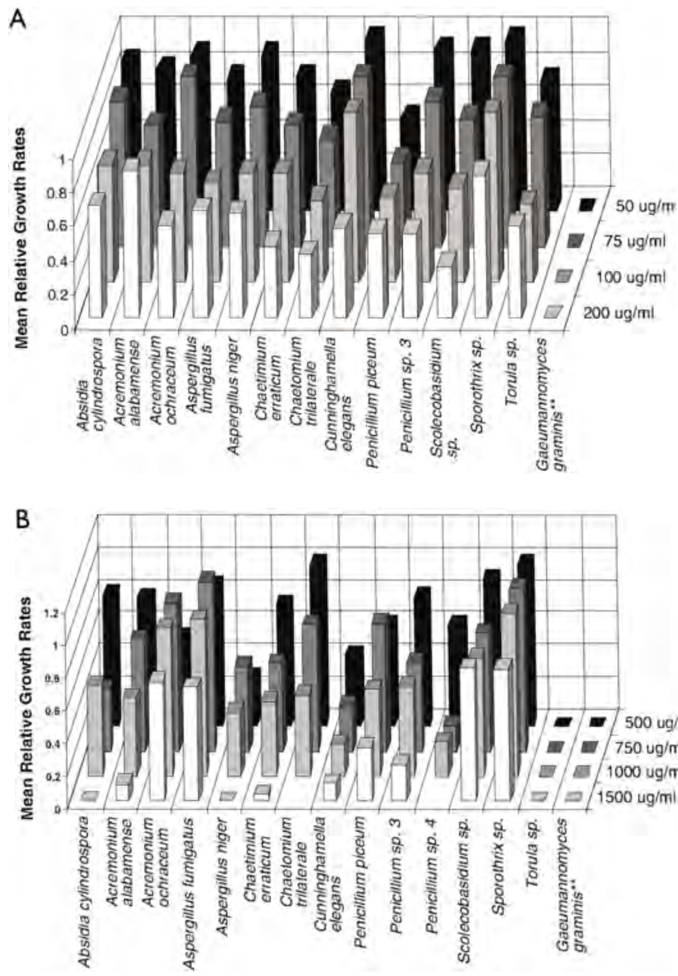
COURTESY JOAN HENSON AND RICH STOUT

Figure 2. *D. lanuginosum* at Amphitheater Springs with rhizosphere (root zone) temperature reading above 50°C.

utilize plants as a nutrient source by establishing symbiotic or saprophytic associations. Their production of extracellular enzymes suggests that the fungi are saprophytic; that is, they degrade and metabolize organic matter from dead plants. Thermostable enzymes from fungi are gaining interest, in part because of the ability of fungi to degrade a broad spectrum of chemicals. It will be of interest to further investigate several of these enzymes secreted by thermophilic or thermotolerant fungi.

Some of Yellowstone's geothermal soil fungi are apparently also well adapted to high levels of iron and lead, and hence may be useful bioremediating agents for metal-laden soils, generated as waste products of the mining industry. Because the geothermally modified soils studied often contained relatively high levels of lead and iron, representative fungal isolates were tested for their metal tolerance on media containing up to 1,500 µg/ml of iron sulfate ($FeSO_4$) and 200 µg/ml of lead nitrate ($PbNO_3$, Fig. 3). Almost all fungi from YNP that we isolated grew on media supplemented with these two metals. For example, growth of *Acremonium ochraceum* appeared unaffected by 75 µg/ml $PbNO_3$, and *Cunninghamella elegans* and *Sporothrix sp.* were unaffected by 100 µg/ml of $PbNO_3$ (Fig. 3A). Moreover, *Chaetomium trilaterale* and *Sporothrix sp.* grew as well with $FeSO_4$ (500 and 1000 µg/ml, respectively) as without supplemental iron, and *Aspergillus fumigatus* grew faster with 750 µg/ml of $FeSO_4$ than without added iron (Fig. 3B). In contrast, a typical soil fungus from non-geothermal soil, *Gaeumannomyces graminis,* was unable to grow on these toxic concentrations of iron and lead.

Endophytic *Curvularia protuberata* and its mutualistic symbiosis with *D. lanuginosum*. As an endophytic fungus, *Curvularia protuberata* is able to live inside plants, and is exclusively associated with plants in geothermal soils (Fig. 4). Over the past 10 years we assayed for this fungus and found it was present in 100% of >200 panic grass plants tested both from at least seven different geothermal areas in Yellowstone National Park and from an additional geothermal soil in Lassen Volcanic National Park. To assess the effect of the endophyte on the thermotolerance of *D. lanuginosum,* we germinated and grew endophyte-free (non-symbiotic) plants and plants inoculated with *Curvularia* (symbiotic plants). After several weeks



**control mesophilic fungus not isolated from YNP

Figure 3. Iron and lead tolerance by geothermal soil fungi from Amphitheater Springs. **A)** Lead tolerance by different isolates. **B)** Iron tolerance by different isolates. Metal concentrations are listed on the right.

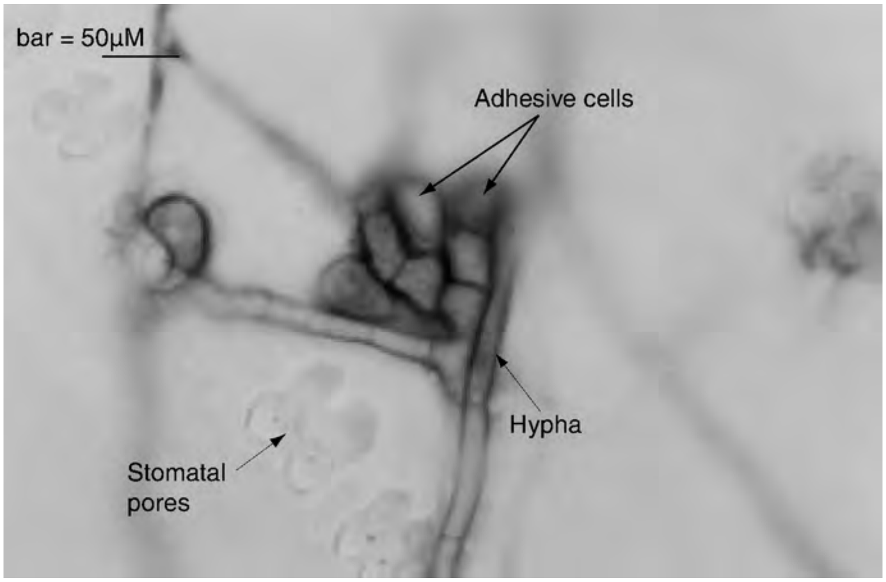


Figure 4. Hyphae, composed of filamentous fungal cells, and adhesive cells of *C. protuberata* on a *D. lanuginosum* leaf.

of growth at room temperature, these plants were exposed to several days of heat treatment. (In the laboratory, electrical heat-tape was used to warm the pots in which the plants were growing in order to simulate the natural geothermal heating of the roots). Endophyte-free host plants shriveled and died after three days of 50°C root zone temperature. In contrast, symbiotic plants thrived during this heat treatment. In addition, we re-isolated *C. protuberata* from heated plant roots of all the symbiotic plants. Because *C. protuberata* cannot survive this temperature when growing alone, our finding that it survived inside the plant provides evidence that the fungus and the host plant provide mutual protection from thermal stress.

This was the first demonstration of thermotolerance provided to both symbiotic partners as a result of their mutualistic interaction. Mechanisms of thermotolerance are currently unknown, but could include activation of plant stress responses, or the production of fungal compounds that enhance plant thermotolerance, desiccation tolerance, or both. For example, fungal melanin, a pigment that binds unstable oxygen radicals generated during heat stress, could provide thermotolerance. Future studies will address these possible mechanisms. Whatever the mechanism of thermotolerance, it is likely to operate in all populations of hot springs panic grass in Yellowstone (and possibly Lassen Volcanic National Park), because all plants tested carry endophytic *Curvularia.*

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COURTESY JOAN HENSON AND RICH STOUT

Left to right: Rusty Rodriguez, Joan Henson, Richard Stout, Regina Redman, Kris Hale, and John Noreika. **Joan Henson** and **Richard Stout** are professors at Montana State University in Microbiology and Plant Sciences, respectively. **Regina Redman** is an affiliate professor of microbiology at Montana State University and the University of Washington and is married to **Rusty Rodriguez**, a research scientist at the U.S. Geological Survey in Seattle, Washington. This is the 10-year anniversary of the authors' collaboration and friendship. Kris Hale and John Noreika are students at Montana State University.

Acknowledgements

Special thanks to the staff of the Yellowstone National Park Research Permitting Office. This work was supported by grants from the U.S. Geological Survey, National Science Foundation (9977922), the U.S. Army Research Office (DAAHO4-96-1-01194 and 35824-LS-DP), and NASA (grant NAG 5-58807 to the MSU Thermal Biology Institute).

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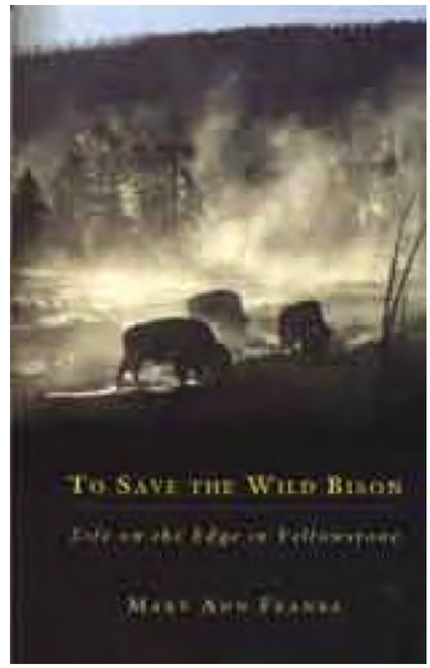
Book Reviews

To Save the Wild Bison: Life on the Edge in Yellowstone by Mary Ann Franke

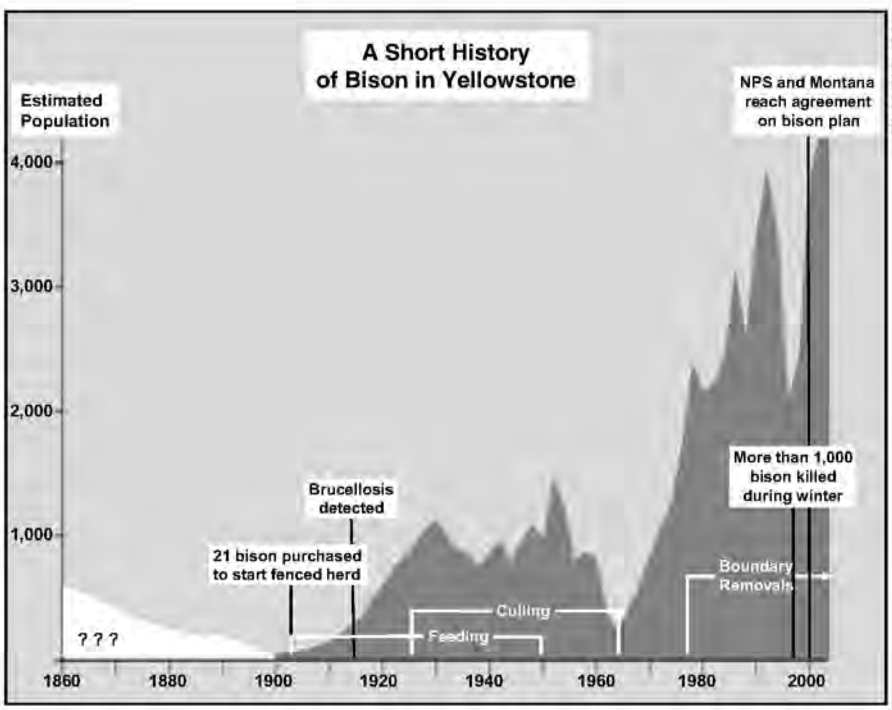
Robert B. Pickering



(Norman, OK: University of Oklahoma Press, 2005. xx plus 328 pages, preface, introduction, illustrations, maps, notes, references, index. $29.95 cloth.)

ANYONE READING today's newspapers sees that Yellowstone National Park is a lightning rod for many issues concerning public access, conservation, and wildlife. Of particular note is the park's management philosophy related to bison, the presence of brucellosis, and the testy legal relationship between the park and its neighbors—individuals and state governments. Mary Ann Franke's fascinating new book, *To Save the Wild Bison,* traces the controversies back to the founding of Yellowstone itself. Franke clearly presents not one or two, but multiple sides of the story.

Ms. Franke addresses the history of bison in the park in five sections



MARY ANN FRANKE

Wildlife counts in Yellowstone are always subject to error because of the unknown number of animals that may go undetected, but estimates made before 1900 were especially unreliable because they were often based on hunches and chance observations rather than systematic surveys.

comprised of 16 separate chapters. The notes section at the end is valuable to any serious researcher. In the first section, Ms. Franke presents a comprehensive discussion of bison in North America and the founding of Yellowstone National Park. For the reader interested in the national scope of bison history, there are other sources that provide more detail. However, this section's focus on the specific history of Yellowstone's bison is excellent.

The second section of the book delves into the romanticism that founded the park and the question of what to do about bison. Coming on the heels of the nineteenth century Great Slaughter, the need to save the bison was not a unanimously held belief. Poachers, who had greater interest in personal gain than in following the law or preserving this great species, considered the park to be their own private hunting grounds. The local controversy over hunting bison and other animals in the park led to the writing of national laws. Thus, the federal government became more active in species and habitat conservation.

Section three introduces a marvelous phrase, "brucellosis in Wonderland," to describe the early contact and conflict between the park's bison and the cattle of neighboring ranchers. Not unlike the poachers, nineteenth century ranchers saw the park as a way to increase their personal gain by grazing their cattle within park boundaries. Franke presents a bare-knuckles assessment of the competing ideas regarding brucellosis in Yellowstone. Some factions propose eradicating the bison altogether. The other end of the spectrum suggests extending the park boundaries to ensure that bison have sufficient winter range and cattle could be totally separated from bison. Interestingly, some of the same folks who want to eliminate bison to get rid of brucellosis seem to turn a blind eye to the elk that also carry the disease and range beyond the park's boundaries at will. When I began reading this section, I thought I knew what Ms. Franke's perspective was going to be. However, she is relentless in pointing out the inconsistencies, fuzzy thinking, and less-than-professional actions that can be found on all sides of this debate. Neither the park officials, the Washington lawmakers, the ranchers, nor the environmentalists are spared from her critical examination.

Section four connects the bison issue with current hot topics in Yellowstone, such as the reintroduction of wolves, snowmobile access, and the expanding grizzly bear population. Here is the background behind the front-page news stories. Again, Franke pulls no punches in her assessment of the actions and motives of the various players in this debate.

Section five enriches an already complicated story by introducing the role of Native Peoples in the park, both historically and as they assert their rights to be players at the table when bison are discussed. Here, we see the historic park stance that overtly diminished, if not totally denied, the role of Native Peoples on the land that became Yellowstone National Park. As tribes have asserted their sovereignty and rights on many other topics from gambling to water, so too, they want to help shape the future of the buffalo—the animal that physically and spiritually sustained Plains peoples for so many generations. However, people representing the tribes are subject to the same critical assessment of actions and motives as Franke gives to all other factions in this great debate.

In summation, this is a straightforward, fact-filled presentation of the state of bison in Yellowstone. On the surface, bison have made an incredible recovery in the last hundred years thanks to the efforts of many people and many diverse organizations. However, there are still powerful interests, private and governmental, who would reverse the success. This is not a book for the casual reader. Franke doesn't tell a pretty story. However, if Yellowstone National Park, bison, and sound governmental policy are important to you, this is a great book.

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NPS

The Yellowstone area is the only place in the United States where wild bison have been present since before the first Euro-Americans arrived.

COURTESY ROBERT PICKERING

Dr. Robert B. Pickering has served as Deputy Director for Collections and Education at the Buffalo Bill Historical Center (BBHC) in Cody, Wyoming, since 1999. He also serves as Director of the Cody Institute of Western American Studies (CIWAS), a forum for researching, discussing, and disseminating significant information on topics of the American West. Dr. Pickering has been involved in museum education, exhibit development, and anthropological research for more than 25 years. His experience in a variety of museums, including the Field Museum of Natural History in Chicago, the Children's Museum of Indianapolis, and the Denver Museum of Nature & Science, as well as the BBHC, makes him keenly aware of the opportunities and challenges offered by museums as well as the needs of the audiences they serve.

Decade of the Wolf by Douglas W. Smith and Gary Ferguson

Hank Fischer

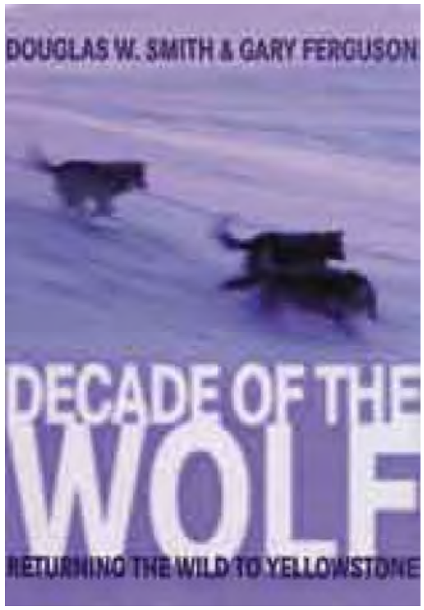
(Guilford, CT: The Lyons Press, 2005. viii plus 212 pages, acknowledgments, graphs, endnotes, index. $23.95 cloth.)

IN HIS 1930 BOOK, *Animal Life of Yellowstone National Park*, noted biologist and federal employee Vernon Bailey wrote dispassionately about shooting the adult wolves from one of Yellowstone's last packs, and then killing their pups in a den on the slopes overlooking Hellroaring Creek. It's a remarkable book because it so graphically captures what was then the prevailing American attitude toward *Canis lupus*.

Fast-forward 75 years, and *Decade of the Wolf*, a book by biologist and federal employee Doug Smith (with co-author Gary Ferguson) provides a new outlook, as well as powerful evidence for how dramatically viewpoints have changed.

This is not a dry, academic science book, and Doug Smith is not an unemotional, just-the-facts-ma'am style of biologist. Smith is enthusiastic about wolves and the wild country they inhabit, and his ardor for the natural world permeates the entire book. This is a guy who can look into a wolf's eyes from a Super Cub airplane traveling 100 miles per hour and imagine what the wolf is thinking (he does it twice in the book!). Moreover, Gary Ferguson is an excellent writer who can bring great stories to life.

Strong narrative connected with good science is what makes this book sing, particularly when Smith and Ferguson tell the fascinating life stories



of individual wolves. For instance, the dramatic story of wolf #9F underscores how important individual animals can be to a population; genetics studies in 1999 revealed that she was related to 75% of Yellowstone's wolves.

The science in *Decade of the Wolf* tends more toward the descriptive than the quantitative. Smith clearly admires the pioneer biologists who studied wildlife by spending long hours in the field using acute observational skills. But Smith and Ferguson also do an excellent job of weaving important Yellowstone research findings into their wolf life histories. We learn that on average, a 10-member wolf pack kills about 180–190 elk per year. We find out that about 70% of wolf dens used each year have been used in previous years, that 35–40% of Yellowstone's wolves are radio-collared, that researchers have only been able to document two bighorn sheep and two mountain goats killed by wolves, that an average of 29 ravens attend every wolf kill, and that the average life span for a Yellowstone wolf is 3.4 years.

An absorbing chapter, "The Wolf Effect," discusses how wolves may influence plant and animal life in Yellowstone. It's an intriguing subject—one on the cutting edge of conservation biology—and the introduction of wolves to Yellowstone provides a textbook opportunity for understanding how top predators can make ripples through the entire food chain. The discussion centers on how willows have begun to grow along river banks and beaver have started to increase on the park's northern range since the Gallatin National Forest reintroduced 150 beaver in the early 1990s, coincident with wolf reintroduction.

What Smith and Ferguson could do better is to distinguish their informed conjecture from actual research findings. Many factors other than wolves are at play in the Yellowstone ecosystem (e.g., drought, global warming, and fire), and so far there is little data that cements the connection between wolves and the vegetation changes that appear to be occurring now. But such questions are of interest mainly to the science community, and that's plainly not who this book is for. The legions of people hungry for more details about Yellowstone's wolves will find a feast of information in this book, and can be counted on to gobble it down enthusiastically.

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COURTESY HANK FISCHER

Hank Fischer worked for 25 years as Defenders of Wildlife's northern Rockies director. He was deeply involved with Yellowstone wolf reintroduction, which was the subject of his book, *Wolf Wars*. He currently works as special projects coordinator for the National Wildlife Federation in Missoula, Montana, and leads wolf and grizzly trips to Yellowstone (www.fischeroutdoor.com).

NPS PHOTOS

The GYCC panel (above, Regional Forester Jack Troyer, USFS Intermountain Region. Above right, left to right: Superintendent Mary Gibson Scott, Grand Teton National Park; Refuge Manager Barry Reiswig, National Elk Refuge; Forest Supervisor Becky Aus, Shoshone National Forest; former Yellowstone Superintendent Bob Barbee; and moderator Yellowstone Superintendent Suzanne Lewis); below, their audience.

8th Biennial Scientific Conference Explores 21st–Century Conservation

Alice Wondrak Biel

THE 8TH BIENNIAL SCIENTIFIC Conference on the Greater Yellowstone Ecosystem, *Greater Yellowstone Public Lands: A Century of Discovery, Hard Lessons, and Bright Prospects,* was held October 17–19, 2005, at the Mammoth Hot Springs Hotel. The conference set a new attendance record, with 209 registered attendees. This year's conference was highly anticipated as being one of the most immediately pragmatic in the 14-year history of the series, and one of the most directly useful to public land managers. Participants focused on the mandates, "cultures," relationships, and accomplishments of the numerous local, state, and federal management agencies responsible for Greater Yellowstone's public lands.

Interagency cooperation was a primary theme, and the meeting kicked off with a screening of *The Greatest Good,* a two-hour film celebrating the centennial of the U.S. Forest Service (1905–2005). On Monday night, U.S. Forest Service Chief Dale Bosworth delivered the opening keynote address to a packed Map Room at the Mammoth Hotel, lit by emergency lights, candles, glowsticks, and flashlights due to a localized power outage. Chief Bosworth outlined what he believes to be the four biggest threats to U.S. national forests: (1) unmanaged recreational use, (2) invasive species, (3) loss of open space, and (4) the unnatural accumulation of fuels, leading to dangerous fire conditions. The chief's declaration that "The day when people can go where they want cross-country (on off-highway vehicles) is over," received a round of applause from the crowd.

Former forest service chief Jack Ward Thomas, now the Boone and Crockett Professor of Conservation at the University of Montana, presented the A. Starker Leopold Lecture on Tuesday night. Dr. Thomas traced 100 years of conservation in the U.S., from its roots in simply preventing resource exploitation to today's ecosystem and multi-use management mandates. Canadian conservationist and activist Harvey Locke delivered the Superintendent's International Lecture. In an inspiring speech that received a standing ovation, Mr. Locke stated that if the dream of the twentieth century was unmitigated progress based in a wealth of natural resources, the dream of the twenty-first century should be ensuring that what was done to the land and resources in the twentieth century is undone. He also detailed the Yellowstone-to-Yukon initiative, expressed confidence in the prospects for the project's success, and told the audience of the most important lesson he's learned in conservation work: never give up.

The Aubrey L. Haines lecturer was Sarah Boehme of the Buffalo Bill Historical Center's Whitney Gallery of Western Art. Dr. Boehme's talk, "Yellowstone Paintings: Artistic Discoveries, Hard Rides, and Golden Vistas," discussed the influence of Yellowstone-inspired art on Washington policymakers as they considered the park's creation and supported the subsequent conservation movement.

Harvey Locke, of the Canadian Parks and Wilderness Society, received a standing ovation for his inspiring speech.

In other keynotes, landscape ecologist Dr. Monica Turner presented an amalgam of lessons and surprises from post-1988 fire research in Yellowstone, and

Karen Wade, former Intermountain Region Director of the National Park Service, spoke on Wednesday morning.

former NPS Intermountain Region director Karen Wade shared her thoughts on the importance of science and individual responsibility in conservation. On Wednesday afternoon, Dr. Richard Knight provided a heartfelt summary of the three days' events that emphasized the import of considering traditional conservation issues from a broad perspective, rather than a narrow focus. According to Knight, we need to concentrate less on endangered species, off-highway vehicles, and ranching, and more on invasive species, unmanaged recreation, and private lands. He also reminded those assembled that their role as scientists and conservationists has changed in recent times; that in the past, they were often the decisionmakers. Today, they are the catalysts, because conservation must operate, and its value be felt, at all levels of the populace.

Community-based conservation, an important theme of the 7th Biennial Scientific Conference, *Beyond the Arch*, was also a recurring topic at this conference, reminding attendees that, in the words of Dr. Knight, in order to manage effectively in today's world, "we will have to manage differently." Broadening the scope of people involved in conservation will require clear explanations of why conservation is important to everyone, and of the science behind it. Thus, another theme that emerged was the importance of training scientists and managers to express themselves clearly, and to perceive of their audience as consisting of far more than other scientists. Drs. Gary Machlis and Alice Wondrak Biel addressed this issue in a description of The Canon National Parks Science Scholars Program, and the conference itself seemed to have achieved this goal when Dr. Knight declared that overall, it had been "not just science for scientists."

The conference was interdisciplinary, as is its hallmark, with panels, sessions, posters, and speakers covering topics that ranged from remote sensing to art history. Superintendent Suzanne Lewis moderated a blue-ribbon panel on Tuesday morning that featured former Yellowstone superintendent Bob Barbee and local, high-level leaders from the U.S. Forest Service, U.S. Fish and Wildlife Service, and the National Park Service, focusing on the history and current challenges of the Greater Yellowstone Coordinating Committee. There were also sessions on history, mammals, biocomplexity, water resources, fire, human values, native plants, and trophic cascade questions, all with a cross-agency or cross-boundary perspective.

Greater Yellowstone Public Lands was sponsored by the Yellowstone Association; Yellowstone National Park; the Draper Museum of Natural History (Buffalo Bill Historical Center); Grand Teton National Park; the University of Wyoming–National Park Service Research Center, Research Office, and Ruckelshaus Institute (University of Wyoming); the Rocky Mountains Cooperative Ecosystem Studies Unit; and the Greater Yellowstone Coordinating Committee, consisting of representatives from the National Park Service (Grand Teton and Yellowstone National Parks, John D. Rockefeller, Jr., Memorial Parkway), the U.S. Fish and Wildlife Service (National Elk Refuge, Red Rock Lakes National Wildlife Refuge), and the U.S. Forest Service (Beaverhead-Deerlodge, Bridger-Teton, Caribou-Targhee, Custer, Gallatin, and Shoshone National Forests). It was planned and organized by the Resource Information Office of the Yellowstone Center for Resources, in conjunction with other YCR staff and a program committee of independent scholars and non-Yellowstone federal agency personnel. The proceedings should be available sometime next year.

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More than 30 papers were presented and 20 posters displayed.

Opening night in the Map Room, with emergency lights during the power outage.

U.S. Forest Service Chief Dale Bosworth gave the opening keynote.

FROM THE ARCHIVES

"Whether or not I shall be able to save them [the park's bison] remains a doubtful problem. The forces of nature and the hand of man are alike against them, and they seem to be struggling against an almost certain fate."

—Captain George S. Anderson, 1896
Acting Superintendent of Yellowstone National Park

YNP, PHOTO ARCHIVES, YELL #11871B

C.J. (Charles Jesse) "Buffalo" Jones, then Yellowstone game warden, with a domestic cow and two bison calves in the Mammoth Hot Springs area of Yellowstone National Park in the early 1900s. These calves may have been among those in the captive herd that received milk from a domestic cow rather than a bison. Brucellosis, caused by the bacterium *Brucella abortus,* may be transmitted through oral contact with the afterbirth or milk from an infected cow.

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NPS/JIM PEACO

Hayden Valley in Yellowstone National Park.

CHARLES R. PRESTON

Site of proposed Copperleaf development in Wyoming.

In this issue

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Coming this winter, *Yellowstone Science* features the Panther Creek Volcano and microbial ecology.

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