

YELLOWSTONE RESOURCES & ISSUES

2006

The new Canyon Visitor Education Center opens this year.



*Division of
Interpretation*

•
*Yellowstone
National Park*

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Contributors

Production of Yellowstone Resources and Issues 2006 is made possible through the efforts of many people in Yellowstone National Park and beyond. These include:

Karen Angermeier
Lane Baker and staff
Tami Blackford
Tom Cawley
Diane Chalfant
Clare Cloghessy
Jennifer Conrad
Katy Duffy and staff
Judy Knuth Folts
Bob Fuhrmann and staff
Deb Guernsey
Henry Heasler
Judy Jensen and staff
Craig Johnson
Beth Kaeding
Steve Miller
Peggy Olliff
Jim Peaco

Roy Renkin
Ann Rodman & staff
Jo Suderman
Brian Suderman and staff
Virginia Warner
Tammy Wert and staff

Dr. Lisa Morgan, U.S. Geological Survey
Dr. Toni K. Ruth, Wildlife Conservation Society

The Yellowstone National Park staff experts who contributed updates to this edition are listed at the end of each chapter in "For More Information."

Editing, design, production:

Carolyn Duckworth, Publications Program Manager, Division of Interpretation

Managing Editor: Linda Young, Deputy Chief of Interpretation: Planning and Media

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In this book, you will find concise information about the park's history, natural resources, cultural resources, issues, and major areas. This material was provided and reviewed by park researchers, resource specialists, and staffs of Planning, Public Affairs, and Interpretation.

Organization of Chapters:

- Summary box containing key facts
- Main text providing overview of subject
- Resource list for more information

Some material is repeated in the book to accommodate users with varying needs.

*margin arrows
point to ...*

*new
and/or changed
information*

New/revised in 2006:

Ch. 4 revised

Ch. 9 bioprospecting &
winter use revised

Updating the Information

Information about Yellowstone constantly changes; the information provided here is current as of March 2006. You can find updates and comprehensive information on the park website (www.nps.gov/yell), in park publications and exhibits, or by asking the park's interpretive rangers who staff the visitor centers.

We welcome your feedback and comments.



INTRODUCTION

The Beginning of an Idea

One of the most enduring legends of Yellowstone National Park involves its beginning. In 1870, explorers gathered around a campfire at the junction of two pristine rivers, overshadowed by the towering cliffs of the Madison Plateau. They discussed what they had seen during their exploration and realized that this land of fire and ice and wild animals needed to be preserved. Thus, the legend goes, the idea of Yellowstone National Park was born.



It is a wonderful story—and a myth. But those men were real, and so is this land they explored. Thanks to their reports and the work of explorers and artists who followed, the United States Congress established Yellowstone National Park in 1872. The Yellowstone National Park Protection Act says “the headwaters of the Yellowstone River . . . is hereby reserved and withdrawn from settlement, occupancy, or sale . . . and dedicated and set apart as a public park or pleasuring-ground for the benefit and enjoyment of the people.” In an era of expansion throughout the young nation, the federal government had the foresight to set aside land deemed too valuable to develop.

For the following 18 years, Yellowstone was “the national park.” Then in 1890 Congress established three more national parks: Sequoia, General Grant (now part of Kings Canyon), and Yosemite. Mount Rainier followed in 1899. In 1906, Congress passed the Antiquities Act, which gave the president authority to establish national monuments. By 1914, the United States had 30 national parks and monuments, each managed separately and administered by three different federal departments—Interior, Agriculture, and War. No unified policy or plan provided for the protection, administration, and development of these parks and monuments.

The management of Yellowstone from 1872 through the early 1900s, which is described in Chapter 1, helped set the stage for the creation of an agency whose sole purpose was to manage the national parks. Promoters of this idea gathered support from influential journalists, railroads likely to profit from increased park tourism, and members of Congress. The National Park Service Organic Act was passed by Congress and approved by President Woodrow Wilson on August 25, 1916:

There is created in the Department of the Interior a service to be called the National Park Service, [which] . . . shall promote and regulate the use of the Federal areas known as national parks, monuments, and reservations . . . by such means and measures as conform to the fundamental purpose to conserve the scenery and the natural and historic objects and the wild life therein and to provide for the enjoyment of the same in such manner and by such means as will leave them unimpaired for the enjoyment of future generations.

**Law information
revised**

TWO “ORGANIC ACTS”

The laws creating Yellowstone National Park and the National Park Service are both called “The Organic Act” because each was significant enabling legislation. However, the name most often refers to the law that created the National Park Service. To avoid confusion, in this book we will refer to the laws by their names as listed in the U.S. Code Table of Popular Names: The Yellowstone National Park Protection Act and The National Park Service Organic Act.

Today's National Park System

Units in the National Park System

Total, as of March 2006:
390

- 1 International historic site
- 3 Natl. battlefield parks
- 1 Natl. battlefield site
- 11 Natl. battlefields
- 42 Natl. historical parks
- 78 Natl. historic sites
- 4 Natl. lakeshores
- 28 Natl. memorials
- 9 Natl. military parks
- 74 Natl. monuments
- 58 Natl. parks
- 4 Natl. parkways
- 18 Natl. preserves
- 18 Natl. recreation areas
- 2 Natl. reserves
- 5 Natl. rivers
- 3 Natl. scenic trails
- 10 Natl. seashores
- 10 Natl. wild & scenic rivers and riverways
- 11 Sites without designation

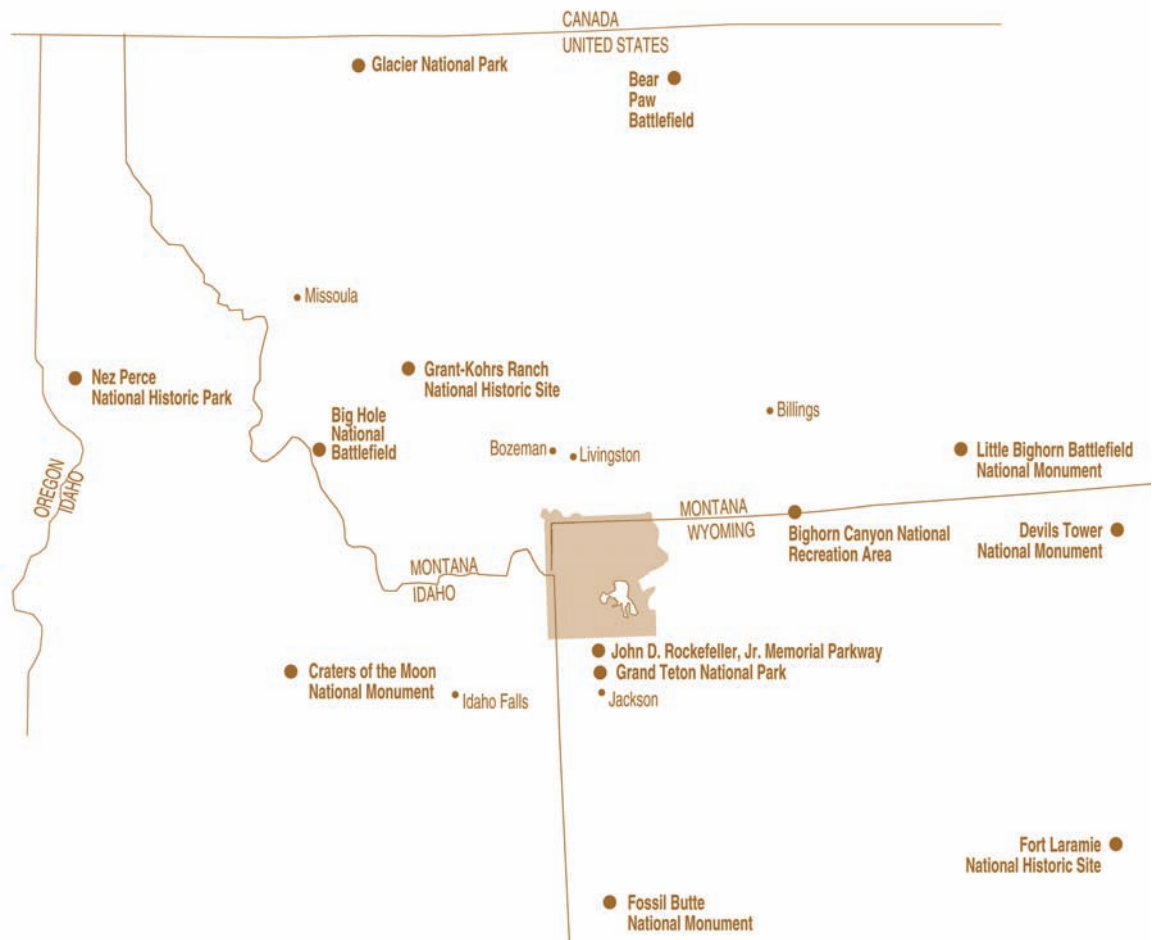
The National Park Service (NPS) manages approximately 83 million acres in 49 states, the Virgin Islands, Puerto Rico, Guam, and American Samoa. Delaware is the only state without an NPS unit.

- **National parks** are the oldest, most well known part of the system and are usually areas of spectacular natural scenery relatively untouched by human development. National parks are established by acts of Congress.
- **National monuments** are areas of historic or scientific interest established by presidential proclamation.
- **National historical parks and national historic sites** are both set aside to commemorate some facet of the history of the people of those areas.

- Many **national memorials** fit the description for national historical parks or sites, but some of these are also set aside because of important historical issues not specifically linked to the site of the memorial, such as Mt. Rushmore and Vietnam Veterans.

Most other types of National Park System units are well defined by their titles.

National Park Units Near Yellowstone



Mission Statement of the National Park Service

Implementing the NPS Mission

System-wide

The NPS Mission Statement expresses the dual responsibility of preserving parks in their natural state (or, at historical areas, to preserve a scene as nearly as it appeared on a certain date), and making these areas accessible for public use and enjoyment. These two fundamental goals can be incompatible and present difficult choices; two policies provide some direction:

- **Natural resources** (plants, animals, water, air, soils, topographic features, paleontologic resources, and esthetic values such as scenic vistas, natural quiet, and clear night skies) are managed to maintain, rehabilitate, and perpetuate their inherent integrity. Native species that have been exterminated should be reintroduced and exotic species eliminated, if possible. Livestock grazing, hunting, and resource extraction are prohibited in National Park System areas, with a few exceptions.
- **Cultural resources** (prehistoric and historic structures and resources, landscapes, archeologic resources, ethnographic resources, and museum collections) are preserved.

Individual Parks

To implement these policies, each park unit prepares a General Management Plan/Master Plan that outlines management zones. In Yellowstone:

- **Natural zones** (most of Yellowstone National Park) protect natural resources and values. All components and processes of park ecosystems, including the natural abundance, diversity, and ecological integrity of the plants and animals, should be maintained. Change is recognized as an integral part of functioning natural systems, and interference is allowed only under special circumstances such as emergencies when human life and property are at stake.
- **Cultural or historic zones**, such as Fort Yellowstone, preserve cultural resources. Where compatible with cultural resource objectives, the policies for natural zones will be followed. Any action that will adversely affect cultural resources will be undertaken only if there is no reasonable alternative, and all reasonable measures to limit adverse effects will be taken, including recovery of data and salvage of materials.

The National Park Service preserves unimpaired the natural and cultural resources and values of the national park system for the enjoyment, education, and inspiration of this and future generations. The Park Service cooperates with partners to extend the benefits of natural and cultural resource conservation and outdoor recreation throughout this country and the world.

- **Development zones**, such as the Old Faithful area, allow for visitor use. Roads, walks, buildings, and other visitor and management facilities may occupy much of the zone and the natural aspect of the land may be altered. However, if a park manager determines that a resource is or would become impaired by public use or development, the manager may limit public use or close a specific area.

International Leadership

The National Park Service example has inspired countries around the world to establish more than 100 national parks—modeled in whole or part on Yellowstone National Park and the National Park Service idea.

Additionally, NPS lends its experienced staff to other countries to evaluate park proposals, management plans, and resource issues.

Yellowstone's Leadership Role

Staff of Yellowstone National Park travel the world to share their expertise. For example:

- the Chief of Interpretation participated in training Chinese officials in the role of education in national parks.
- the Director of Yellowstone Center for Resources has trained park personnel throughout Africa on bioprospecting and benefits-sharing (*see Chapter 9*).
- staff scientists collaborate with scientists in Russia to conduct research on brucellosis (*see Chapter 9*).

As the first national park, Yellowstone also continues to be a leader in developing and implementing policies in the National Park Service, such as the benefits-sharing policies mentioned above and described in Chapter 9.



Mission Statement of Yellowstone National Park

Purpose Statement

Significance of Yellowstone National Park

Preserved within Yellowstone National Park are Old Faithful and the majority of the world's geysers and hot springs. An outstanding mountain wildland with clean water and air, Yellowstone is home of the grizzly bear and wolf and free-ranging herds of bison and elk. Centuries-old sites and historic buildings that reflect the unique heritage of America's first national park are also protected. Yellowstone National Park serves as a model and inspiration for national parks throughout the world. The National Park Service preserves, unimpaired, these and other natural and cultural resources and values for the enjoyment, education, and inspiration of this and future generations.

Yellowstone, the world's first national park:

- preserves geologic wonders, including the world's most extraordinary collection of geysers and hot springs and the underlying volcanic activity that sustains them;
 - preserves abundant and diverse wildlife in one of the largest remaining intact wild ecosystems on Earth, supporting unparalleled biodiversity;
 - preserves an 11,000-year-old continuum of human history, including the sites, structures, and events that reflect our shared heritage; and
 - provides for the benefit, enjoyment, education, and inspiration of this and future generations.
-
- International symbol of natural preservation.
 - A Biosphere Reserve and a World Heritage Site (*see page 13*).
 - Contains approximately half of the world's hydrothermal features—more than 10,000—including the world's largest concentration of geysers—more than 300.
 - Home of the world's tallest active geyser, Steamboat, which erupts to more than 300 feet.
 - One of the few places in the world with active travertine terraces.
 - Hydrothermal features are habitats for microbes that are providing links to primal life, origins of life, and astrobiology; plus they are proving useful in solving some of our most perplexing medical and environmental problems (*see Chapter 9*).
 - With the restoration of the gray wolf in 1995, the park now contains all the large mammal species known to be present when European Americans first arrived.
 - Protects the gray wolf (federally listed as endangered and designated experimental and non-essential in Yellowstone National Park) and three threatened species—the grizzly bear, the bald eagle, and the lynx.
 - Home to one of the largest concentrations of elk in the world. (Rocky Mountain National Park also has a large concentration of elk.)
 - Only place in the U.S. where bison have existed in the wild since primitive times. The early legislation that protected these bison, the Lacey Act of 1894, was a precursor to the Endangered Species Act.
 - Site of one of the largest volcanic eruptions in the world, which left behind one of the largest calderas. (*See Chapter 3.*)
 - Site of the spectacular Grand Canyon of the Yellowstone River. (*See Chapter 10.*)
 - Location of largest lake above 7,000 feet in North America—Yellowstone Lake. (*See Chapter 10.*)
 - Source of two great North American rivers: two of the three forks of the Missouri River, and the Snake, which is part of the Columbia River system. The Yellowstone River, which begins just south of the park, is the longest free-flowing river in the U.S.

GEOLOGY

An active volcano
1,000–3,000 earthquakes annually
More than 10,000 hydrothermal features
More than 300 geysers
One of the world's largest calderas,
measuring 45 x 30 miles
Approximately 290 waterfalls,
15 ft. or higher, flowing year-round
Tallest waterfall in the front country:
Lower Falls of the Yellowstone River at
308 ft.

YELLOWSTONE LAKE

131.7 square miles of surface area
141 miles of shoreline
20 miles north to south
14 miles east to west
Average depth: 140 feet
Maximum depth: About 430 feet

WILDLIFE

61 species of mammals, including:
7 species of native ungulates
2 species of bears
320 recorded species of birds (148 nesting
species)
16 species of fish (5 non-native)
6 species of reptiles
4 species of amphibians
3 threatened species: bald eagle, grizzly bear,
lynx
2 endangered species: whooping crane
(currently absent), gray wolf (designated
an experimental and non-essential
population in Yellowstone National Park)

FLORA

7 species of conifers
Approximately 80% of forest is comprised
of lodgepole pine
Approximately 1,098 species of native
vascular plants
More than 199 species of exotic
(non-native) plants
186 species of lichens
At least 406 species of thermophiles (only
1% of hydrothermal areas inventoried)

CULTURAL RESOURCES

Approximately 1,100 documented
archeological sites
26 associated Native American tribes
6 National Historic Landmarks
1 National Historic Landmark District
5 National Historic Districts
More than 379,000 cultural objects and
natural science specimens
Thousands of books (many rare),
manuscripts, and periodicals
90,000 historic photographs

VISITATION

2005: 2,835,649 entries to the park
2005–2006 winter: 88,718 entries
Record year: 1992—3,144,405 entries

FACILITIES

9 visitor centers, museums, and contact
stations
9 hotels/lodges (2,238 hotel rooms/cabins)
7 NPS-operated campgrounds (454 sites)
5 concession-operated campgrounds (1,747
sites)
More than 1,500 buildings (NPS and
concessions)
52 picnic areas
1 marina
13 self-guiding trails

ROADS AND TRAILS

5 park entrances
466 miles of roads (310 paved/primary
miles)
More than 15 miles of boardwalk
Approximately 1,000 miles of backcountry
trails
92 trailheads
301 backcountry campsites

EMPLOYEES

Approximately 800 people work for the
National Park Service at peak summer
levels; about 400 year-round
Approximately 3,500 people work for
concessioners at peak summer levels

Park Facts

*World's first national
park*

*A designated World
Heritage Site and
Biosphere Reserve*

** 3,472 square miles
or 8,987 square km*

** 2,221,766 acres or
899,139 hectares*

*63 air miles north to
south (102 km)*

*54 air miles east to
west (87 km)*

*96% in Wyoming,
3% in Montana,
1% in Idaho*

*Highest Point: 11,358
ft. (Eagle Peak)*

*Lowest Point: 5,282 ft.
(Reese Creek)*

*Larger than the states
of Rhode Island &
Delaware combined*

*Approximately 5% of
park is covered by
water; 15% is
grassland; and 80%
is forested*

*Precipitation ranges
from 10 inches (26
cm) at the north
boundary to 80
inches (205 cm)
in the southwest
corner*

*Temperatures
Average at Mammoth*

*Hot Springs:
January: 9°F
July: 80°F*

*Records:
High: 99°F
(Mammoth, 2002)
Low: -66°F
(Madison, 1933)*

*** About park square mileage and acreage:** No area figures for the park have been scientifically verified. The figures used here have been used for many years and in different references. They differ from the park's master deed, which also contains unverified figures. Efforts to confirm the total park area continue.

Frequently Asked Questions: General

How did Yellowstone get its name?

When French-Canadian trappers encountered the Minnetaree tribe along this river in what is today eastern Montana, they asked about the name of the river. The Minnetaree responded “Mi tse a-da-zi,” which translates as “Rock Yellow River.” (Historians do not know why the Minnetaree gave this name to the river.) The trappers translated this into French—“Roche Jaune” or “Pierre Jaune.” In 1797, explorer-geographer David Thomson used the English version—“Yellow Stone.” Lewis and Clark called the Yellowstone River by the French and English forms. Subsequent usage formalized the name as “Yellowstone.”

Did other national parks exist before Yellowstone?

Some sources list Hot Springs in Arkansas as the first national park—it was set aside in 1832, forty years before Yellowstone was established—but it was actually the nation’s oldest national *reservation*, set aside to preserve and distribute a utilitarian resource (hot water), much like our present national forests. In 1921, an act of Congress established Hot Springs as a national park.

Other sources argue Yosemite was the first national park, but it was actually a state park. In 1864, Congress set aside the area surrounding the Yosemite Valley and the Mariposa Grove of Big Trees and gave them to the state of California to administer for public use and recreation. In 1890, Congress established

Yosemite as a national park 18 years after it established Yellowstone National Park.

Is Yellowstone the largest national park?

No. More than half of Alaska’s national park units are larger, including Wrangell–St. Elias National Park and Preserve, which is the largest unit in the National Park System (13 million acres). Until 1994, Yellowstone (at 2.2 million acres) was the largest national park in the contiguous states. That year Death Valley National Monument was expanded and became a national park—it has more than 3 million acres.

Does Yellowstone include a federally designated wilderness?

No. Most of the park was recommended for this designation in 1972, but Congress has not acted on the recommendation. *See Chapter 9, “Wilderness.”*

Is Yellowstone the most visited national park?

No. It’s the sixth-most visited. Great Smoky Mountains National Park has the most visitors—more than 9 million.

How many rangers work in Yellowstone?

Approximately 180 rangers work in the park during the peak summer season; less than 100 year-round. Park rangers perform duties in interpretation, education, resource management, law enforcement, emergency medical services, and backcountry operations. Many

other people work in research, maintenance, management, administration, trail maintenance, fire management, and fee collection. In total, approximately 800 people are employed by the National Park Service in Yellowstone (approximately 387 permanent, 500 seasonal).

What is the highest peak in Yellowstone?

Eagle Peak in the southeastern part of the park is the highest at 11,358 feet.



How cold does Yellowstone get in winter?

Average winter highs are 20–30°F; average lows are 9–0°F. The record low was –66°F (–54°C) at Madison on February 9, 1933.

What is the Continental Divide?

Think of the Continental Divide as the crest of the continent. Theoretically, when precipitation falls on the west side of the Divide, it eventually reaches the Pacific Ocean. When it falls on the east side of the Divide, it eventually reaches the Atlantic Ocean. In Yellowstone (as elsewhere), this ridgeline is not straight. It follows the twists and turns of the mountains through the southwestern part of the park. Therefore, you cross the Continental Divide three times while traveling from the South Entrance to Old Faithful.

Why is Yellowstone called a Biosphere Reserve and a World Heritage Site, and what do these designations mean?

The United Nations designated Yellowstone National Park as a Biosphere Reserve and a World Heritage Site because of the worldwide significance of its natural and cultural resources. These designations have nothing to do with how Yellowstone is managed—the United Nations has no authority to dictate federal land management decisions in the United States—nor do they change the fact that Yellowstone is under the legal authority of the United States of America.

The October 26, 1976, United Nations designation of Yellowstone as a Biosphere Reserve stated: “Yellowstone National Park is recognized as part of the international network of biosphere reserves. This network of protected samples of the world’s major ecosystem types is devoted to conservation of nature and scientific research in the service of man. It provides a standard against which the effect of man’s impact on the environment can be measured.”

The September 8, 1978, United Nations designation of Yellowstone as a World Heritage Site, requested by U.S. President Richard Nixon and Congress, stated: “Through the collective recognition of the community of nations . . . Yellowstone National Park has been designated as a World Heritage Site and joins a select list of protected areas around the world whose out-

standing natural and cultural resources form the common inheritance of all mankind.”

In 1995, Yellowstone was placed on a list of endangered World Heritage sites in part because of a proposed gold mine outside the Northeast Entrance. In 2003, it was removed from the list because the mine was no longer a threat.

What is the difference between a national park and a national forest?

National parks are administered by the Department of the Interior and national forests by the Department of Agriculture. The National Park Service is mandated to preserve resources unimpaired, while the U.S. Forest Service is mandated to wisely manage resources for a variety of sustainable uses.

Yellowstone National Park is surrounded by six units in the national forest system, as shown in the map below.

FAQ: General



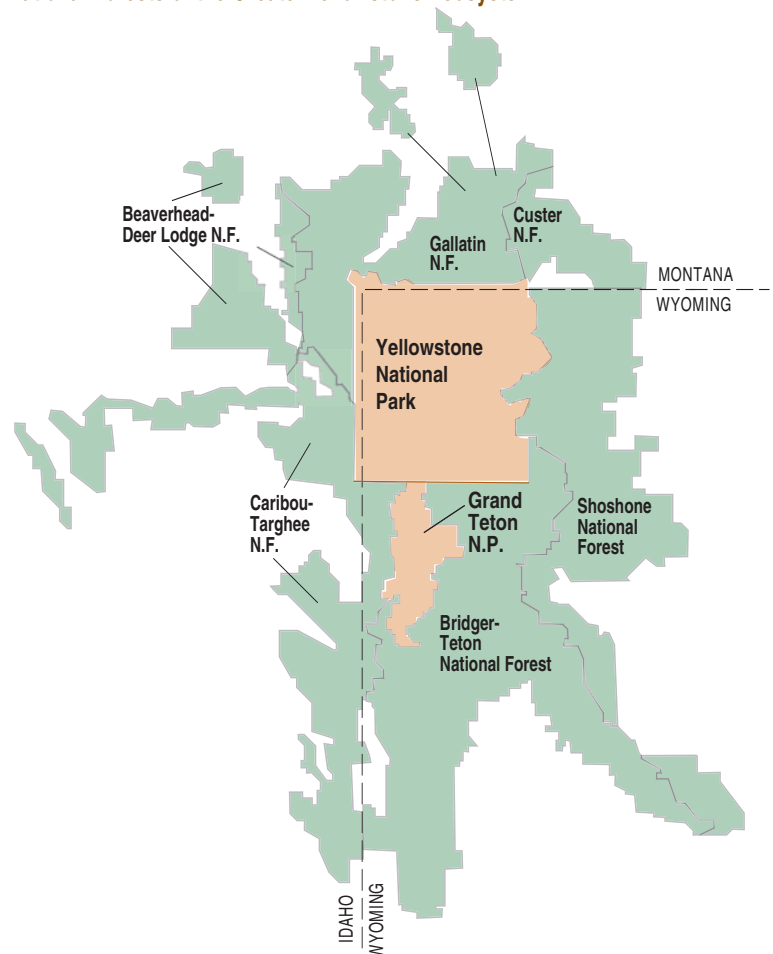
Yellowstone is an international Man and the Biosphere site.

www.cr.nps.gov/worldheritage

www.unesco.org/whc

www.unesco.org/mab

National Forests of the Greater Yellowstone Ecosystem



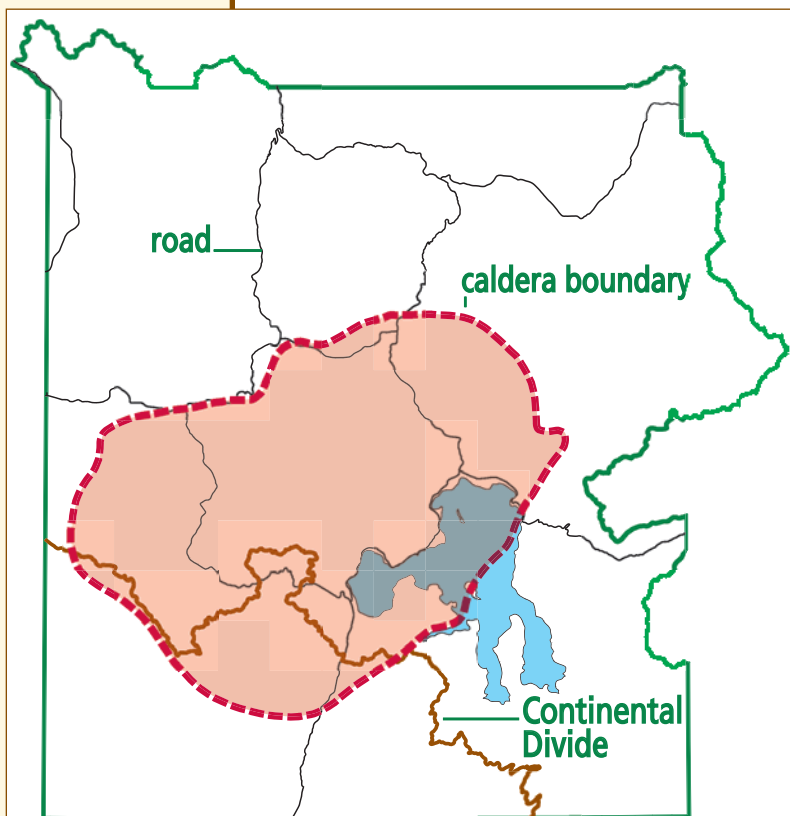
FAQ: Volcanic Geology

Is Yellowstone a volcano?

Yes. Within the past two million years, many volcanic eruptions have occurred in the Yellowstone area—three of them major.

What is the caldera line on the park map?

The caldera line marks the rim of a crater, or caldera, created by a massive volcanic eruption in Yellowstone approximately 640,000 years ago. (This date changes as scientists fine-tune their ability to determine events in geologic time.) Subsequent lava flows filled in the crater, and it is now measured at 30 x 45 miles. Its rim can be seen from these areas in the park: Mt. Washburn, Gibbon Falls, Lewis Falls, and Flat Mountain Arm of Yellowstone Lake.



Is Yellowstone's volcano still active?

Yes. The park's vast hydrothermal features attest to the heat still beneath this area. Numerous earthquakes—1,000 to 3,000 per year—also reveal activity below ground. The Yellowstone Volcano Observatory (YVO) monitors an array of signals to track this activity. (See page 49 for more about YVO.)

What is a supervolcano?

Some scientists consider Yellowstone to be a "supervolcano," which refers to an eruption of more than 240 cubic miles of magma. Two of Yellowstone's three major eruptions met the criteria. (See Chapter 3.)

Will Yellowstone erupt soon?

There is no evidence that a catastrophic eruption is imminent. Current geologic activity at Yellowstone has remained relatively constant since earth scientists first started monitoring some 30 years ago. Though another caldera-forming eruption is theoretically possible, it is very unlikely to occur in the next thousand or even 10,000 years. Scientists have also found no indication of an imminent smaller eruption of lava.

How do scientists know Yellowstone won't erupt?

As mentioned earlier, the Yellowstone Volcanic Observatory has an array of monitors in place throughout the region. These monitors would detect sudden or strong movements or shifts in heat that would indicate increasing activity. No such evidence exists at this time.

In addition, YVO scientists collaborate with scientists from all over the world to study and assess the hazards of the Yellowstone volcano. To learn more about Yellowstone's volcanic past, to view current data about earthquakes, ground movement, and stream flow, visit the YVO website at <http://volcanoes.usgs.gov/yvo/>.

What is Yellowstone National Park doing to stop or prevent an eruption?

Nothing can be done to prevent an eruption. The temperatures, pressures, physical characteristics of partially molten rock and immensity of the magma chamber are beyond human ability to impact—much less control.

If Old Faithful Geyser quits erupting, would that be a sign the volcano is about to erupt?

All geysers are highly dynamic, including Old Faithful. We expect Old Faithful to change in response to the ongoing geologic processes associated with mineral deposition and earthquakes. Thus, a change in Old Faithful Geyser will not necessarily indicate a change in volcanic activity.

FAQ: Hydrothermal Geology

Why are geysers in Yellowstone?

Yellowstone's volcanic geology provides the three components for geysers and other hydrothermal features: heat, water, and a natural "plumbing" system. Magma beneath the surface provides the first ingredient: heat. Ample rain and snowfall supply the second ingredient: water. The water seeps several thousand feet (more than a kilometer) below the surface where it is heated. Underground cracks and fissures form the third ingredient: plumbing. Hot water rises through the plumbing to surface as hydrothermal features in Yellowstone. Geysers occur when that plumbing is constricted. (*See Chapter 3.*)

What exactly is a geyser basin?

A geyser basin is a geographically distinct area that contains a "cluster" or array of hydrothermal features that may include geysers, hot springs, mudpots, and fumaroles. These distinct areas often (but not always) occur in topographically low places because hydrothermal features tend to be concentrated around the margins of lava flows and in areas of faulting.

Why can't I bring my dog on geyser basin trails?

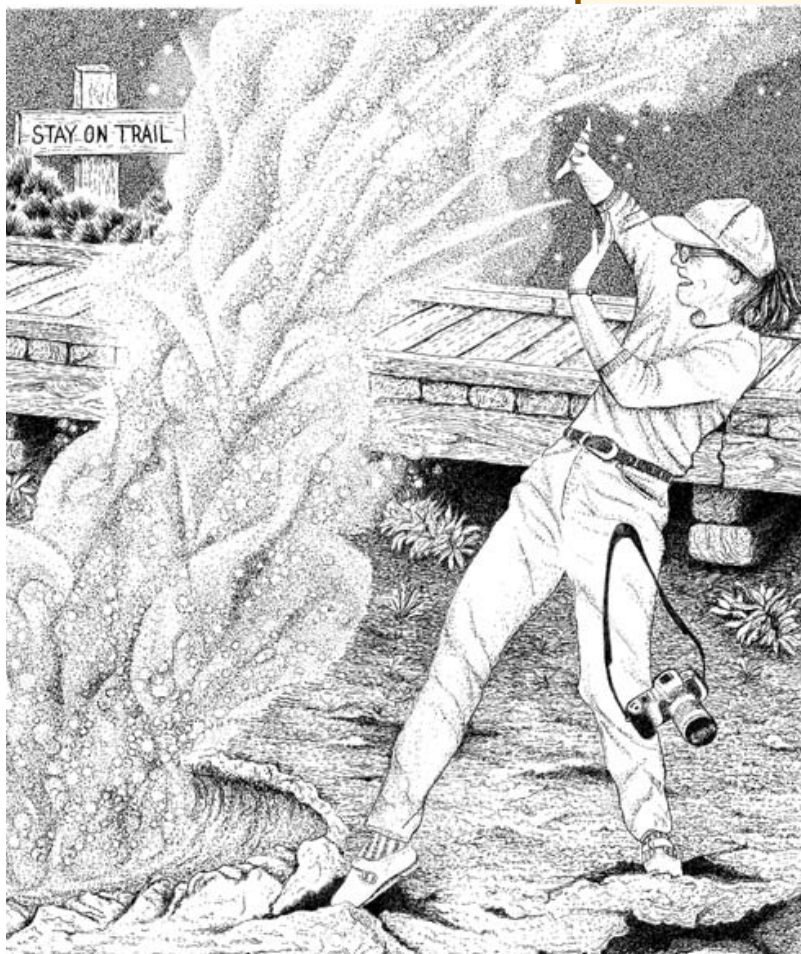
Dogs do not seem to recognize the difference between hot and cold water. Dogs have died diving into hot springs. They also disturb wildlife and are prohibited from all park trails. Pets must be kept on a leash at all times. Ask at a visitor center where you can safely and legally walk a pet.

Is it really dangerous to walk off the boardwalks in geyser basins?

YES! Geyser basins are constantly changing. Boiling water surges just under the thin crust of most geyser basins, and many people have been severely injured (second and third degree burns) when they have broken through the fragile surface. Some people have died from falling into hydrothermal features.

Why can't I smoke in the geyser basins?

Litter of any kind can clog vents, thus altering or destroying hydrothermal activity. Cigarette butts quickly accumulate if smoking is allowed. Also, sulfur deposits exist in these areas, and they easily catch fire, producing dangerous—sometimes lethal—fumes.



Were Native Americans afraid of geysers?

The associated tribes of Yellowstone state their people have used the park as a place to live, to collect food and other resources, and as a passage through to the bison hunting grounds of the Great Plains. Archeologists and historians have also uncovered ample evidence that people lived in and visited Yellowstone for thousands of years before historic times. *See chapters 1 and 8 for more about Native Americans in Yellowstone.*

See chapters 2–4 for more information about geology in Yellowstone.

FAQ: Wildlife



Where are the bears?

People who visited Yellowstone prior to the 1970s often remember seeing bears along roadsides and within developed areas of the park. Although observing these habituated bears was very popular with park visitors, it was not good for the people or the bears. (See Chapter 9.) In 1970, the park initiated an intensive bear management program to return the grizzly and black bears to feeding on natural food sources and to reduce bear-caused human injuries. Among the measures: garbage cans were bear-proofed and garbage dumps within the park were closed.

Bears are still sometimes seen near roads and they may be viewed occasionally in the wild. Grizzly bears are active primarily at dawn, dusk, and night. In spring, they may be seen around Yellowstone Lake, Fishing Bridge, and the East Entrance due to the trout spawning creeks in these areas. In mid-summer, they are most commonly seen in the meadows between Tower–Roosevelt and Canyon, and in the Lamar Valley. Black bears are most active at dawn and dusk, and sometimes during the middle of the day. Look for black bears in open spaces within or near forested areas. Black bears are most commonly observed between Mammoth, Tower, and the Northeast Entrance.

Where can I see wildlife?

It helps to know the habits and migration patterns of the animals you want to see and the habitats in which they live. For example, bighorn sheep are adapted to live on steep terrain; so you might see them on cliffs in the Tower area. Osprey eat fish, so you would expect to see them along rivers. “Yellowstone Today,” the park’s newspaper, provides general guidelines for wildlife watching and information about the park’s wolves. Rangers at the visitor centers can also provide local details. Reference lists at the end of chapters 7 & 9 provide further sources of information about Yellowstone’s wildlife. You’ll find more on the park’s official website, www.nps.gov/yell.

What is the difference between a bison and a buffalo?

None. In North America, both terms refer to the American bison; the scientific name is *Bison bison*. Early European explorers called this animal by many names. Historians believe that the term “buffalo” grew from the French word for beef, “boeuf.” Some people insist that the term “buffalo” is incorrect because the “true” buffalo exist on other continents and are only distant relatives. However, “buffalo” is used for less formal, everyday use; “bison” is preferred for scientific use. In this book, we use “bison.”

Why is fishing lead-free in Yellowstone?

Scientific evidence continues to mount regarding the dangers of lead concentrations in aquatic environments. Birds, such as loons, waterfowl, cranes, and shorebirds, are vulnerable to lead poisoning. Of particular concern in Yellowstone are the alarmingly low populations of trumpeter swans and loons. We strive to maintain viable breeding populations of these sensitive birds. While we can do little about natural hazards, we can minimize the effects of lead on these species. Yellowstone National Park bans most lead tackle. (Terminal tackle must be lead-free; sinkers used to fish for deep-dwelling lake trout are permissible because they are too large to be ingested.)

See Chapter 7 for more information about wildlife in Yellowstone.

How much of the park burned in 1988?

The 1988 fires affected 793,880 acres or 36 percent of the park. Most of these acres sustained ground surface burns. Five fires burned into the park that year from adjacent public lands, including the largest, the North Fork fire. It started accidentally and burned more than 410,000 acres.

Could the fires have been predicted? How were weather conditions different than in previous years?

Yellowstone usually experiences afternoon showers three or four days each week during the summer, but in 1988 no rain fell for almost three months. The most severe drought in the park's recorded history occurred that summer. Also, a large number of lightning strikes came with a series of dry storm fronts. This lightning started many of the fires and storm fronts stoked them with particularly high and sustained winds.

Could the fires have been put out?

It is possible that the few fires that started in early June might have been extinguished. However, between 1972 and 1987, the average fire had gone out naturally after burning only one acre. So, while the early fires were monitored closely and some were contained from going out of the park, the history of fire behavior in Yellowstone, coupled with an abnormally wet spring, suggested these fires would go out as previous fires had. After July 15, all fires were fought aggressively from the moment they were detected. Despite the largest firefighting effort in the history of the nation, weather finally contained the fires when snow fell in September.

Did Yellowstone's fire management policy change after the fires of 1988?

After 1988, the fire policy underwent extensive review and a revised Fire Management Plan was implemented in 1992. As before, fires that threaten life and property and fires that are human-caused will be suppressed immediately. Plus, even naturally ignited (lightning-caused) fires may be put out if they do not meet all the criteria to be allowed to burn. The National Fire Plan 2000 was implemented late in 2000 in response to the extensive fire season that summer. (*See Chapter 6.*)

How does fire benefit Yellowstone?

Fires are a natural part of the Northern Rockies ecosystem. Vegetation in the Greater Yellowstone Ecosystem has adapted to fire and in some cases may be dependent on it. Fire promotes habitat diversity by removing the forest overstory, allowing different plant communities to become established, and preventing trees from becoming established in grassland. Fire increases the rate that nutrients become available to plants by rapidly releasing them from wood and forest litter and by hastening the weathering of soil minerals. This is especially important in a cold and dry climate like Yellowstone's, where decomposition rates are slower than in more hot and humid areas.

In addition, the fires of 1988 provided a rare natural laboratory for scientists to study the effects of fire on an ecosystem.

**FAQ:
Fires of
1988**

See Chapter 6 for more information about fire ecology, management, and the fires of 1988.

HISTORY OF THE PARK

1

The human history of the Yellowstone region goes back more than 11,000 years. How far back is still to be determined, but humans probably were not here when the entire area was covered by ice caps and glaciers. The last period of ice coverage ended approximately 14,000 years ago—and sometime after that, humans arrived here.

The Earliest Humans in Yellowstone

Human occupation of the greater Yellowstone area seems to follow environmental changes of the last 15,000 years. Glaciers and a continental ice cap covered most of what is now Yellowstone National Park. They receded approximately 14,000 B.P. (before present) and left behind rivers and valleys that people could follow in pursuit of Ice Age mammals such as the mammoth and the giant bison.

The first people arrived in this region sometime before 10,000 B.P. Archeologists have found little physical evidence of their presence except for their distinctive stone tools and projectile points. From these artifacts, scientists surmise that they hunted mammals and ate berries, seeds, and roots.

As the climate in the Yellowstone region warmed and dried, the animals, vegetation, and human lifestyles also changed. Large Ice Age animals that were adapted to cold and wet conditions became extinct. The glaciers left behind layers of sediment in valleys in which grasses and sagebrush thrived and pockets of exposed rocks that provided protected areas for aspens and fir to grow. The uncovered volcanic plateau sprouted lodgepole forests. By about 7,000 B.P., people had adapted to these changing conditions. They could no longer rely on large mammals for food. Instead, smaller animals such as deer and bighorn sheep became more important in their diet as did plants such as bitterroot and prickly pear. They may have also established a distinct home territory in the valleys and surrounding mountains.

HIGHLIGHTS OF YELLOWSTONE'S HISTORY

- People have been in Yellowstone more than 11,000 years, as evidenced by archeological sites, trails, and oral histories.
- Although Sheep Eaters are the most well-known group of Native Americans to use the park, many other tribes and bands lived in and traveled through what is now Yellowstone National Park prior to and after European American arrival.
- European Americans began exploring Yellowstone in the early 1800s.
- First organized expedition explored Yellowstone in 1870.
- Yellowstone National Park established in 1872.
- Railroad arrived in 1883, allowing easier visitor access.
- The U.S. Army managed the park from 1886 through 1918.
- Automobiles allowed into the park in 1915, making visits easier and more economical.
- First boundary adjustment of the park made in 1929.
- "Leopold Report" released in 1963; its recommendations changed how wildlife is managed in the park.
- 1970: First bear management plan.
- 1988: "Summer of Fire."
- 1995: Wolves restored to the park.



*Knife (9350 B.P.)
from the Yellowstone
National Park
Museum Collection*

PaleoIndian Period

Folsom people were in the greater Yellowstone area as early as 10,900 B.P.—the date of an obsidian Folsom projectile point found near Pinedale, Wyoming.

Sites along the Canyon to Lake Road yielded PaleoIndian artifacts.

Hell Gap Point (shown at right), 9600–10,000 B.P.

10,000 B.P.



Archaic Period

9350 B.P.

A site on the shore of Yellowstone Lake was excavated in 2000 and 2002, and dated to 9350 B.P. The points had traces of blood from rabbit, dog, deer, and bighorn. People seem to have occupied this site for short, seasonal periods.

7000 B.P.

Vegetation similar to what we find today begins to appear. Sites reveal earth ovens used for preparing food. Food used included meat, roots, seeds. Projectile points begin to be notched.



Obsidian Cliff, a major source of obsidian for western North America, was designated a National Historic Landmark in June 1996.

This favorable climate would continue more than 9,000 years. Evidence of these people in Yellowstone remained uninvestigated, even long after archeologists began excavating sites elsewhere in North America.

Archeologists used to think high regions such as Yellowstone were inhospitable to humans and thus, did little exploratory work in these areas. However, park superintendent Philetus W. Norris (1877–82) found artifacts in Yellowstone and sent them to the Smithsonian Institution in Washington, D.C. Today, archeologists study environmental change as a tool for understanding human uses of areas such as Yellowstone.

About 1,100 archeological sites have been documented in Yellowstone National Park, with the majority from the Archaic period. Sites contain evidence of successful hunts for bison, sheep, and elk.

Campsites and trails in Yellowstone (see map next page) also provide evidence of early use. Some trails have been used by people since the PaleoIndian period.

No scientific evidence conclusively connects prehistoric tribes with historic people such as the Crow and Sioux, but oral histories provide links. For example, the oral tradition of the Salish places their ancestors in this region several thousand years ago. The Shoshone say they originated here.

Increased Use

People seem to have increased their use of the Yellowstone area beginning about 3,000 years ago. During this time, they developed the bow and arrow, which replaced the atlatl, or spear-thrower, that had been used for thousands of years. With the bow and arrow, people hunted more efficiently. They also developed sheep traps and bison corrals. Remains of sheep traps are assumed to have existed in the mountains of Yellowstone at least prior to

continued on page 22

Archaic Period

Beginning 9000 B.P. until 1000 A.D., people leave traces of camps on shores of Yellowstone Lake.

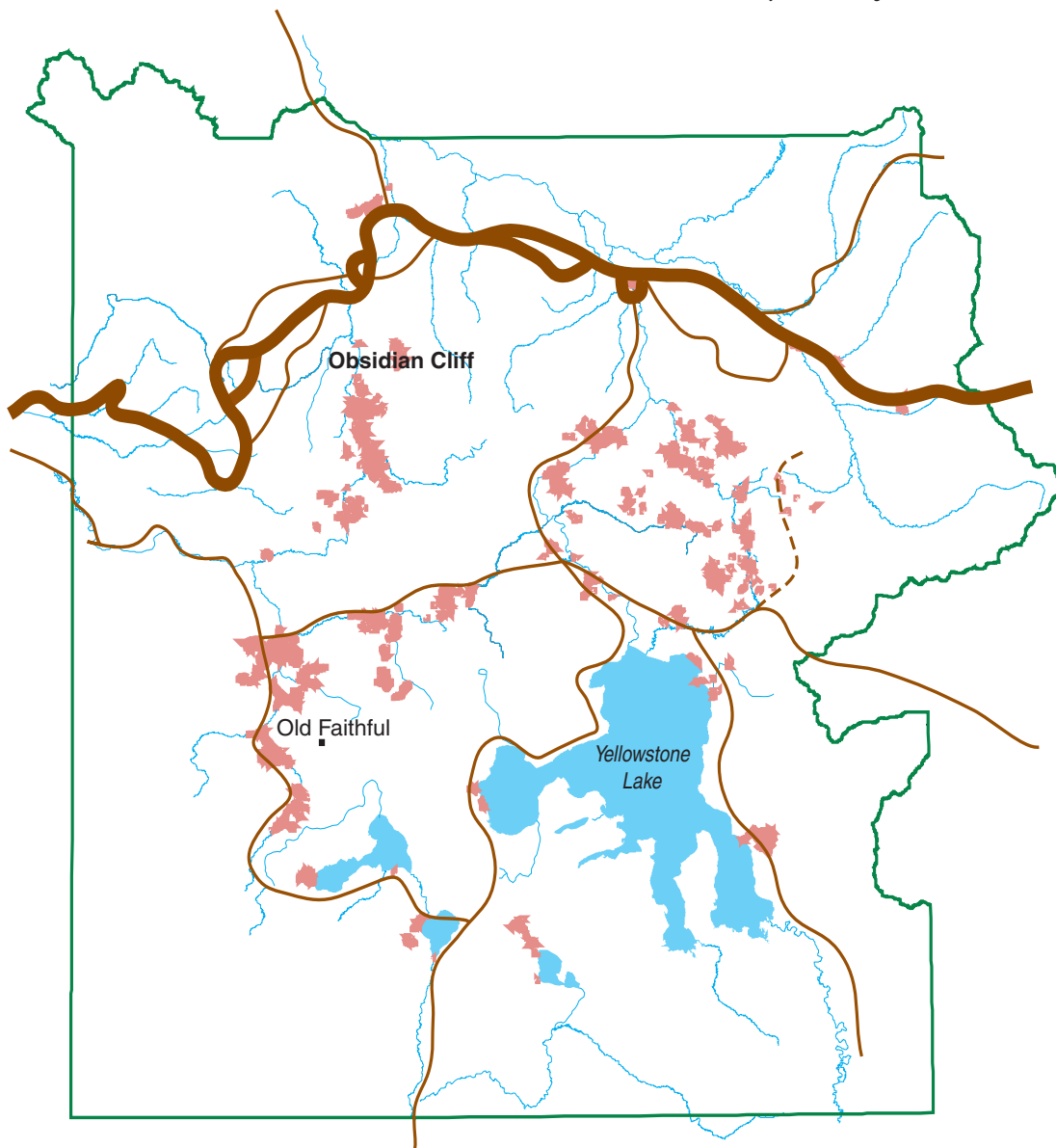
Prehistoric Period

3000 B.P.

Oral histories of the Salish place their ancestors in the Yellowstone area.

1500 B.P.

After 1500 B.P., bow and arrow replaces atlatl (throwing spear); sheep traps (in the mountains) and bison corrals (on the plains) begin to be used in the Rocky Mountain region.



Bannock Trail

The Bannock Trail probably was used off and on for centuries. Its current name comes from the frequent use in the 1800s by the Bannock, who crossed the Yellowstone Plateau to reach the plains east of the park to hunt bison after the animal had been exterminated from the tribe's homeland, the Snake River Plains. They crossed the Yellowstone River upstream from its confluence with Tower Creek. Many people have thought this ford was an ancient crossing. However, archeological investigations have found no evidence of repeated, long-term use. Ethnographers are consulting with tribes to find out if their traditions include information on the ford. (See Chapter 8 for more about archeological and ethnographic approaches to cultural resources.)

- Bannock Trail
- Other Trails
- Possible Trail
- Lakes
- Rivers
- Hydrothermal Areas

Map adapted from "Fear or Reverence? Native Americans and the Geysers of Yellowstone," by Joseph Weixelman, *Yellowstone Science*, Fall 2001.

1

History

Determining Dates

Archeologists in this region commonly use two techniques to date their findings:

Radiocarbon dating measures the amount of carbon 14 remaining in an organic sample, usually charcoal or bone. Atmospheric radiocarbon enters the life cycle of plants and animals during respiration. After death, carbon 14 no longer enters the organism and begins to decay at a known rate. Sophisticated equipment measures the amount of remaining carbon 14, which is used to calculate the time since death.

Obsidian hydration measures the rate obsidian absorbs water at its surface, which is dependent on temperature. Measuring the thickness of the hydration layer determines an artifact's date of manufacture.

Tribes used hydrothermal sites ceremonially and medicinally. The Mud Volcano area was especially significant for the Kiowa. Their tradition says that a hot spring called Dragon's Mouth (below) is where their creator gave them the Yellowstone area for their home. The Crow also have stories about this feature.

A.D. 1000

1400

1450

1600s

Oral histories of the Kiowa place their ancestors in the Yellowstone area from this time through the 1700s.

Little Ice Age begins.

North American tribes begin acquiring horses in the mid- to late 1600s.

Ancestors of the Crow may have come into Yellowstone during this time.

the 1988 fires; bison corrals were used in the Yellowstone River valley north of the park.

This increased use of Yellowstone may have occurred when the environment was warmer, favoring extended seasonal use on and around the Yellowstone Plateau. Archeologists and other scientists are working together to study evidence such as plant pollen, landforms, and tree rings to understand how the area's environment changed over time.

The Little Ice Age

Climatic evidence has already confirmed the Yellowstone area experienced colder temperatures during what is known as the Little Ice Age—mid-1400s to mid-1800s.

Archeological evidence indicates fewer people used this region during this time. Campsites appear to have been used by smaller groups of people, mostly in the summer. Such a pattern of use would make sense in a cold region where hunting and gathering were practical for only a few months each year. The Shoshone say family groups came to Yellowstone to gather obsidian, which they used on site to field dress buffalo.

Historic Tribes

Tribal oral histories indicate more extensive use during the Little Ice Age. Kiowa stories place their ancestors here from around A.D. 1400 to A.D. 1700. Ancestors to contemporary Blackfeet, Cayuse, Coeur d'Alene, Bannock, Nez Perce, Shoshone, and Umatilla, among others, continued to travel the park on the already established trails. They visited geysers, conducted ceremonies, hunted, gathered plants and minerals, and engaged in trade. Some tribes used the Fishing Bridge area as a rendezvous site.

The Crow occupied the country generally east of the park, and the Blackfeet occupied the country to the north. The Shoshone, Bannock, and other tribes of the plateaus to the west traversed the park annually to hunt on the plains to the east. Other Shoshonean groups hunted in open areas west and south of Yellowstone.

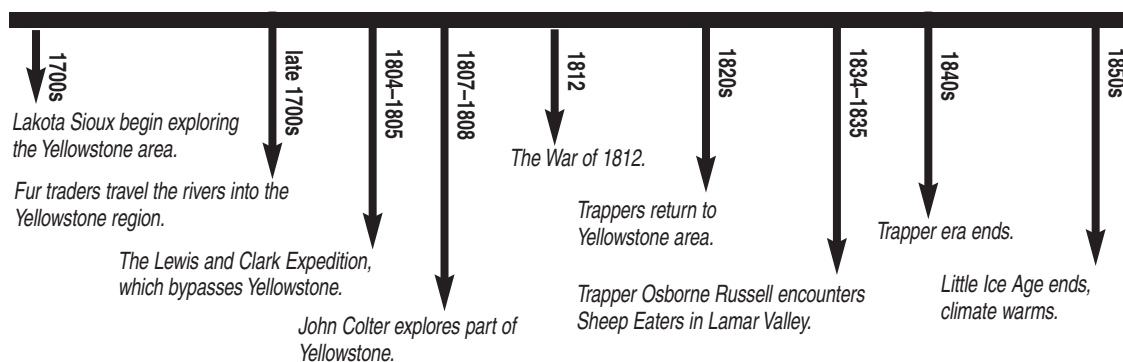
In the early 1700s, some tribes in this region began to acquire the horse. Some historians believe the horse fundamentally changed lifestyles because tribes could now travel faster and farther to hunt bison and other animals of the plains. However, the horse does not seem to have changed the tribes' traditional uses of the Yellowstone area.

The "Sheep Eaters"

Some groups of Shoshone who adapted to a mountain existence chose not to acquire the horse. These included the Sheep Eaters, or Tukudika, who used their dogs to transport food, hides, and other provisions.

Sheep Eaters acquired their name from the bighorn sheep whose migrations they followed. Bighorn sheep were a significant part of their diet, and they crafted the carcasses into a wide array of tools and implements. For example, they made bows from sheep horn made pliable from soaking in hot





springs. They traded these bows, plus clothing and hides, to other tribes.

European Americans Arrive

In the late 1700s, fur traders traveled the great tributary of the Missouri River, the Yellowstone, in search of Native Americans to trade with. They called the river by its French name, “Roche Jaune.” As far as we know, pre-1800 travelers did not observe the hydrothermal activity in this area but they probably learned of these features from Native American acquaintances.

The Lewis and Clark Expedition, sent by President Thomas Jefferson to explore the newly acquired lands of the Louisiana Purchase, bypassed Yellowstone. They had heard descriptions of the region, but did not explore the Yellowstone River beyond what is now Livingston, Montana.

A member of the Lewis and Clark Expedition, John Colter, left that group during its return journey to join trappers in the Yellowstone area. During his travels, Colter probably skirted the northwest shore of Yellowstone Lake and crossed the Yellowstone River near Tower Fall, where he noted the presence of “Hot Spring Brimstone.”

Not long after Colter’s explorations, the United States became embroiled in the War of 1812, which drew men and money away from exploration of the Yellowstone region. The demand for furs resumed after the war and trappers returned to the Rocky Mountains in the 1820s. Among them was Daniel Potts, who also published the first account of Yellowstone’s wonders as a letter in a Philadelphia newspaper (see quote at right).

Jim Bridger also explored Yellowstone during this time. Like many trappers, Bridger spun tall tales as a form of entertainment around the evening fire. His stories inspired future explorers to discover the truth.



As quickly as it started, the trapper era ended. By the mid-1840s, beaver became scarce and fashions changed. Trappers turned to guiding or other pursuits.

Looking for Gold

During 1863–1871, prospectors crisscrossed the Yellowstone Plateau every year and searched every crevice for gold and other precious minerals. Although gold was found nearby, no big strikes were ever made inside what is now Yellowstone National Park.

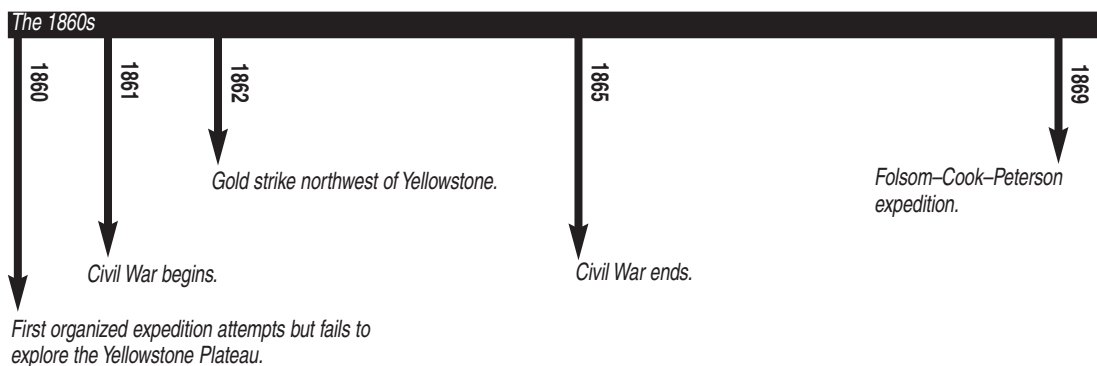
Expeditions “Discover” Yellowstone

Although Yellowstone had been thoroughly tracked by trappers and tribes, in the view of the nation at large it was really “discovered” by formal expeditions. The first organized attempt came in 1860 when Captain William F. Reynolds led a military expedition, but it was unable to explore the Yellowstone Plateau because of late spring snow. The Civil War preoccupied the government during the next few years. Afterward, several explorations were planned but none actually got underway.

Wickiups provided temporary shelter for some Native Americans while they were in Yellowstone. A few, probably built in the 1800s, remain standing in the park.

On the south border of this lake is a number of hot and boiling springs some of water and others of most beautiful fine clay and resembles that of a mush pot and throws its particles to the immense height of from twenty to thirty feet in height.

—from trapper Daniel Potts, in a letter to a Philadelphia newspaper, 1827



This photo of Tower Fall was one of many taken by W.H. Jackson during the 1871 Hayden Survey. His photos helped to bring public attention to the wonders of Yellowstone. Both the 1870 and 1871 expeditions spread the word through newspaper and magazine articles, speaking tours, and other publicity.

The 1869 Folsom-Cook-Peterson Expedition

In 1869, three members of one would-be expedition set out on their own. David E. Folsom, Charles W. Cook, and William Peterson ignored the warning of a friend who said their journey was “the next thing to suicide” because of “Indian trouble” along the way. From Bozeman, they traveled down the divide between the Gallatin and Yellowstone rivers, crossed the mountains to the Yellowstone and continued into the

present park. They observed Tower Fall, the Grand Canyon of the Yellowstone—“this masterpiece of nature’s handiwork”—continued past Mud Volcano to Yellowstone Lake, then south to West Thumb. From there, they visited Shoshone Lake and the geyser basins of the Firehole River. The expedition updated an earlier explorer’s map (DeLacy, in 1865), wrote an article in *Western Monthly* magazine, and refueled the excitement of scientists who decided to see for themselves the truth of the party’s tales of “the beautiful places we had found fashioned by the practiced hand of nature, that man had not desecrated.”

The 1870 Washburn-Langford-Doane Expedition

In August 1870, a second expedition set out for Yellowstone, led by Surveyor-General Henry D. Washburn, politician and businessman Nathaniel P. Langford, and attorney Cornelius Hedges. Lt. Gustavus C. Doane

provided military escort from Fort Ellis (near present-day Bozeman, Montana). The explorers traveled to Tower Fall, Canyon, and Yellowstone Lake, followed the lake’s eastern and southern shores, and explored the Lower, Midway, and Upper geyser basins (where they named Old Faithful). They climbed several peaks, descended into the Grand Canyon of the Yellowstone, and attempted measurements and analyses of several of the prominent natural features.

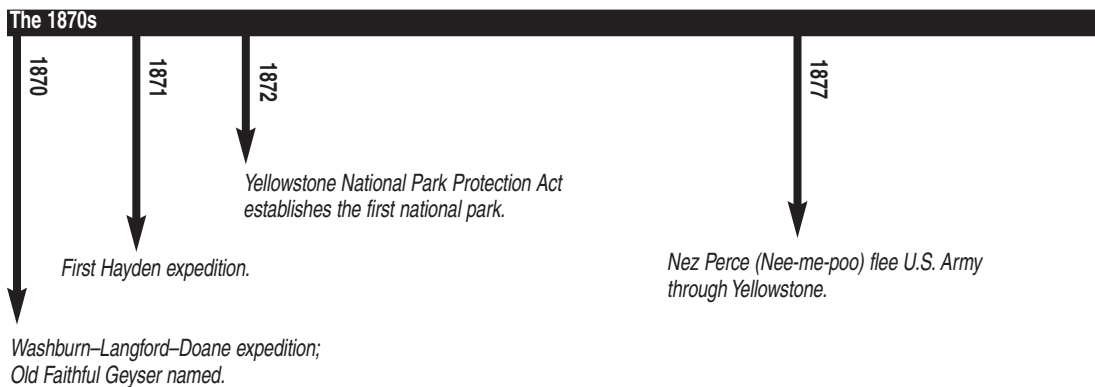
The 1871 Hayden Expedition

Ferdinand V. Hayden, head of the U.S. Geological and Geographical Survey of the Territories, led the next scientific expedition in 1871, simultaneous with a survey by the U.S. Army Corps of Engineers.

The Hayden Survey brought back scientific corroboration of the earlier tales of thermal activity. The expedition gave the world an improved map of Yellowstone and visual proof of the area’s unique curiosities through the photographs of William Henry Jackson and the art of Henry W. Elliot and Thomas Moran. The expedition’s reports excited the scientific community and aroused even more national interest in Yellowstone.

1872—Birth of a National Park

The crowning achievement of Yellowstone’s explorers was helping to save Yellowstone from private development. They promoted a park bill in Washington in late 1871 and early 1872 that drew upon the precedent of the Yosemite Act of 1864, which reserved Yosemite Valley from settlement and entrusted it to the care of the state of California. To permanently close to settlement an expanse of the public domain the size of Yellowstone would depart from the established policy of transferring public lands to private ownership. But the wonders of Yellowstone—shown through Jackson’s photographs, Moran’s paintings, and Elliot’s sketches—had caught the imagination of



Congress. On March 1, 1872, President Ulysses S. Grant signed the Yellowstone National Park Protection Act into law. The world's first national park was born.

The Formative Years

The park's promoters envisioned Yellowstone National Park would exist at no expense to the government. Nathaniel P. Langford, member of the Washburn expedition and advocate of the Yellowstone National Park Act, was appointed to the unpaid post of superintendent. Because he received no salary, he earned his living elsewhere. He entered the park twice during five years in office—as part of the 1872 Hayden expedition and to evict a squatter in 1874. His task was made more difficult by the lack of laws protecting wildlife and other natural features.

Political pressure forced Langford's removal in 1877. The next year, Congress authorized a salary for the next superintendent and appropriations "to protect, preserve, and improve the Park."

Philetus W. Norris was appointed the second superintendent. He constructed roads, built a park headquarters at Mammoth Hot Springs, hired the first "gamekeeper," and waged a difficult campaign against hunters and vandals. Much of the primitive road system he laid out remains today as the Grand Loop Road. Through constant exploration, Norris also added immensely to geographical knowledge of the park.

Norris's tenure occurred during an era of warfare between the United States and many Native American tribes. To reassure the public that they faced no threat from these conflicts, he promoted the idea that Native Americans shunned this area because they feared the hydrothermal features, especially the geysers. This idea belied evidence to the contrary from trappers and early explorers, but the myth spread.

Norris fell victim to political maneuvering and was removed from his post in 1882. He was succeeded by three powerless superintendents who could not protect the park. Even when ten assistant superintendents were authorized to act as police, they failed to stop the destruction of wildlife. Poachers, squatters, woodcutters, and vandals ravaged Yellowstone.



Touring the Park

During the early years, visitation remained low because access to and travel within the park were difficult. Visitors either had to transport themselves or patronize one of the costly transportation enterprises. Once in the park, they found only a few concessioners providing food and minimal sleeping accommodations. Access improved in 1883 when the Northern Pacific Railroad reached Cinnabar, Montana, a new town near the north entrance of Yellowstone.

A typical tour began when visitors descended from the train in Cinnabar, boarded large "tally ho" stagecoaches (above), and headed up the scenic Gardner River Canyon to Mammoth Hot Springs. After checking into the large hotel, they spent the afternoon touring the hot springs. For the next four days, tourists bounced along in passenger coaches called "Yellowstone wagons," which had to be unloaded at steep grades. Each night visitors enjoyed a warm bed and a lavish meal at a grand hotel.

These visitors carried home unforgettable memories of experiences and sights, and they wrote hundreds of accounts of their trip. They recommended the tour to their friends, and each year more of them came to Yellowstone to see its wonders themselves. When the first automobile entered in 1915, Yellowstone truly became a national park, accessible to anyone who could afford a car.

The 1880s & 1890s

1883

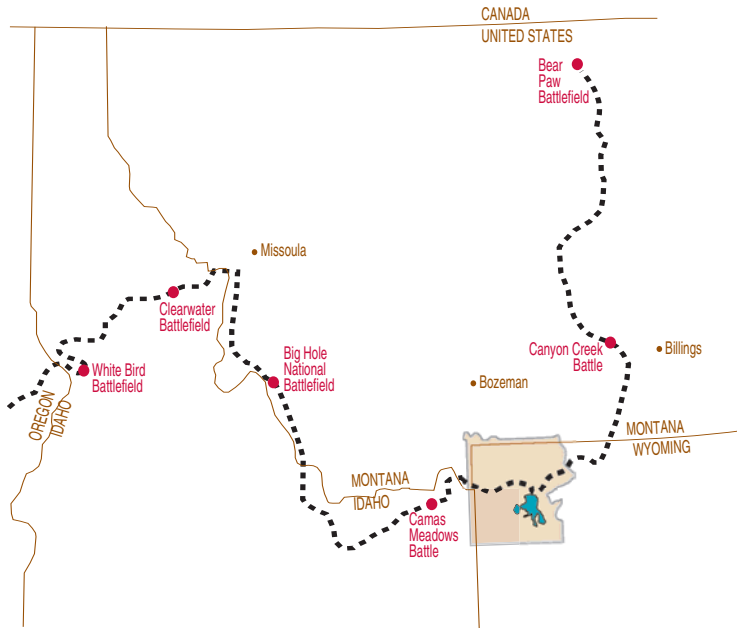
Northern Pacific Railroad reaches the North Entrance of the park.

1886

The U.S. Army arrives to administer the park. They stay until 1918.

1894

Poacher Ed Howell captured; National Park Protection Act (Lacey Act) passed.



In August 1877, the Nez Perce crossed Yellowstone as they fled the U.S. Army. The dotted line on the map traces their 1,170 mile ill-fated flight from Oregon to the end near Canada.

Flight of the Nez Perce

Summer 1877 brought tragedy to the Nez Perce (or, in their language, Nimiipu or Nee-Me-Poo). A band of 800 men, women, and children—plus almost 2,000 horses—left their homeland in what is now Oregon and Idaho. Settlers were moving into their homeland and the U.S. Government was trying to force them onto a reservation. At Big Hole, Montana, many of their group, including women and children, were killed in a battle with the Army. The remainder of the group continued fleeing, and entered Yellowstone National Park on the evening of August 23rd. During the two weeks they crossed the park, the Nez Perce encountered all 25 people known to be visiting the new park at that time, some more than once. Warriors took hostage or attacked several of these tourist parties. The group continued traveling through the park and over the Absaroka Mountains into Montana. The Army stopped them near the Bear's Paw Mountains, less than 40 miles from the Canadian border. Some Nez Perce escaped into Canada, but after fierce fighting and a siege, the rest of the band surrendered on October 5. This is where it is believed that Chief Joseph said, "From where the sun now stands, I will fight no more forever." The 1,170-mile flight had ended.

Today, the flight of the Nez Perce is commemorated at 38 sites in Washington, Oregon, Idaho, and Montana as part of the Nez Perce National Historical Park. Some of these sites are shown above; to learn more about the Nez Perce National Historic Trail, visit the website at www.fs.fed.us/npnht.

1886—The Army Arrives

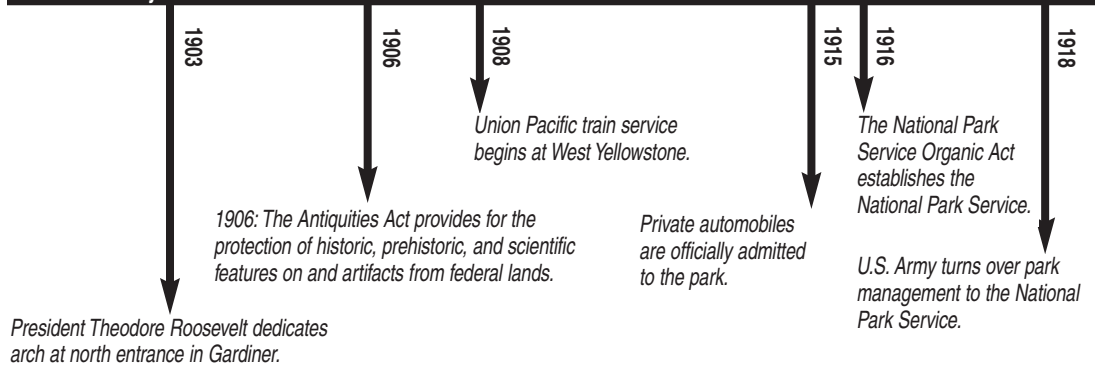
In 1886 Congress refused to appropriate money for ineffective administration. The Secretary of the Interior, under authority given by the Congress, called on the Secretary of War for assistance. On August 20, 1886, the U.S. Army took charge of the administration and protection of Yellowstone.

The Army strengthened regulations, posted them around the park, and enforced them. Troops guarded the major attractions and evicted troublemakers, and cavalry patrolled the vast interior of the park.

The most persistent menace came from poachers, whose activities threatened to exterminate animals such as the bison. In 1894, soldiers arrested a man named Ed Howell for slaughtering bison in Pelican Valley. The maximum sentence possible was banishment from the park. Emerson Hough, a well-known journalist, was present and wired his report to *Forest & Stream*, a popular



Fort Yellowstone at Mammoth Hot Springs as it looked around 1895. Some of its buildings remain today and serve as park headquarters.



Soldiers pose with bison heads captured from poacher Ed Howell. When Howell returned to the park later that year, he was the first person arrested and punished under the new National Park Protection Act, passed in 1894.



When Frances Pound applied for a law enforcement position in 1926, Superintendent Albright suggested she use her nickname, "Jim," because she would be one of the first women hired to do law enforcement in Yellowstone.

magazine of the time. Its editor, renowned naturalist George Bird Grinnell, helped create a national outcry. Within two months Congress passed the National Park Protection Act (the Lacey Act), which increased the Army's authority for protecting Yellowstone's treasures.

Running a park was not the Army's usual line of work. The troops could protect the park and ensure access, but they could not fully satisfy the visitor's desire for

knowledge. Moreover, each of the 14 other national parks established during this period was separately administered, resulting in uneven management, inefficiency, and a lack of direction.

1916: The National Park Service Begins

National parks clearly needed coordinated administration by professionals attuned to the special requirements of these preserves. Accordingly, in 1916, Congress passed the National Park Service Organic Act, creating the National Park Service.

Yellowstone's first rangers, which included veterans of Army service in the park, became responsible for Yellowstone in 1918. The park's first superintendent under the new National Park Service was Horace M. Albright, who served simultaneously as assistant to Stephen T. Mather, Director of the National Park Service. Albright established a framework of management that guided administration of Yellowstone for decades.

1

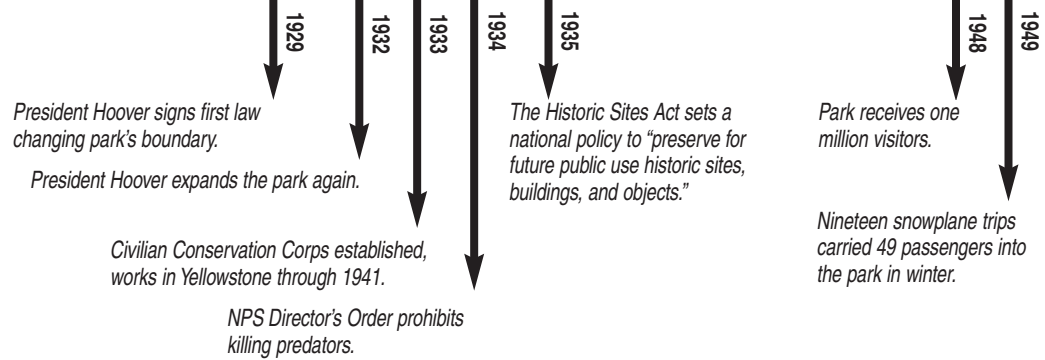
History

The National Park Service Organic Act
Passed in 1916, this law created the National Park Service and established its mission:

"to conserve the scenery and the natural and historic objects and the wildlife therein and to provide for the enjoyment of the same in such manner and by such means as will leave them unimpaired for the enjoyment of future generations."

Updated mission statement on page 9.

The 20th Century



Boundary Adjustments

Almost as soon as the park was established, people began suggesting that the boundaries be revised to conform more closely to natural topographic features, such as the ridgeline of the Absaroka Range along the east boundary. Although these people had the ear of influential politicians, so did their opponents—which at one time also included the United States Forest Service. Eventually a compromise was reached and in 1929, President Hoover signed the first bill changing the park's boundaries: The northwest corner now included a significant area of petrified trees; the northeast corner was defined by the watershed of Pebble Creek; the eastern boundary included the headwaters of the

Lamar River and part of the watershed of the Yellowstone River. (The Yellowstone's headwaters remain outside the park in Bridger-Teton National Forest.)

In 1932, President Hoover added more than 7,000 acres between the north boundary and the Yellowstone River, west of Gardiner. These lands provided winter range for elk, pronghorn, and other ungulates.

Efforts to exploit the park also expanded during this time. Water users from the town of Gardiner to the potato farmers of Idaho wanted the park's water. Proposals included damming the southwest corner of the park—the Bechler region. The failure of these schemes confirmed that Yellowstone's

wonders were so special that they should be forever preserved from exploitation.

The 1940s

World War II drew away employees, visitors, and money from all national parks, including Yellowstone. The park's employees, who at this time were mostly men, were pulled away for military service. Visitors were few due to gasoline and other commodity rationing. The money needed to maintain the park's facilities, much less construct new ones, was directed to the war effort. Among other projects, the road from Old Faithful to Craig Pass was left unfinished.

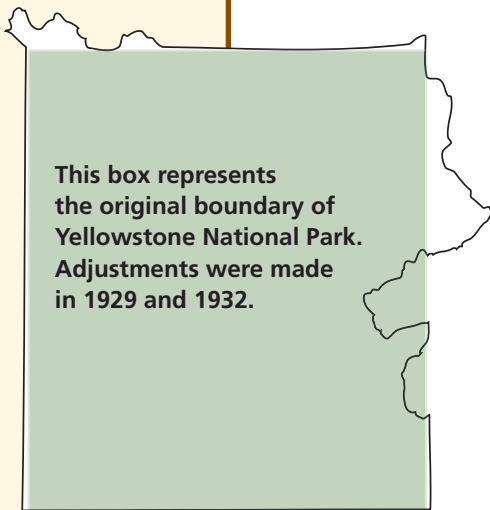
Proposals again surfaced to use the park's natural resources—this time in the war effort. As before, the park's wonders spoke for themselves and were preserved.

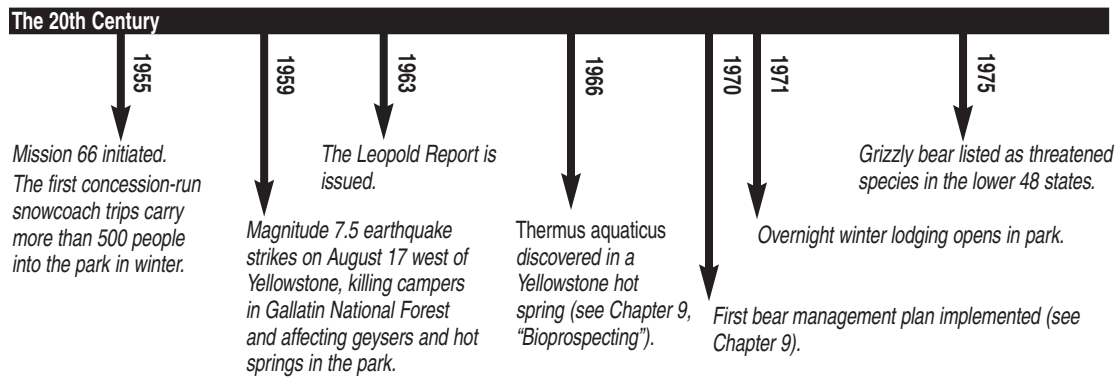
Visitation jumped as soon as the war ended. By 1948, park visitation reached one million people per year. The park's budget did not keep pace, and the neglect of the war years quickly caught up with the park.

Mission 66

In 1955 the National Park Service initiated a program to address backlogged construction and maintenance and to provide modern facilities for the traveling public. The program was targeted for completion by 1966, the golden anniversary of the National Park Service, and was called Mission 66.

In Yellowstone, the Canyon Area was redeveloped as part of Mission 66. Visitor facilities were designed to reflect American attitudes of the 1950s: Anything "old" had no value or relevance in "modern" times, and convenience was paramount. Visitor services were arranged around a large parking plaza with small cabins a short distance away. Canyon Village opened in July 1958, the first Mission 66 project completed by the National Park Service.





From Managed to "Natural"

Until the mid-1960s, park managers actively managed the elk and bison of Yellowstone. Elk population limits were determined according to formulas designed to manage livestock range. When elk reached those limits, park managers "culled" or killed the animals to reduce the population. Bison were likewise heavily managed.

In 1963, a national park advisory group, comprised of prominent scientists, released a report recommending parks "maintain biotic associations" within the context of their ecosystem, and based on scientific research. Known as the Leopold Report, this document established the framework for park management still used today throughout the National Park System. By adopting this new management philosophy, Yellowstone went from an unnatural managing of resources to "natural regulation"—today known as Ecological Process Management.

The Leopold Report's recommendations were upheld by the 2002 National Academy of Science report, *Ecological Dynamics On Yellowstone's Northern Range*.

Complex Times

Although change and controversy have occurred in Yellowstone since its inception, the last three decades have seen many issues arise. Most involve natural resources, and those still current are described elsewhere in the book (see list at right).

In an effort to resolve park management issues throughout the system, Congress passed the The National Parks Omnibus Management Act in 1998. This law mandates the use of high quality science from inventory, monitoring, and research to understand and manage park resources.

One issue resolved was the threat of water pollution from a gold mine outside the north-east corner of the park. Among other concerns, the New World Mine would have sited

A Decade of Environmental Laws

Beginning in the late 1960s, the U.S. Congress passed an unprecedented suite of laws to protect the environment. The laws described here particularly influence the management of our national parks.

The National Environmental Policy Act, passed in 1970, establishes a national policy "to promote efforts which will prevent or eliminate damage to the environment...stimulate the health and welfare of man...and enrich the understanding of ecological systems..." It requires detailed analysis of environmental impacts of any major federal action that significantly affects the quality of the human environment. Environmental assessments (EAs) and environmental impact statements (EISs) are written to detail these analyses and to provide forums for public involvement in management decisions.

The Endangered Species Act (1973) requires federal agencies to protect species that are (or are likely to become) at risk of extinction throughout all or a significant part of their range. It prohibits any action that would jeopardize their continued existence or result in the destruction or modification of their habitat.

The Clean Water Act (1972) is enacted to "restore and maintain the chemical, physical, and biological integrity of the Nation's waters" by prohibiting the discharge of pollutants.

The Clean Air Act (1970) mandates protection of air quality in all units of the National Park System; Yellowstone is classified as Class 1, the highest level of clean air protection.

waste storage along the headwaters of Soda Butte Creek, which flows into the Lamar River and then the Yellowstone River. After years of public debate, a federal buyout of the mining company was authorized in 1996.

Park facilities, underfunded for decades, are seeing some improvements due to a change in how such projects can be funded. In 1994, as part of a national pilot program, Yellowstone National Park was authorized to increase its entrance fee and retain more than half of the fee for park projects. (Previously, none of the entrance fees specifically funded projects in Yellowstone.) In 2004, the U.S. Congress made this program permanent under the Federal Lands Recreation Enhancement Act. Projects funded in part by this program include a major renovation of Canyon Visitor Education Center and development of new geology exhibits, campground and amphitheater upgrades, preservation of rare documents, and studies on bison.

For Information on Current Issues

Fire Management (and the fires of 1988): Chapter 6

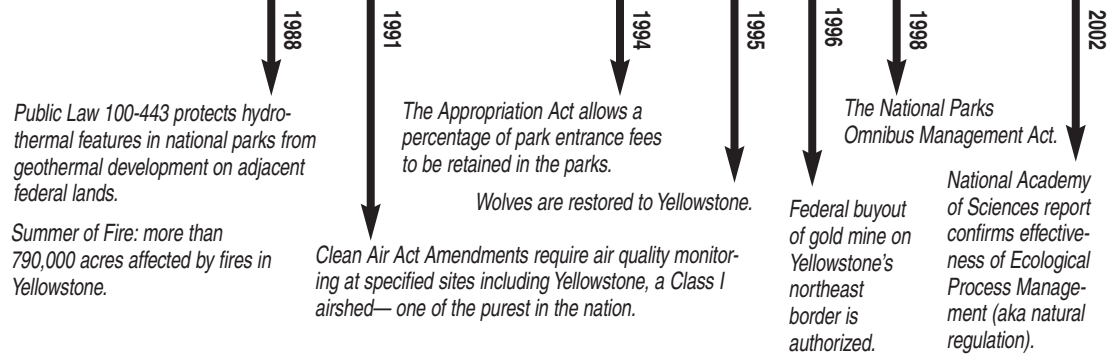
Bioprospecting, bison management, lake trout and other aquatic concerns, and winter use: Chapter 9.

Yellowstone National Park website, www.nps.gov/yell.

Yellowstone Science, free from the Yellowstone Center for Resources, in the Yellowstone Research Library, or online at www.nps.gov/yell.

Yellowstone Today, distributed at entrance gates and visitor centers.

The 20th Century



The Legacy of Yellowstone

The years have shown that the legacy of those who worked to establish Yellowstone National Park in 1872 was far greater than simply preserving a unique landscape. This one act has led to a lasting concept—the national park idea. This idea conceived wilderness to be the inheritance of all people, who gain more from an experience in nature than from private exploitation of the land.

The national park idea was part of a new view of the nation's responsibility for the public domain. By the end of the 19th century, many thoughtful people no longer believed that wilderness should be fair game for the first person who could claim and plunder it. They believed its fruits were the rightful possession of all the people, includ-

ing those yet unborn. Besides the areas set aside as national parks, still greater expanses of land were placed into national forests and other reserves so that the country's natural wealth—in the form of lumber, grazing, minerals, and recreation lands—should not be consumed at once by the greed of a few, but should perpetually benefit all people.

The preservation idea, born in Yellowstone, spread around the world. Scores of nations have preserved areas of natural beauty and historical worth so that all humankind will have the opportunity to reflect on their natural and cultural heritage and to return to nature and be spiritually reborn. Of all the benefits resulting from the establishment of Yellowstone National Park, this may be the greatest.

Staff reviewers: Ann Johnson, Archeologist; Herb Dawson, Architectural Historian; Rosemary Sucec, Cultural Anthropologist; Lee Whittlesey, Park Historian

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|---|---|---|--|
| Bartlett, Richard. 1974. <i>Nature's Yellowstone</i> . Tucson: University of Arizona Press. | Haines, Aubrey. 1996. <i>The Yellowstone Story: A History of Our First National Park</i> . 2 vols. Niwot: U. Press of Colorado. | Journals, Letters, and Images from the 1871 Hayden Expedition. Lincoln: University of Nebraska Press. | ciated University Press. |
| Bartlett, Richard. 1985. <i>Yellowstone: A Wilderness Besieged</i> . Tucson: University of Arizona Press. | Haines, Aubrey. 1974. <i>Yellowstone National Park: Its Exploration and Establishment</i> . National Park Service. | Milstein, Michael. 1996. <i>Yellowstone: 125 Years of America's Best Idea</i> . Billings MT: Billings Gazette. | Schullery, Paul. 1997. <i>Searching for Yellowstone</i> . Houghton Mifflin. |
| Clary, David. 1993. <i>The Place Where Hell Bubbed Up: A History of Yellowstone National Park</i> . Moose, WY: Homestead Publishing. | Janetski, Joel C. 2002. <i>Indians of Yellowstone Park</i> . Revised edition. Salt Lake City: University of Utah Press. | Nabokov, Peter and Larry Loendorf. 2004. <i>Restoring a Presence: American Indians in Yellowstone National Park</i> . Norman/UOklahoma National Park Service. | Schullery, Paul. 1965. <i>Yellowstone's Ski Pioneers</i> . High Plains Publishing Company. |
| Cook, Charles W., David E. Folsom, and William Peterson. 1965. <i>The Valley of the Upper Yellowstone: An Exploration of the Headwaters of the Yellowstone River in the Year 1869</i> . Norman: University of Oklahoma Press. | Keller, Robert and Michael Turek. 1998. <i>American Indians and National Parks</i> . Tucson: University of Arizona Press. | National Park System Advisory Board. 2001. <i>Rethinking the National Parks for the 21st Century</i> . www.nps.gov/policy | Strong, W.E. 1968. <i>A Trip to Yellowstone National Park in July, August, and September of 1875</i> . Norman: University of Oklahoma Press. |
| Everhart, William. 1983. <i>The National Park Service</i> . Boulder: Westview Press. | Langford, Nathaniel P. 1972. <i>The Discovery of Yellowstone Park</i> . Lincoln: University of Nebraska Press. | Russell, Osborne. 1997. <i>Journal of a Trapper</i> . New York: MJF Books. | Weixelman, Joseph. 2001. <i>Fear or reverence? Yellowstone Science</i> . Fall. |
| Frison, George. 1978. <i>Prehistoric Hunters of the High Plains</i> . New York: Academic Press. | Leopold, A.S. et al. 1963. <i>Wildlife Management in the National Parks</i> . www.nps.gov | Schullery, Paul, editor. 1979. <i>Old Yellowstone Days</i> . Boulder: Colorado Asso- | Whittlesey, Lee H. 1998. <i>Yellowstone Place Names</i> . Helena: Montana Historical Society. |
| | Merrill, M. 1999. <i>Yellowstone and the Great West</i> : | | Whittlesey, Lee H. and National Park Service Staff. <i>A Yellowstone Album</i> . Boulder: Roberts Rinehart. |
| | | | Whittlesey, Lee H. and Paul Schullery. 2003. <i>Myth and History in the Creation of Yellowstone National Park</i> . Lincoln/UNebraska |

Yellowstone National Park forms the core of the Greater Yellowstone Ecosystem (GYE)—and at 28,000 square miles, is one of the largest intact temperate-zone ecosystems on Earth today.

Each of Yellowstone National Park's separate parts—the hydrothermal features, the wildlife, the lakes, the Grand Canyon of the Yellowstone River, and the petrified trees—could easily stand alone as a national park. That they are all at one place is testimony to Greater Yellowstone's diversity and natural wealth.

Geological characteristics form the foundation of an ecosystem. In Yellowstone, the interplay between volcanic, hydrothermal, and glacial processes and the distribution of flora and fauna are intricate and unique.

The topography of the land from southern Idaho northeast to Yellowstone probably results from millions of years of hotspot influence (*see Chapter 3*). Some scientists believe the Yellowstone Plateau itself is a result of uplift due to hotspot volcanism. Today's landforms even influence the weather, channeling westerly storm systems onto the plateau where they drop large amounts of snow.

The distribution of rocks and sediments in the park also influences the distributions of flora and fauna. The volcanic rhyolites and tuffs of the Yellowstone Caldera are rich in quartz and potassium feldspar, which form nutrient-poor soils. Thus, areas of the park underlain by rhyolites and tuffs generally are characterized by extensive stands of lodgepole pine, which are drought tolerant and have shallow roots that take advantage of the nutrients in the soil. In contrast, andesitic volcanic rocks that underlie the Absaroka Mountains are rich in calcium, magnesium, and iron. These minerals weather into soils that can store more water and provide better nutrients than rhyolitic soils. These soils support more vegetative growth, which adds organic matter and enriches the soil. You can see the result when you drive over Dunraven Pass or through other areas of the park with Absaroka rocks. They have a more diverse flora, including mixed forests interspersed with meadows. Lake sediments such as those underlying Hayden Valley, which were deposited during glacial periods, form clay soils that allow meadow communities to out-compete trees for water. The patches of lodgepole pines in Hayden Valley grow in areas of rhyolite rock outcrops.

GYE BASICS

- 12–18 million acres; 18,750–28,125 square miles (*see map, next page, for why it varies*)
- States: Wyoming, Montana, Idaho
- Encompasses state lands, two national parks, portions of six national forests, three national wildlife refuges, Bureau of Land Management holdings, private and tribal lands
- Managed by state governments, federal government, tribal governments, and private individuals
- One of the largest elk herds in North America

- Largest free-roaming, wild herd of bison in U.S.
- One of two grizzly populations in contiguous U.S.
- Home to the rare wolverine and lynx

In Yellowstone National Park:

61 mammals
320 bird species; 148 species nest here
16 fish species: 11 native, 5 non-native
10 reptiles and amphibians
12,000+ insect species, including 128 species of butterflies
1,100+ species of vascular plants



These whitebark pines grow in the andesitic soils on Mount Washburn.

2

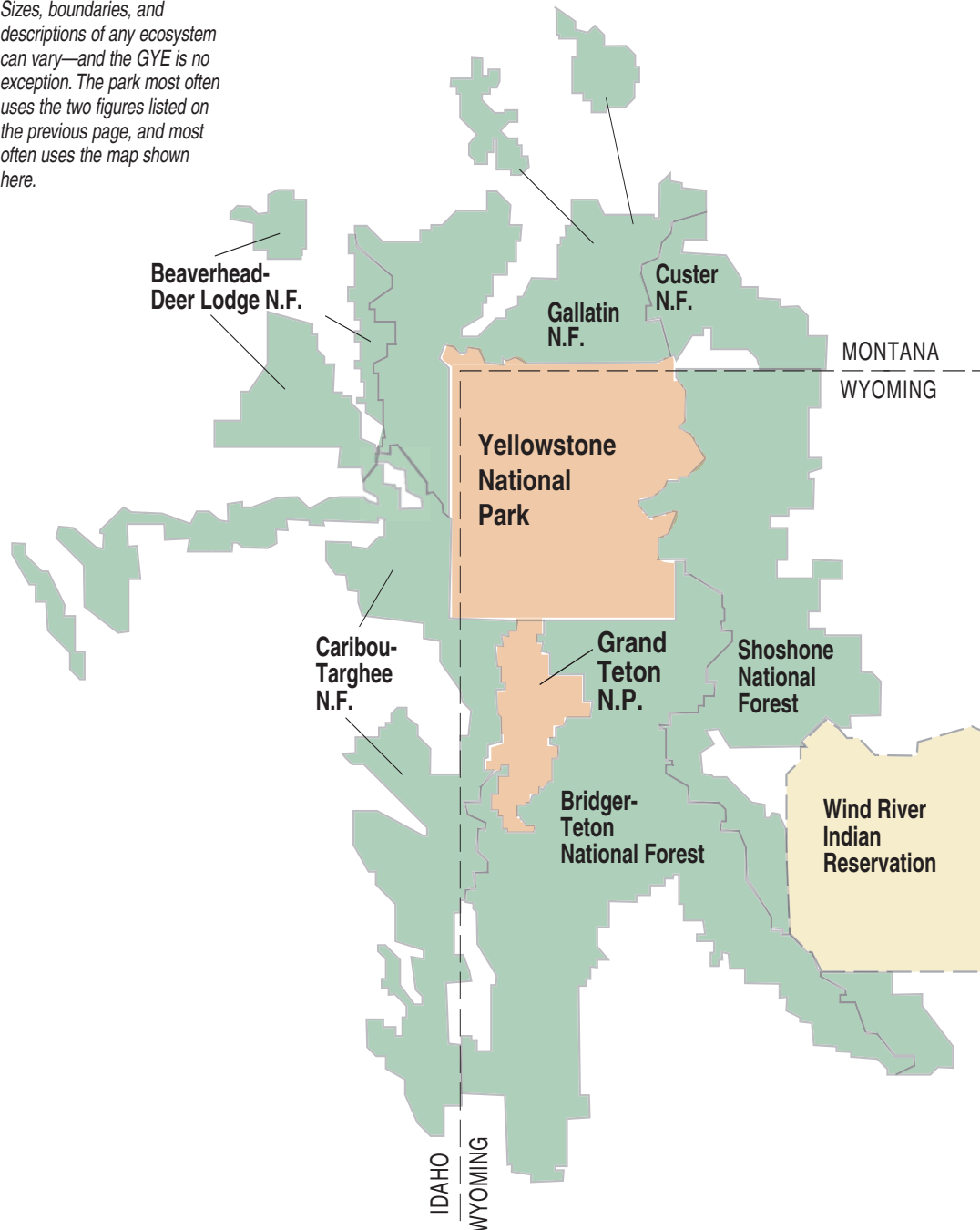
Greater Yellowstone Ecosystem

Because of the influence rock types have on plant distribution, some scientists theorize that geology also influences wildlife distributions and movement. Whitebark pine is an important food source for grizzly bears during autumn. The bears migrate to whitebark pine areas such as the andesitic volcanic terrain of Mt. Washburn. Grazing animals such as elk

and bison are found in the park's grasslands, which grow best in soils formed by sediments in valleys such as Hayden and Lamar. And the many hydrothermal areas of the park, where grasses and other food remain uncovered, provide sustenance for animals during winter.

How big is the Greater Yellowstone Ecosystem?

Sizes, boundaries, and descriptions of any ecosystem can vary—and the GYE is no exception. The park most often uses the two figures listed on the previous page, and most often uses the map shown here.



Biological Diversity

Biological diversity is one of the benchmarks measuring the health of an ecosystem. Biodiversity can be measured two ways: the number of different species (also called richness) and the abundance of each species (also called evenness). The diversity of animals within the Greater Yellowstone Ecosystem is as great as that found anywhere in the lower 48 states.

Significantly, Greater Yellowstone's natural diversity is still essentially intact. With the exception of the black-footed ferret, the region appears to have retained or restored its full historic complement of vertebrate wildlife species—something truly unique in the wildlands of the contiguous 48 states.

The extent of wildlife diversity is due in part to the different habitats found in the region, ranging from high alpine areas to sagebrush country, hydrothermal areas, forests, meadows, and other habitat types. All of these are connected, including linkages provided by streams and rivers that course through the changing elevations.

Other unique life forms are protected here, too. Various species of microorganisms are the living representatives of the primitive life forms now recognized as the beginnings of life on this planet. Cyanobacteria found in Yellowstone's hot springs are similar to the cyanobacteria that were among the first organisms capable of photosynthesis (the process by which plants use sunlight to convert carbon dioxide to oxygen and other byproducts). Because Earth's original atmosphere was anoxic (without oxygen), cyanobacteria's photosynthesis began to create an atmosphere on Earth that would eventually support plants and animals.

Cycles and Processes

Cycles and processes are the building blocks in the foundation of any ecosystem. Photosynthesis, predation, decomposition, climate, and precipitation facilitate the flow of energy and raw materials. Living things absorb, transform, and circulate energy and raw materials and release them again. Cycles and



processes are the essential connections within the ecosystem.

Life forms are active at all levels. Microbes beneath Yellowstone Lake thrive in hydrothermal vents where they obtain energy from sulfur instead of the sun. Plants draw energy from the sun and cycle nutrients such as carbon, sulfur, and nitrogen through the system. Herbivores, ranging from ephydrid flies to elk, feed on the plants and, in turn, provide food for predators like coyotes and hawks. Decomposers—bacteria, fungi, other microorganisms—link all that dies with all that is alive.

The ecosystem is constantly changing and evolving. A forest fire is one example of such an integral, dynamic process. Fires rejuvenate forests on a grand scale. Some species of plants survive the intense burning to resprout. The serotinous cones of lodgepole pines pop open in heat generated by fires, spreading millions of seeds on the forest floor. After fire sweeps through an area, mammals, birds, and insects quickly take advantage of the newly created habitats. Fires recycle and release nutrients and create dead trees or snags that serve a number of ecological functions, such as the addition of organic matter to the soil when the trees decompose (*see Chapter 5*).

The Lamar Valley's thick grasses grow in soils formed from sediments laid down by glaciers. This and other Yellowstone grasslands provide habitat for bison, elk, deer, pronghorn, coyote, wolf, grizzly and black bear, golden and bald eagles, ravens, osprey, and many other species.

revised to include
trophic cascade

For many, the sight of a wolf chasing an elk through a meadow is the highest symbol of wildness. That's a good start, but it's the meadow that is telling us the most about what wildness really means.

—Paul Schullery

For more information about wolf recovery and elk on the northern range, see Chapter 9.

Increasing Community Complexity

Many scientists consider the restoration of the wolf to Yellowstone to be the restoration of ecological completeness in the Greater Yellowstone Ecosystem. This region now contains every large wild mammal, predator or prey, that inhabited it when Europeans first arrived in North America. But the wolf is only one factor—albeit restored—in the extremely complex and dynamic community of wild Yellowstone.

For the visitor, this community's complexity has been highlighted primarily through the large predators and their prey species. This ecological "suite" of species provides a rare display of the dramatic pre-European conditions of wildlife in North America.

Intricate Layers

Since wolves were restored, scientists have discovered layers of complexity reaching far beyond the photogenic and obvious large mammals. For example, the carcasses of elk, bison, and other large mammals each become ecosystems of their own. Researchers have identified at least 57 species of beetle associated with these ungulate carcasses on the northern range. Only one of those 57 species eats ungulate meat. All the rest prey on other small scavengers, especially the larvae of flies and beetles. Others consume carcass byproducts such as microscopic fungal spores. In this very busy neighborhood, thousands of appetites interact until the carcass melts away and everybody moves on.

Thus the large predators point us toward the true richness, messiness, and subtlety of wild Yellowstone. For a wolf pack, an elk is dinner waiting to happen; for beetles, flies, and many other small animals, the elk is a village waiting to happen.

Trophic Cascades

Scientists in Yellowstone have been exploring the hypothesis that wolf restoration is causing changes in predator/prey/vegetation relationships—what ecologists call a "trophic cascade." Some researchers say wolves have changed elk behavior so they don't linger in willow or aspen areas where they would eat the plants; they point to recent strong willow growth as evidence. If wolves are the main factor in willow increase, they could also be

indirectly increasing riparian bird habitat and improving fish habitat.

It is too soon to know for sure if this trophic cascade is actually happening, and how extensive it might be. Plus, other factors are at work here. For example, ecologists have documented a substantial rise in temperature in the northern range: From 1995 to 2005, the number of days above freezing has increased from 90 to 110 days. Changes in precipitation and effects of global climate change may also be affecting vegetation growth. Ongoing, long-term scientific research will continue to examine these complicated interweavings of the Greater Yellowstone Ecosystem.

Balancing Nature?

In some public circles, some people expected wolves would restore a "balance" to park ecosystems, meaning that animal populations would stabilize at levels pleasing to humans. Instead, a more dynamic variability is present, which probably characterized this region's wildlife populations for millennia. Nature does have balances, but they are fluid rather than static, flexible rather than rigid.

Consider the northern Yellowstone elk herd, which has been declining. The recovery of the wolf occurred simultaneously with increases in grizzly bear and mountain lion populations, increased human hunting of elk (especially female or "antlerless") north of the park, and an extended drought. Computer models prior to wolf recovery predicted a decline in elk, but did not incorporate these other factors, and the decline has exceeded predictions. Populations of prey species that share their habitat with more, rather than fewer species of predators are now thought to fluctuate around lower equilibria. The elk populations of Yellowstone will no doubt continue to adjust to all the pressures and opportunities they face, just as all their wild neighbors, large and small, will.

While some people delight in the chance to experience the new completeness of the Yellowstone ecosystem, others are alarmed and angered by the changes. But with so few places remaining on Earth where we can preserve and study such ecological completeness, there seems little doubt about the extraordinary educational, scientific, and even spiritual values of such a wild community.

Bison can reach food beneath three feet of snow, as long as the snow is not solidified by melting and refreezing. A bison's hump is made of elongated vertebrae to which strong neck muscles are attached, which enable the animal to sweep its massive head from side to side.



Winter in Yellowstone

Deep snow, cold temperatures, and short days characterize winter in the Greater Yellowstone Ecosystem, conditions to which plants and animals are adapted. For example, conifers retain their needles through the winter, which extends their ability to photosynthesize. Aspens and cottonwoods contain chlorophyll in their bark, enabling them to photosynthesize before they produce leaves.

Animal Behavioral Adaptations

- Red squirrels and beavers cache food before winter.
- Some birds roost with their heads tucked into their back feathers to prevent heat loss.
- Deer mice huddle together to stay warm.
- Ungulates like deer, elk, and bison sometimes follow each other through deep snow to save energy.
- Small mammals find insulation, protection from predators, and easier travel by living beneath the snow.
- Grouse roost overnight by burrowing into snow for insulation.
- Bison, elk, geese, and other animals find food and warmth in hydrothermal areas.

Animal Morphological/Physical Adaptations

- Mammals molt their fur in fall. Incoming guard hairs are longer and protect the underfur. Additional underfur grows each fall and consists of short, thick, often wavy hairs designed to trap air. A sebaceous (oil) gland, adjacent to each hair canal, secretes oil to waterproof the fur. Mammals have muscular control of their fur, fluffing it up to trap air when they are cold and sleeking it down to remove air when they are warm.
- River otters' fur has long guard hairs with interlocking spikes that protect the underfur, which is extremely wavy and dense to trap insulating air. Oil secreted from sebaceous glands prevents water from contacting the otters' skin. After emerging from water, they replace air in their fur by rolling in the snow and shaking their wet fur.

- Snowshoe hares, white-tailed jackrabbits, long-tailed weasels, and short-tailed weasels turn white for winter. White color provides camouflage but may have evolved primarily to keep these animals insulated as hollow white hairs contain air instead of pigment.
- Snowshoe hares have large feet to spread their weight over the snow; martens and lynx grow additional fur between their toes to give them effectively larger feet.
- Moose have special joints that allow them to swing their legs over snow rather than push through snow as elk do.
- Chickadees' half-inch-thick layer of feathers keeps them up to 100 degrees warmer than the ambient temperature.

Biochemical/physiological

- Mammals and waterfowl exhibit counter-current heat exchange in their limbs that enables them to stand in cold water: Cold temperatures cause surface blood vessels to constrict, shunting blood into deeper veins that lie close to arteries. Cooled blood returning from extremities is warmed by arterial blood traveling towards the extremities, conserving heat.
- At night, chickadees undergo regulated hypothermia. Their body temperature drops from 108°F to 88°F, which lessens the sharp gradient between the temperature of their bodies and the external temperature. This leads to a 23 percent decrease in the amount of fat burned each night.
- Chorus frogs tolerate freezing by becoming severely diabetic in response to cold temperatures and the formation of ice within their bodies. At this point the liver quickly converts glycogen to glucose, which enters the blood stream and serves as an anti-freeze. Within eight hours, blood sugar rises 200-fold. When a frog's internal ice content reaches 60–65 percent, the frog's heart and breathing stop. Within one hour of thawing, the frog's heart resumes beating.

Winter in Yellowstone

Types of Snow
Temperature Gradient Snow or "depth hoar," forms through snow metamorphosis during cold air temperatures when water moves from warmer snow near the ground to colder snow near the surface. Snow crystals grow in size, forming sugar snow where small mammals burrow.

Equitemperature Snow forms as new crystals of snow become rounded and snow-pack settles.

Rime Frost forms when super-cooled water droplets contact an object and freeze in place.

Hoar Frost forms when water vapor sublimates onto a surface. Formation of surface hoar occurs when night temperatures are very low.

2

Management Challenges

For More Information

Ecosystem Management Challenges

Despite the size of the ecosystem, Greater Yellowstone's biodiversity is in jeopardy. Many of its plant and animal species are rare, threatened, endangered, or of special concern—including more than 100 plants, hundreds of invertebrates, six fish species, several amphibian species, at least 20 bird species, and 18 mammal species. These are estimates because, even in this vital region, comprehensive inventories have not been completed. Carnivorous mammals—including the grizzly bear, wolverine, and lynx—represent more than half of the mammals in danger.

Habitat modification—beyond the levels of natural disturbance—poses a serious threat to both biodiversity and to ecosystem processes. Such modifications fragment habitats and isolate populations of plants and animals from each other, cutting them off from processes necessary for survival.

Ecosystem management is gaining support among conservationists and resource managers who recognize that most protected parks and reserves represent fragments of much larger ecosystems. Ecosystem management addresses the whole ecosystem, including preserving individual components and the relationships and linkages between them. Maintaining healthy, functioning ecosystems more effectively preserves species than do emergency measures to bring back threatened species from the brink of extinction.

Ecosystem management includes human activities. Development proposals are evaluated using methods such as “cumulative effects analysis,” which considers combined effects of all development—not just one activity—on an entire area.

In the past, GYE has been managed as individual units drawn along political lines, which results in fragmented, inconsistent, and sometimes contradictory management. However, the ecosystem management approach is gaining support. For example, managers for the two national parks and six of seven national forests in the ecosystem collaborate as the Greater Yellowstone Coordinating Committee to discuss common issues and seek solutions.

GYE is included in the Yellowstone to Yukon Conservation Initiative, or “Y2Y.” More than 170 organizations, institutions, and foundations based in Canada and the United States are working together to ensure the long-term survival of wildlife in the Northern Rockies from the Greater Yellowstone Ecosystem to the Yukon Highlands—a distance of 1,900 miles. Ecosystem management on this scale is needed for wide-ranging wildlife species such as grizzly bears and wolves; Y2Y seeks to build and maintain a life-sustaining system of core reserves and connecting wildlife corridors. Existing national, state, and provincial parks and wilderness areas will anchor the system, while the creation of new protected areas and cooperation of land-owners will provide the additional reserves and corridors.

Staff reviewers: Douglas W. Smith, Wolf Project Leader; P.J. White, Wildlife Biologist

Despain, D. G. 1987. The two climates of Yellowstone National Park. *Biological Science Proceedings of The Montana Academy of Science*. 47:11–20.

Forrest, Louise. 1988. *Field Guide to Tracking Animals in Snow*. Harrisburg, PA: Stackpole Books.

Fortin, D. et al. 2005. Wolves influence elk movements: behavior shapes a trophic cascade in YNP. *Ecology*. 86(5):1320+

Halfpenny, James C. and Roy D. Ozanne. 1989 *Winter: An Ecological Handbook*. Boulder: Johnson Books

Marchand, Peter J. 1996 *Life in the Cold*. University Press of New England.

Meagher, M. and D. B. Houston. 1998. *Yellowstone and the Biology of Time*. Norman: Univ. of Oklahoma Press.

Wilmers, et al. 2003. Resource dispersion and consumer dominance: scavenging at wolf- and hunter-killed carcasses in Greater Yellowstone. *Ecology Letters*. 6:996–1003.

Wilmers, et al. 2003. Trophic facilitation by introduced top predators: grey wolf subsidies to scavengers in YNP. *J Animal Ecology*. 72:909–916

Ripple, W.J. et al. 2001. Trophic cascades among wolves, elk and aspen on YNP's northern range. *Bio. Cons.* 102: 227+.

Additional Information from Yellowstone National Park

www.nps.gov/yell

Yellowstone Science, published quarterly, reports on research and includes articles on natural and cultural resources. Free; available from the Yellowstone Center for Resources, in the Yellowstone Research Library, or online at www.nps.gov/yell.

Yellowstone Today, published seasonally and distributed at entrance gates and visitor centers, includes features on park resources such as hydrothermal features.

Area trail guides detail geology of major areas of the park.

Available for a modest donation at Canyon, Fountain Paint Pot, Mammoth, Norris, Old Faithful, and West Thumb areas.

Site Bulletins, published as needed, provide more detailed information on park topics such as bison management, lake trout, grizzly bears, and wolves. Free; available upon request from visitor centers.

Yellowstone National Park's unique physical landscape has been and is being created by many geological forces. Here, some of the Earth's most active volcanic, hydrothermal (water + heat), and earthquake systems make this national park a priceless treasure. In fact, Yellowstone was established as the world's first national park primarily because of its extraordinary geysers, hot springs, mudpots and steam vents, and other geologic wonders such as the Grand Canyon of the Yellowstone River.

What Lies Beneath

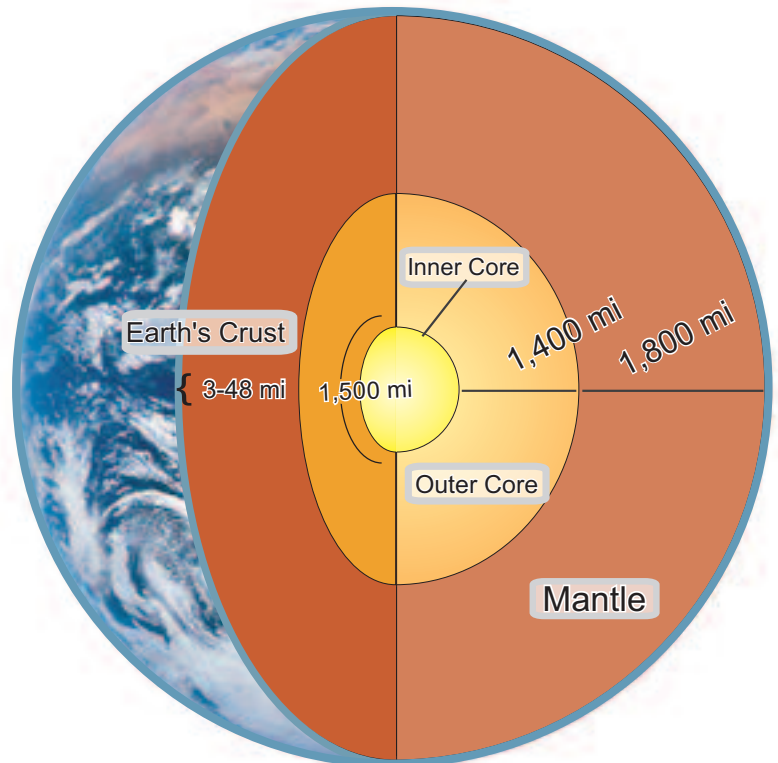
Yellowstone's geologic story provides examples of how geologic processes work on a planetary scale. The foundation to understanding this story begins with the structure of the Earth and how this structure gives rise to forces that shape the planet's surface.

The Earth is frequently depicted as a ball with a central core surrounded by concentric layers that culminate in the crust or surface layer (*see at right*). The distance from the Earth's surface to its center or core is approximately 4,000 miles. The core may once have been entirely molten, but, as the planet cooled, the inner core (about 1,500 miles thick) solidified. The outer core (about 1,400 miles thick) remains molten and is surrounded by a 1,800 mile thick mantle of dense, mostly solid rock. Above this layer is the relatively thin crust, three to forty-eight miles thick, on which the continents and ocean floors are found.

The Earth's lithosphere (crust and upper mantle) is divided into many plates, which are in constant motion. Where plate edges meet, one plate may slide past another, one plate may be driven beneath another (subduction), or upwelling volcanic material pushes the plates apart at mid-ocean ridges. Continental plates are made of less dense rocks (granites) than oceanic plates (basalts) and thus, "ride" higher than oceanic plates. Many theories have been proposed to explain crustal plate movement. Currently, most evidence supports the theory that convection

YELLOWSTONE'S GEOLOGIC SIGNIFICANCE

- One of the most geologically dynamic areas on Earth due to shallow source of magma and resulting volcanic activity.
- One of the largest volcanic eruptions known to have occurred in the world, creating one of the largest known calderas.
- More than 10,000 hydrothermal features, including more than 300 geysers.
- The largest concentration of active geysers in the world—approximately half of the world's total.
- Most of the undisturbed geyser basins left in the world (Kamchatka Peninsula has the others; the rest have been modified or destroyed by human development.)
- One of the few places in the world where active travertine terraces are found, at Mammoth Hot Springs.
- Site of many petrified trees resulting from repeated volcanic eruptions over the ages.



currents in the partially molten asthenosphere (the zone of mantle beneath the lithosphere) move the rigid crustal plates above. The volcanism that has so greatly shaped today's Yellowstone is a product of plate movement combined with upwellings of molten rock, as described on the next pages.

Illustrations on pages 38, 39, 40, and 46 adapted with permission from Windows Into the Earth, Dr. Robert Smith and Lee J. Siegel, 2000.

See Chapter 10 for more information about geology in the park's major areas.

▲ 50–40 million years ago
—Absaroka Volcanics— ▲

This chapter focuses on events and processes of the last 20 million years that have created the park we see today—a tiny fraction of the 4.6 billion years of the planet's existence.

Most of Earth's history (from the beginning to approximately 570 million years ago) is known as the Precambrian era. Rocks of this age are found in northern Yellowstone and in the hearts of the Teton, Beartooth, Wind River, and Gros Ventre ranges. Throughout much of this era, the West was repeatedly flooded by ancient seas. During the Paleozoic and Mesozoic eras (570 to 66 million years ago), this area was covered at times by ocean. At other times it was a land of sand dunes, tidal flats, and vast plains. Near the end of this era, mountain building processes created the Rocky Mountains.

During the Cenozoic era (approximately the last 66 million years of Earth's history), widespread mountain-building, volcanism, faulting, and glaciation sculpted the Yellowstone area. The Absaroka Range along the park's north and east sides was formed by numerous volcanic eruptions about 50 million years ago. Volcanic debris buried trees that are seen today as fossilized remnants along Specimen Ridge in northern Yellowstone. This period of volcanism is not related to the present Yellowstone volcano.

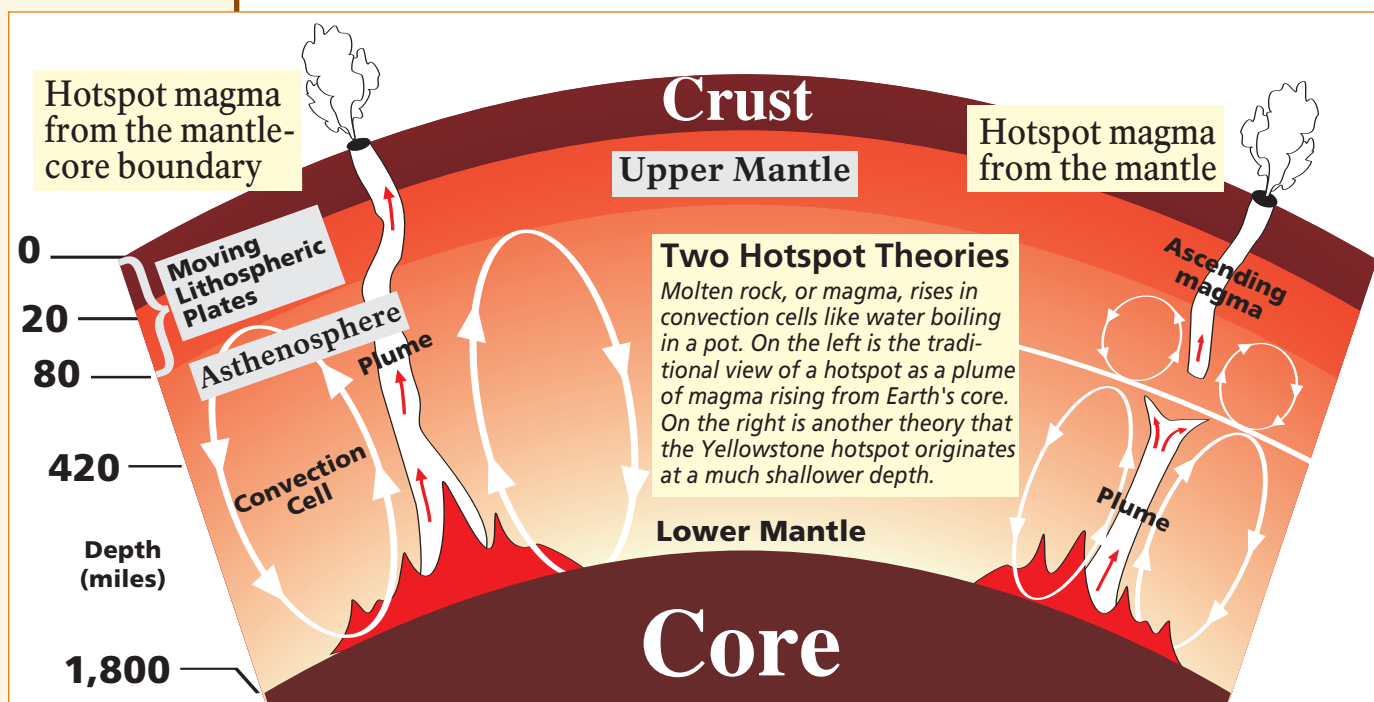
Approximately 30 million years ago, vast expanses of the West began stretching apart along an east-west axis. This stretching process increased about 17 million years ago and continues today, creating the modern basin and range topography (north-south mountain ranges interspersed with long north-south valleys) characterizing much of the Western landscape.

About 16.5 million years ago, a great period of volcanism appeared near the area now marked by the convergence of the Nevada, Oregon, and Idaho state lines. Repeated volcanic eruptions can be traced across southern Idaho into Yellowstone National Park. This volcanism remains a driving force in Yellowstone today.

Magma & Hotspots

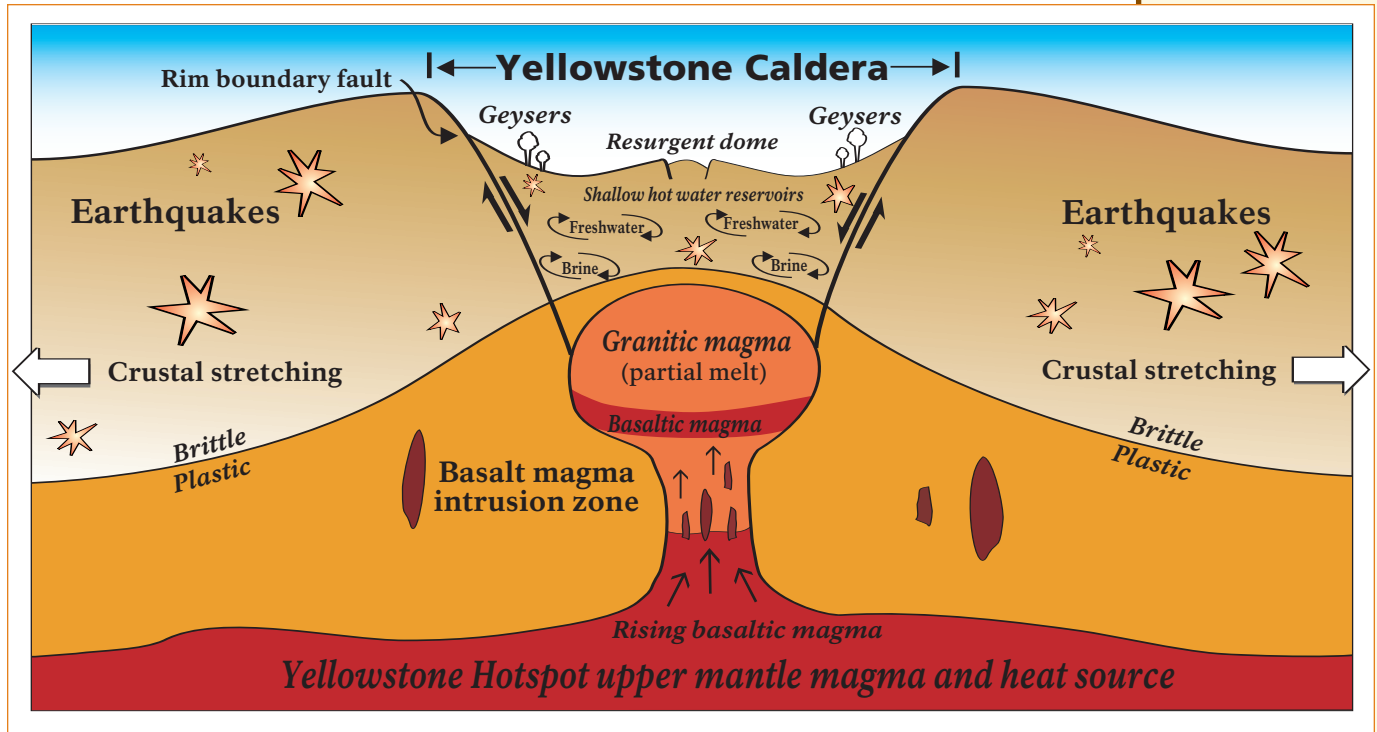
Magma (molten rock from Earth's mantle) rises to within a few miles of the surface in Yellowstone. This heat fuels the Yellowstone volcano and its associated hydrothermal areas. How it rises and whether or not a hotspot is involved remain the subject of much scientific research and discussion. (See illustration below.)

Traditional hotspot theory holds that a plume of molten rock rises all the way from Earth's core-mantle boundary to trigger volcanic



eruptions at the surface. Newer theories relate the rise of molten rock to areas in Earth's crust weakened by stretching and thinning such as that which is ongoing throughout the interior West. Some of these theories also propose a shallower mantle origin for hotspots. Still other theories place Yellowstone's hotspot on the surface as a

crust, creating a magma chamber of partially molten, partially solid rock (see below). Upward pressure from the shallow magma chamber cause overlying rocks to break, forming faults and causing earthquakes. Eventually, these faults reached the deep magma chamber. Magma oozed through these cracks, releasing pressure within the



manifestation of longlived volcanism.

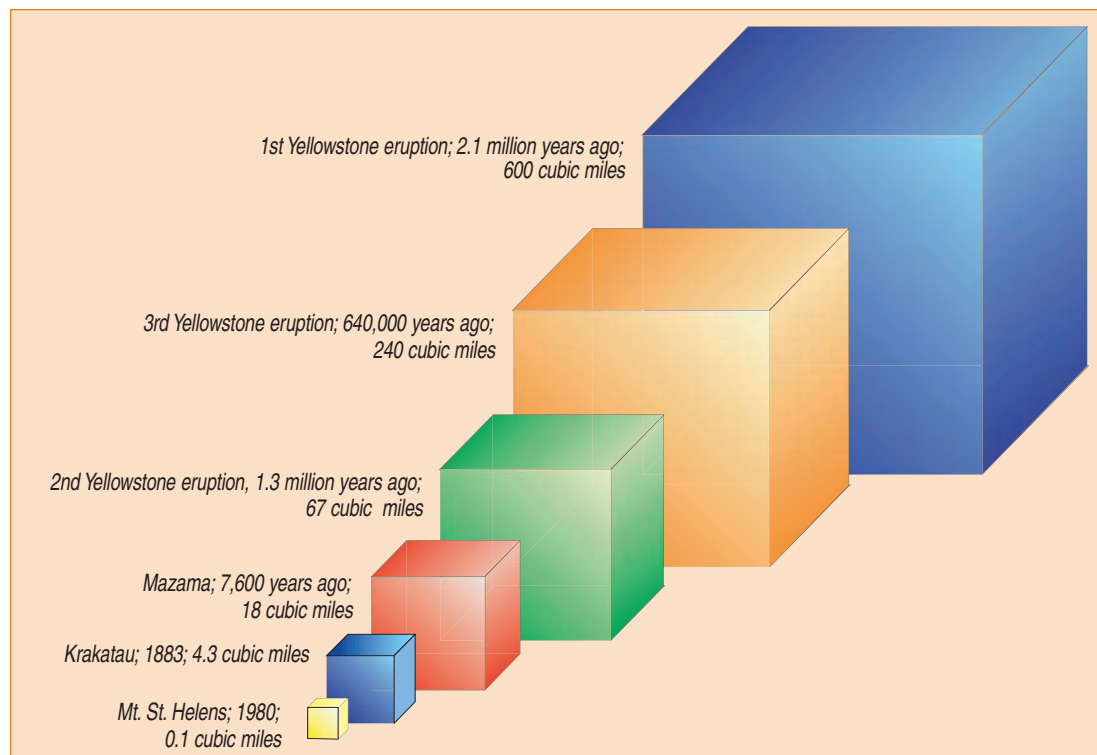
Regardless of its origins and subsurface behavior, the magma chamber feeding Yellowstone's volcano has been close to the surface for some 16.5 million years, erupting repeatedly and leaving a track of 100 gigantic calderas (craters) across 500 miles from the Nevada-Oregon border northeast up Idaho's Snake River Plain and into central Yellowstone. This trail of evidence was created as the North American plate moved in a south-western direction over the shallow magma. Earth's surface bulges above it, notable in the Yellowstone area where the average elevation is 1,700 feet higher than surrounding regions.

About 2.1 million years ago, the movement of the North American plate brought the Yellowstone area into proximity with the shallow magma. The heat melted rocks in the

chamber and allowing trapped gases to expand rapidly. A massive eruption then occurred, spewing volcanic ash and gas high into the atmosphere and causing fast-moving superhot pyroclastic flows on the ground. As the underground magma chamber emptied, the ground above it sunk, creating a huge crater known as the Huckleberry Ridge Caldera. Smaller lava flows eventually filled in the caldera over tens to hundreds of thousands of years.

The volume of material ejected during this eruption is estimated to have been 2,400 times the size of the 1980 eruption of Mt. St. Helens in Washington (see illustration next page), and ash has been found as far away as Missouri. Approximately 800,000 years later, a second, smaller volcanic eruption occurred on the western edge of the Huckleberry

At Yellowstone and some other volcanoes, some scientists theorize that Earth's crust fractures and cracks in a concentric or ring-fracture pattern. At some point these cracks reach the magma "reservoir," release the pressure, and the volcano explodes. The huge amount of material released causes the volcano to collapse into a huge steaming crater—a caldera.



Ridge Caldera and created the Henry's Fork Caldera. Then 640,000 years ago, the third massive volcanic eruption in central Yellowstone created the Yellowstone Caldera, 30 by 45 miles in size. About 162,000 years ago, a volcanic eruption created a smaller caldera now filled by the West Thumb of Yellowstone Lake.

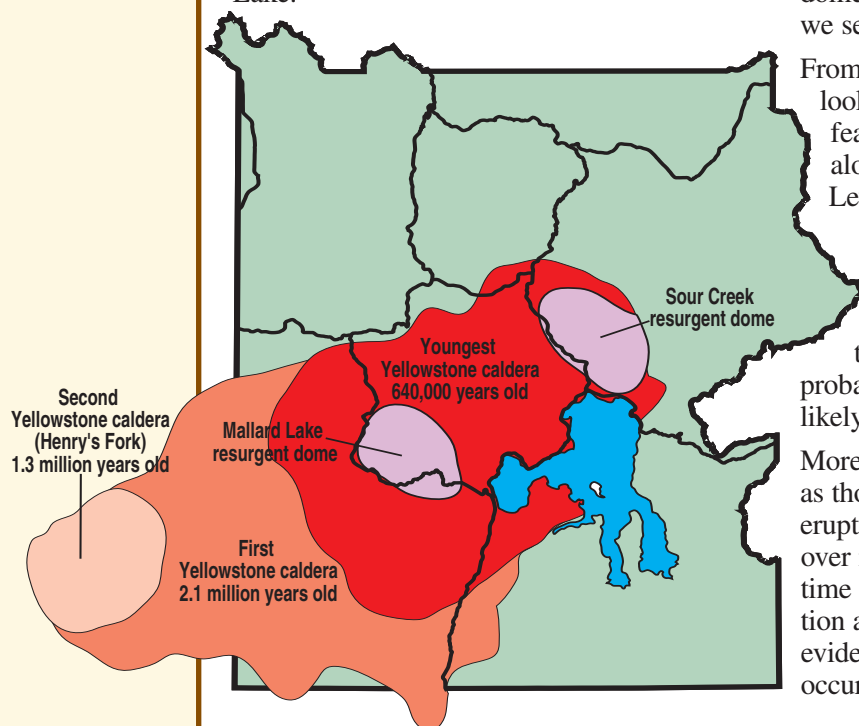
Yellowstone remains atop the shallow magma. The pressure and movement of the underlying heat, magma, and fluids cause the entire caldera floor to inflate and deflate rapidly (compared to more typical geologic processes). Rising magma has created two large bulges in the Earth called resurgent domes (Sour Creek and Mallard Lake), which we see as large hills.

From the summit of Mt. Washburn, one can look south into much of this vast volcanic feature. The caldera rim is also visible along the park road system at Gibbon Falls, Lewis Falls, and Lake Butte.

Future Volcanic Activity

Will Yellowstone's volcano have another catastrophic eruption? Over the next thousands to millions of years, probably. In the next few hundred years? Not likely.

More likely activity would be lava flows, such as those that occurred after the last major eruption. Such a lava flow would ooze slowly over months and years, allowing plenty of time for park managers to evaluate the situation and protect people. There is no scientific evidence indicating such a lava flow will occur soon.



Geyser Basin Systems

Yellowstone's hydrothermal features would not exist without the underlying magma body that releases tremendous heat. They also depend on sources of water, such as in the mountains surrounding the Yellowstone Plateau. There, snow and rain slowly percolate through layers of porous rock riddled with cracks and fissures. Some of this cold water meets hot saline brine directly heated by the shallow magma body. The water's temperature rises well above the boiling point but the water remains in a liquid state due to the great pressure and weight of the overlying rock and water. The result is superheated water with temperatures exceeding 400°F.

The superheated water is less dense than the colder, heavier water sinking around it. This creates convection currents that allow the lighter, more buoyant, superheated water to begin its slow journey back to the surface following the cracks, fissures, and weak areas

through rhyolitic lava flows. As hot water travels through this rock, high temperatures dissolve some silica in the rhyolite.

While in solution underground, some silica coats the walls of the cracks and fissures to form a nearly pressure-tight seal. This locks in the hot water and creates a "plumbing" system that can withstand the great pressure needed to produce a geyser. At the surface, silica precipitates to form either geyserite or sinter, creating the massive geyser cones, the scalloped edges of hot springs, and the seemingly barren landscape of geyser basins.



***Geysers** are hot springs with constrictions in their plumbing, usually near the surface, that prevent water from circulating freely to the surface where heat would escape. The deepest circulating water can exceed the surface boiling point (199°F/93°C). Surrounding pressure also increases with depth, much as it does with depth in the ocean. Increased pressure exerted by the enormous weight of the overlying rock and water prevents the water from boiling. As the water rises, steam forms. Bubbling upward, steam expands as it nears the top of the water column until the bubbles are too large and numerous to pass freely through the tight spots. At a critical point, the confined bubbles actually lift the water above, causing the geyser to splash or overflow. This decreases pressure on the system, and violent boiling results. Tremendous amounts of steam force water out of the vent, and an eruption begins. Water is expelled faster than it can enter the geyser's plumbing system, and the heat and pressure gradually decrease. The eruption stops when the water reservoir is depleted or when the system cools.*



***Geyser basin landscapes**, as at Norris (above right), owe their light, barren appearance to a rock called sinter. **Cone geysers**, such as Riverside in Upper Geyser Basin (above) erupt in a narrow jet of water, usually from a cone. **Fountain geysers**, such as Echinus in Norris Geyser Basin (right) shoot water in various directions, typically from a pool.*



3

Hydrothermal Features

Fumaroles or steam vents, are the hottest hydrothermal features in the park. They have so little water that it all flashes into steam before reaching the surface. At places like Roaring Mountain (right), the result is a loud hissing of steam and gases.



Travertine terraces, found at Mammoth Hot Springs (right), are formed from limestone (calcium carbonate). Thermal waters rise through the limestone, carrying high amounts of dissolved carbonate. At the surface, carbon dioxide is released and calcium carbonate is deposited as travertine, the chalky white rock of the terraces. Due to the rapid rate of deposition, these features constantly and quickly change.

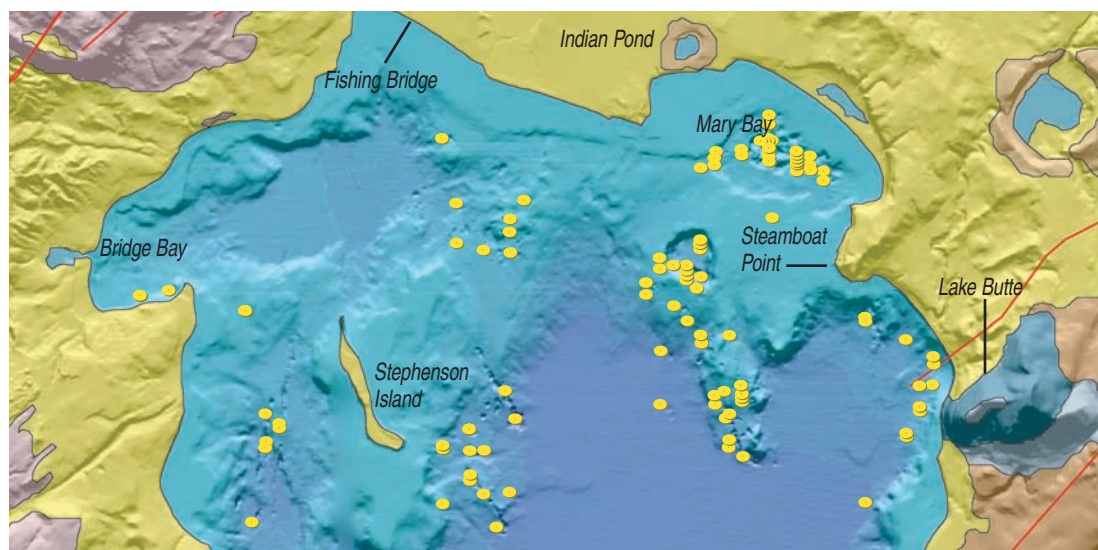


Mudpots such as Fountain Paint Pot (center, right) are acidic hot springs with a limited water supply. Some micro-organisms use hydrogen sulfide, which rises from deep within the earth, as an energy source. They help convert the gas to sulfuric acid, which breaks down rock into clay. Various gases escape through the wet clay mud, causing it to bubble. Mudpot consistency and activity vary with the seasons and precipitation.



Hot Springs such as this one at West Thumb (right) are the most common hydrothermal features in the park. Their plumbing has no constrictions. Superheated water cools as it reaches the surface, sinks, and is replaced by hotter water from below. This circulation, called convection, prevents water from reaching the temperature needed to set off an eruption.





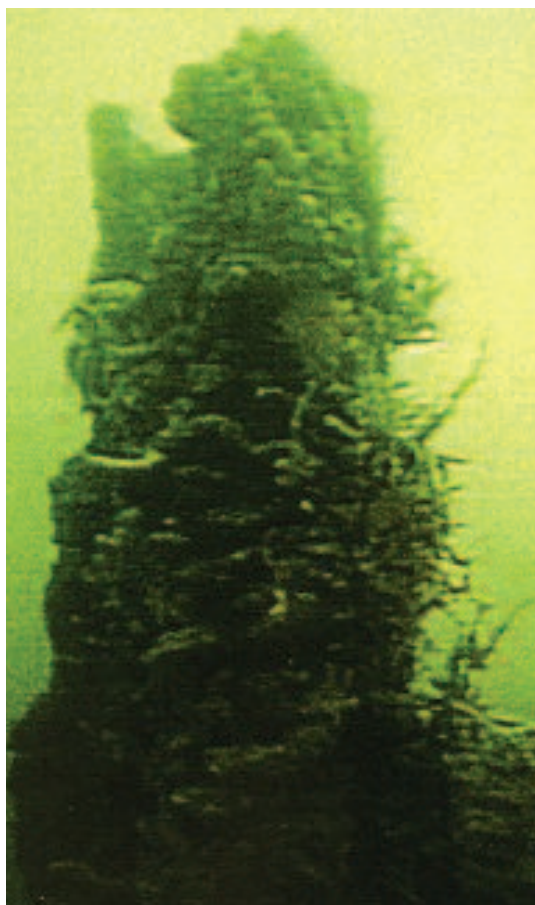
Beneath Yellowstone Lake

Until the late 1990s, few details were known about the geology beneath Yellowstone Lake. In 1996, researchers saw anomalies on the floor of Bridge Bay in the results of single-channel depth soundings. They deployed a submersible remotely operated vehicle (ROV), equipped with photographic equipment and sector-scan sonar. Large targets appeared on the sonar image when suddenly very large, spire-like structures appeared in the photographic field of view (photo at right). These structures looked similar to hydrothermal structures found in deep ocean areas, such as the Mid-Atlantic Ridge and the Juan de Fuca Ridge. They also provided habitat for aquatic species such as fresh water sponges and algae.

Lake-bottom Surveys

From 1999 to 2003, scientists from the U.S. Geological Survey and a private company, Eastern Oceanics, surveyed the bottom of Yellowstone Lake using high-resolution, multi-beam swath sonar imaging, seismic reflection profiling, and a ROV. The survey showed the northern half of the lake to be inside the 640,000-year-old Yellowstone Caldera and mapped previously unknown features such as large hydrothermal explosion craters, siliceous spires, hundreds of hydrothermal vents and craters, active fissures, and domal features containing gas pockets and deformed sediments. Also mapped were young previously unmapped faults, landslide deposits, and submerged older lake shorelines. These features are part of an undulating landscape shaped by old rhyolitic lava flows that filled the caldera.

Hydrothermal vents in northern Yellowstone Lake (above) were mapped as part of a five-year project. Scientists also are studying spires from Bridge Bay (below) that no one knew existed a decade ago. Scientists think they may be very old hydrothermal vents.



The southern half of the lake lies outside the caldera and has been shaped by glacial and other processes. The floor of the Southeast Arm has many glacial features, similar to the glacial terrain seen on land in Jackson Hole, south of the park.

3

Beneath Yellowstone Lake

These new surveys give an accurate picture of the geologic forces shaping Yellowstone Lake and determine geologic influences affecting the present-day aquatic biosphere. For example, craters result from hydrothermal explosions caused by water flashing to steam which is often accompanied by failure and fragmentation of overlying caprock. Spires may be formed in a way similar to black smoker chimneys, which are hydrothermal features associated with oceanic plate boundaries.

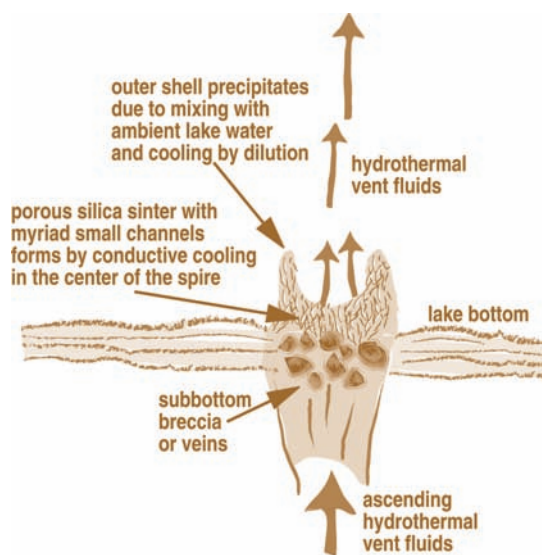
Spire Analysis

With the cooperation of the National Park Service, scientists from the University of Wisconsin–Milwaukee collected a small spire for study by several teams. They conducted a CAT scan of the spire, which showed structures seeming to be conduits, perhaps for hydrothermal circulation. When they cut open the spire, they confirmed the presence of conduits and also saw a layered structure.

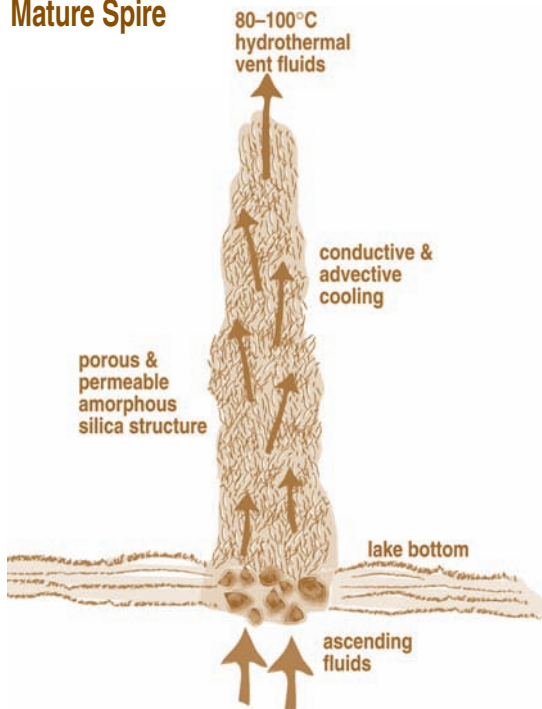
Early tests by the U.S. Geological Survey show that the spire may be more than 11,000 years old, which indicates it was formed after the last glaciers retreated. In addition to silica, the spire contains diatom tests (shells) and silica produced by underwater hydrothermal processes. Ongoing investigations include confirming the spire's age and composition.

Both research projects have already expanded our understanding of the geological forces at work beneath Yellowstone Lake. Additional study of the spires and other underwater features will continue to contribute to our understanding of the relationship between these features and the aquatic ecosystem.

Initial Spire Growth



Mature Spire



*Illustrations on this page
adapted from originals by
Dr. Lisa A. Morgan,
U.S.G.S. Research
Geologist*

Earthquakes

Earthquakes occur along fault zones in the crust where forces from crustal plate movement build to a significant level. The rock along these faults becomes so stressed that eventually it slips or breaks. Energy is then released as shock waves (seismic waves) that reverberate throughout the surrounding rock.

Different kinds of seismic waves are released inside the earth during an earthquake.

Primary waves (“P-waves”) move quickly in the direction of travel, compressing and stretching the rock. Secondary waves (“S-waves”) move up, down, and sideways through rock in a rolling motion. Once a seismic wave reaches the surface of the earth, it may be felt. Surface waves affect the ground, which can roll, crack open, or be vertically and/or laterally displaced. Structures are susceptible to earthquake damage because the ground motion is usually horizontal.

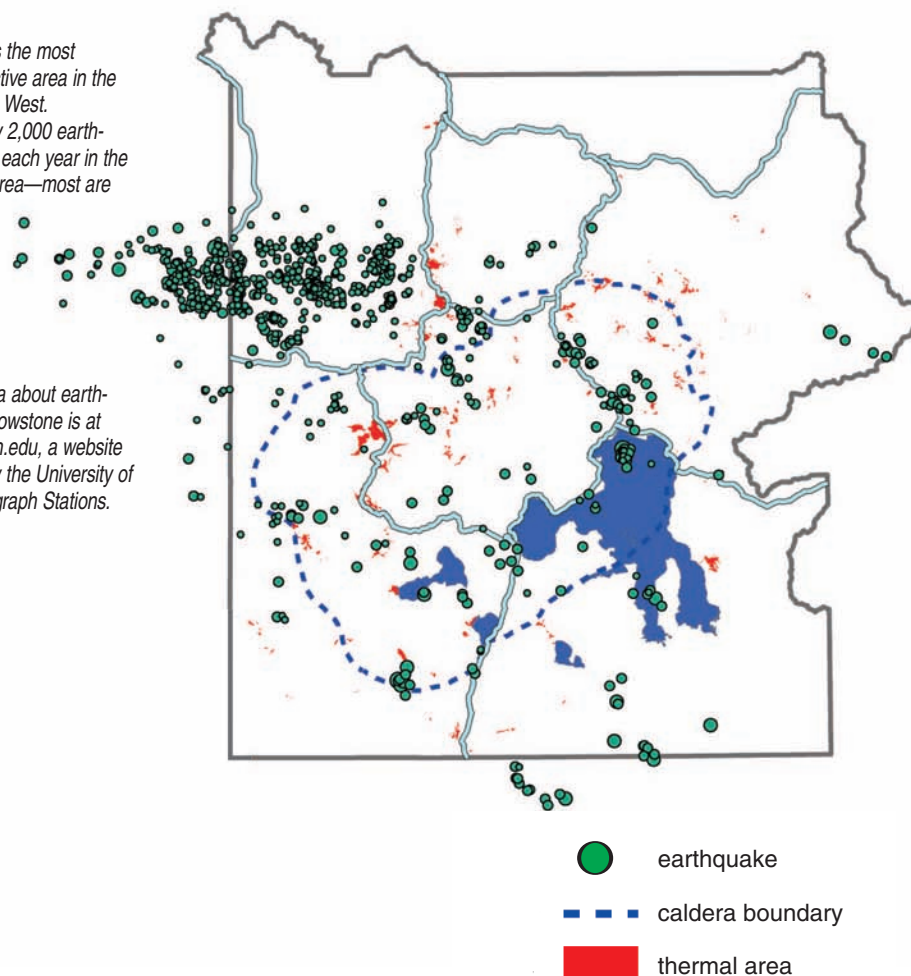
Earthquakes in Yellowstone help to maintain hydrothermal activity by keeping the “plumbing” system open. Without the periodic disturbance of relatively small earthquakes, the small fractures and conduits that supply hot water to geysers and hot springs might be sealed by mineral deposition. Some earthquakes generate changes in Yellowstone’s hydrothermal systems. For example, the 1959 Hebgen Lake and 1983 Borah Peak earthquakes caused measurable changes in Old Faithful Geyser and other hydrothermal features.

Earthquakes help us understand the subsurface geology around and beneath Yellowstone. The energy from earthquakes travels through hard and molten rock at different rates. We can “see” the subsurface and make images of the magma chamber and the caldera by “reading” the energy emitted during earthquakes. An extensive geological monitoring system is in place to aid in that interpretation.

1,293 Earthquakes in 2004, Yellowstone Area

Yellowstone is the most seismically active area in the Intermountain West. Approximately 2,000 earthquakes occur each year in the Yellowstone area—most are not felt.

Real-time data about earthquakes in Yellowstone is at www.seis.utah.edu, a website maintained by the University of Utah Seismograph Stations.



Scales of Magnitude

The size of an earthquake is given by its magnitude, which is often referred to as Richter Magnitude. On this scale, the amplitude of shaking goes up by a factor of 10 for each unit on the scale. Thus, at the same distance from the earthquake, the shaking will be 10 times as large during a magnitude 5 earthquake as during a magnitude 4 earthquake. The total amount of energy released by the earthquake, however, goes up by a factor of 32. There are many different ways that magnitude is measured from seismograms, partially because each method only works over a limited range of magnitudes and with different types of seismometers. But, all of the methods are designed to agree well over the range where they overlap.

The methods used in University of Utah earthquake listings include: ML—local magnitude, the original scale defined by Richter and Gutenberg based on the maximum amplitude of the waves. This is the preferred magnitude, when available.

MC—coda magnitude, based on measurements of the duration of the seismic waves for earthquakes up to about magnitude 5.

3

Glaciers

The extent of two major glaciations are shown on this map:
Bull Lake—orange outline
Pinedale—blue outline



Scientific understanding of glacier dates, sequence, and extent continues to evolve, and varying information appears in different references (including previous editions of this book). The information here is considered current by Yellowstone's geologist as of March 2006.

Glaciers

Glaciers result when, for a period of years, more snow falls in an area than melts. Once the snow reaches a certain depth, it turns into ice and begins to move under the force of gravity or the pressure of its own weight. During this movement, rocks are picked up and carried in the ice, and these rocks grind Earth's surface, eroding and carrying material away. Glaciers also deposit materials. Large U-shaped valleys, ridges of debris (moraines), and out-of-place boulders (erratics) are evidence of a glacier's passing.

Yellowstone and much of North America have experienced numerous periods of glaciation during the last two million years. Succeeding periods of glaciation have destroyed most surface evidence of previous glacial periods, but scientists have found evidence of them in sediment cores taken on land and in the ocean.

The Bull Lake Period glaciers covered the region about 140,000 years ago. Evidence exists that this glacial episode extended farther south and west of Yellowstone than the subsequent Pinedale Glaciation

(described in the next paragraph), but no evidence of it is found to the north and east. This indicates that the Pinedale Glaciation destroyed surface evidence of Bull Lake Glaciation in these areas.

In the Yellowstone region, the last (and most studied) major glaciation, the Pinedale, may have begun as early as 70,000 years ago. It ended more than 14,000 years ago. At the peak of the Pinedale Glaciation—25,000 years ago—nearly all of today's Yellowstone National Park was covered by a huge ice cap 4,000 feet thick (at a point above present-day Yellowstone Lake, *see above*). Mount Washburn and Mount Sheridan were both completely covered by ice. This ice field was not part of the continental ice sheet extending south from Canada. The ice field occurred here, in part, because the hotspot beneath Yellowstone had pushed up the area to a higher elevation with colder temperatures and more precipitation than the surrounding land.

Sedimentation & Erosion

Not all the rocks in Yellowstone are of “recent” volcanic origin. Precambrian igneous and metamorphic rock in the northeastern portion of the park and Beartooth Mountains are at least 2.7 billion years old. These rocks are very hard and erode slowly.

Sedimentary sandstones and shales, deposited by seas during the Paleozoic and Mesozoic eras (570 million to 66 million years ago) can be seen in the Gallatin Range and Mount Everts. Sedimentary rocks in Yellowstone tend to erode more easily than the Precambrian rocks.

Weathering breaks down earth materials from large sizes to small particles, and happens in place. The freeze/thaw action of ice is one

type of weathering common in Yellowstone. Agents of erosion—wind, water, ice, and waves—move weathered materials from one place to another.

When erosion takes place, sedimentation—the deposition of material—also eventually occurs. Through time, sediments are buried by more sediments and the material hardens into rock. This rock is eventually exposed (through erosion, uplift, and/or faulting), and the cycle repeats itself. Sedimentation and erosion are “reshapers” and “refiners” of the landscape—and they also expose Yellowstone’s past life as seen in fossils like the petrified trees (*see next page*).



The Beartooth Mountains northeast of Yellowstone (left) are actually an uplifted block of Precambrian rock.

Mt. Everts, near Mammoth, (below) exposes sedimentary rock, which erodes easily and often tumbles into Gardner Canyon.



Fossils

Paleobotany

Nearly 150 species of fossil plants (exclusive of fossil pollen specimens) from Yellowstone have been described, including ferns, horsetail rushes, conifers and deciduous plants such as sycamores, walnuts, oaks, chestnuts, maples, and hickories. Sequoia is abundant, and other species such as spruce and fir are also present.

Most petrified wood and other plant fossils come from Eocene deposits about 50 million years old, which occur in many northern parts of the park, including the Gallatin Range, Specimen Creek, Tower, Crescent Hill, Elk Creek, Specimen Ridge, Bison Peak, Barronette Peak, Abiathar Peak, Mount Norris, Cache Creek, and Miller Creek. Petrified wood is also found along streams

in areas east of Yellowstone Lake. The most accessible petrified tree site is on Specimen Ridge.

The first fossil plants from Yellowstone were collected by the early Hayden Survey parties. In his 1878 report, Holmes made the first reference to Yellowstone's fossil "forests." The report identified the petrified trees on the north slope of Amethyst Mountain opposite the mouth of Soda Butte Creek, about eight miles southeast of Junction Butte.

Around 1900, F.H. Knowlton identified 147 species of fossil plants from Yellowstone, 81 of them new to science. He also proposed the theory that the petrified trees on the northwest end of Specimen Ridge were forests petrified in place.

Another theory proposes that the trees were uprooted by volcanic debris flows and transported to lower elevations. The 1980 eruption of Mount St. Helens supported this idea. Mud

flows not only transported trees to lower elevations, they also deposited the trees upright.

Cretaceous marine and nonmarine sediments are exposed on Mount Everts. The area is under study; fossil leaves, ferns, clam-like fossils, shark teeth, and several species of vertebrates have been found. In 1994 fossil plants were discovered in Yellowstone during the East Entrance road construction project, which uncovered areas containing fossil sycamore leaves and petrified wood.

Fossil Invertebrates

Fossil invertebrates are abundant in Paleozoic rocks, especially the limestones associated with the Madison Group in the northern and south-central parts of the park. They include corals, bryozoans, brachiopods, trilobites, gastropods, and crinoids. Trace fossils, such as channeling and burrowing of worms, are found in some petrified tree bark.

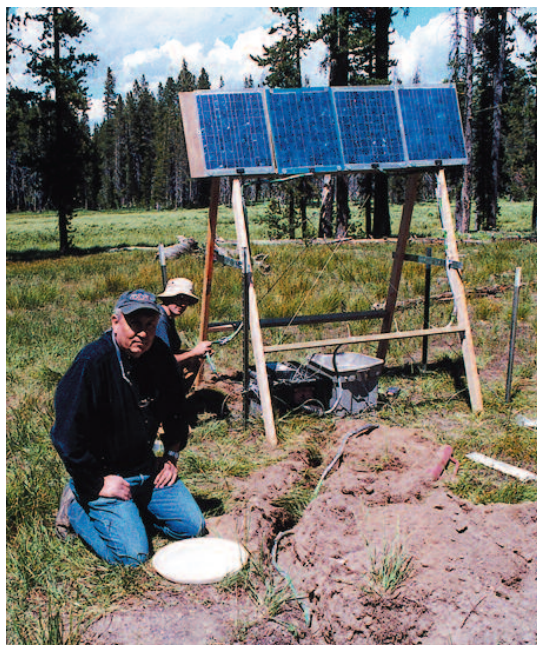
Fossil Vertebrates

Fossil remains of vertebrates are rare, but perhaps only because of insufficient field research. A one-day survey led by paleontologist Jack Horner, of the Museum of the Rockies, Bozeman, Montana, resulted in the discovery of the skeleton of a Cretaceous vertebrate. Other vertebrate fossils found in Yellowstone include:

- Fish: crushing tooth plate; phosphatized fish bones; fish scales; fish teeth.
- Horse: possible Pleistocene horse, *Equus nebraskensis*, reported in 1939.
- Other mammals: Holocene mammals recovered from Lamar Cave; Titanotheres (type of rhinoceros) tooth and mandible found on Mt. Hornaday in 1999.



In Yellowstone, many petrified trees can be seen. Resulting from volcanic eruptions about 50 million years ago, they present questions that scientists continue to ponder: Were the trees petrified in place and thus represent layers of forest? Or were they scattered before and after petrification, which means the number of forests cannot be determined?



Yellowstone As a Geologic Laboratory

Yellowstone is a unique outdoor laboratory for research scientists. Many of these scientific studies have ramifications far beyond Yellowstone National Park. Current research examples:

- Earthquake monitoring stations detect the numerous daily tremors occurring in the Yellowstone region, and the patterns are studied to develop an understanding of the geodynamics of Yellowstone's hotspot.
- Studies on the location of previously unmapped geologic structures should help us understand what controls subsurface fluid flow and recharge in geothermal systems.
- Baseline geochemical studies help distinguish between human and natural influences on the underground water network in the region.
- Underwater studies in Yellowstone Lake have identified hydrothermal vents where organisms have been found that survive on sulphur emissions and that resemble life found under the ocean near similar hydrothermal vents; comparison studies continue.
- The deposition of sinter around hydrothermal springs is being studied to understand how early life developed on Earth and to look for similarities on other planets, particularly Mars.

Dr. Robert Smith and assistant set up a temporary seismographic station. It is one of dozens throughout the Greater Yellowstone Ecosystem sending seismic data to researchers at the University of Utah.

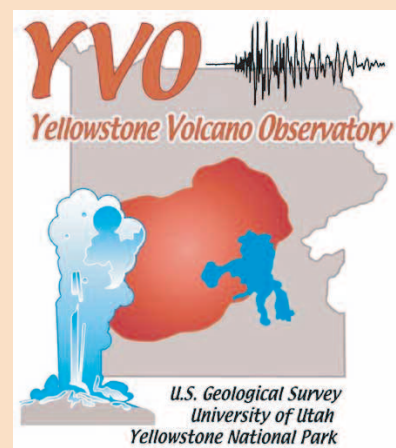
- Thermophiles—microorganisms that can live in extreme environments—are being collected from the park's hydrothermal features, identified, and their heat-resistant enzymes are being studied. Some already are being used in a variety of medical and forensic processes. (See Chapters 4 & 9.)

All scientists in Yellowstone work under special permits and are closely supervised by National Park Service staff.

THE YELLOWSTONE VOLCANO OBSERVATORY

Increased scientific surveillance of Yellowstone in the past 30 years has detected unmistakable changes in its vast underground volcanic system, similar to historical changes observed at many other large calderas (volcanic depressions) in the world. To strengthen the capabilities of scientists to track and respond to changes in Yellowstone's activity, a fifth U.S. volcano observatory was created in 2001, complementing existing ones for Hawaii, Alaska, the Cascades, and Long Valley, California. The

Yellowstone Volcano Observatory (YVO) is supported jointly by the U.S. Geological Survey, the University of Utah, and Yellowstone National Park.



The principal goals of YVO include:

- * Strengthening the monitoring system for tracking earthquake activity, uplift and subsidence, and changes in the hydrothermal (hot water) system;
- * Assessing the long-term potential hazards of volcanism, earthquakes, and explosive hydrothermal activity in the Yellowstone region;
- * Enhancing scientific understanding of active geologic and hydrologic processes occurring beneath Yellowstone and in the surrounding region of the Earth's crust; and
- * Communicating new scientific results, the current status of Yellowstone's activity, and forecasts of potential hazardous hydrothermal explosions or volcanic eruptions to Yellowstone National Park staff, the public, and local, State, and Federal officials.

Current real-time-monitoring data are online at volcanoes.usgs.gov/yvo/monitoring.html.

This text from a YVO pamphlet, "Steam Explosions, Earthquakes, and Volcanic Eruptions—What's in Yellowstone's Future?," sold by the Yellowstone Association.

For More Information

Additional Information from Yellowstone National Park

Yellowstone National Park website, www.nps.gov/yell, includes an array of park information about resources, science, recreation, and issues.

Yellowstone Science, published quarterly, reports on research and includes articles on natural and cultural resources. Free from the Yellowstone Center for Resources, in the Yellowstone Research Library, or online at www.nps.gov/yell.

Yellowstone Today, published seasonally and distributed at entrance gates and visitor centers, includes features on park resources such as hydrothermal features.

Area trail guides detail geology of major areas of the park. Available for a modest donation at Canyon, Fountain Paint Pot, Mammoth, Norris, Old Faithful, and West Thumb areas.

Site Bulletins, published as needed, provide more detailed information on park topics such as bison management, lake trout, grizzly bears, and wolves. Free; available upon request from visitor centers.

Anderson, Roger J. and D. Harmon, eds. 2002 *Yellowstone Lake: Hotbed of Chaos or Reservoir of Resilience? Proceedings of the 6th Biennial Scientific Conference on the Greater Yellowstone Ecosystem*. Yellowstone Center for Resources and George Wright Society.

Brock, Thomas. 1994. *Life at High Temperatures*. Mammoth, WY: Association for Natural Science, History, and Education.

Bryan, T. Scott. 1990. *Geysers: What They Are and How They Work*. Niwot, CO: Roberts Rinehart.

Bryan, T. Scott. 1995. *The Geysers of Yellowstone*. Boulder: Colorado Associated University Press. Third Edition.

Cannon, K.P. et al. 1997 *Results of Archeological and Paleoenvironmental Investigations Along the North Shore of Yellowstone Lake, Yellowstone National Park, Wyoming: 1990-1994*. Lincoln: NPS Midwest Archeological Center.

Christiansen, Robert L. 2000. The Quaternary + Pliocene, Yellowstone Plateau Volcanic Field of Wyoming, Idaho, and Montana. USGS Professional Paper 729-6.

Christiansen, Robert L. et al. 2002. Upper-mantle origin of the Yellowstone hotspot. *Geological Society of American Bulletin*. October. 114:10, pgs. 1245-1256.

Christiansen, Robert L. et al. 1994. *A Field-Trip Guide to Yellowstone National Park, Wyoming, Montana, and Idaho—Volcanic, Hydrothermal, and Glacial Activity in the Region*. U.S. Geological Survey Bulletin 2099.

Cottrell, Dr. William H. 1987. *Born of Fire: The Volcanic Origin of Yellowstone National Park*. Boulder: Roberts Rinehart.

Cuhel, Russell et al. 2005. *The Bridge Bay Spires*. *Yellowstone Science*. 12(4): 25-40/

Decker, Robert and Barbara. 1980. *Volcano Watching*. Hawaii Natural History Association.

Ehrlich, Gretel. 1987. *Land of Fire and Ice*. New York: Harper Collins.

Fouke, B. W. et al. 2000. Depositional facies and aqueous-solid geochemistry of travertine-depositing hot springs (Angel Terrace, Mammoth Hot Springs, Yellowstone National Park, U.S.A.) *J. Sedimentary Res.* 70(3): 565-585.

Fournier, R. O. 1989. Geochemistry and dynamics of the Yellowstone National Park hydrothermal system. *Ann. Rev. Earth Planet. Sci.* 17:13-53.

Francis, Peter. 1983. Giant Volcanic Calderas. *Scientific American*. June.

Fritz, William J. 1985. *Roadside Geology of the Yellowstone Country*. Missoula: Mountain Press Publishing Company.

Gallant, Roy A. 1997. *Geysers: When Earth Roared*. Franklin Watts.

Good, John M. and Kenneth L. Pierce. 1996. *Interpreting the Landscapes of Grand Teton and Yellowstone National Parks: Recent and Ongoing Geology*. Moose, WY: Grand Teton Natural History Association.

Hadly, Elizabeth. 1995. *Evolution, ecology, and taphonomy of late-Holocene mammals from Lamar Cave, Yellowstone National Park, Wyoming*. Ph.D. dissertation. University of California, Berkeley.

Hadly, E. A. 1999. Fidelity of terrestrial vertebrate fossils to a modern ecosystem. *Palaeogeography, Palaeoclimatology, Palaeoecology* 149(1999): 389-409.

Hadly, E.A. 1990. *Late holocene mammalian fauna of Lamar Cave and its implications for ecosystem dynamics in Yellowstone National Park, Wyoming*. Master's thesis. Northern Arizona University.

Hamilton, Wayne L. Geological investigations in Yellowstone National Park, 1976-1981. In *Wyoming Geological Association Guidebook*.

Ingebritsen, S. E. and S. A. Rojstaczer. 1993. Controls on geyser periodicity. *Science*. 262: 889-892.

Ingebritsen, S. E. and S. A. Rojstaczer. 1996. Geyser periodicity and the response of geysers to deformation. *J. Geophys. Res.* 101(B10): 21,891-21,905.

Kay, Glen 1982. *Hawaii Volcanoes: The Story Behind the Scenery*. KC Publications.

Keefer, William R. 1976. *The Geologic Story of Yellowstone National Park*. U.S. Geological Survey.

Kharaka, Y.K. and A.S. Maest, eds. 1992. *Proc. of the 7th intern. symp. on water-rock interaction-WRI-7*. Park City, Utah.

Marler, George D. 1973. Inventory of thermal features of the Firehole River geyser basins and other selected areas of Yellowstone National Park. U.S. Department of Commerce, National Technical Information Service, Publication PB221 289.

Marler, George D. 1969. *The Story of Old Faithful*. Mammoth, WY: Yellowstone Library and Museum Association.

Morgan, Lisa et al. 2003. The Floor of Yellowstone Lake Is Anything but Quiet. *Yellowstone Science*. 11(2): 15-30.

Pierce, Kenneth L. 1979. *History and dynamics of glaciation in the Northern Yellowstone National Park Area* U.S. Geological Survey Professional Paper 729-F.

Pierce, Kenneth L. 2004 Pleistocene glaciations of the Rocky Mountains in *Developments in Quaternary Science*, J. Rose (ed). 1: 63-76. Elsevier Press.

Puskas, C. M. 2000. *Deformation of the Yellowstone Caldera, Hebgen Lake fault zone, and eastern Snake River plain from GPS, seismicity, and moment release*. Masters thesis. Univ. of Utah.

Raymo, Chet. *The Crust of Our Earth*. Englewood Cliffs, NJ: Prentice-Hall.

Rinehart, John S. 1976. *Guide to Geyser Gazing*. Santa Fe: Hyper Dynamics.

Scientific American. 1982. *Volcanoes and the Earth's Interior*. W.H. Freeman & Co.

Smith, Robert B. and Robert L. Christiansen. 1980. Yellowstone Park as a window on the earth's interior. *Scientific American*. 242(2): 1004-117. February.

Smith, Robert B. and Lee J. Siegel. 2000. *Windows Into the Earth: The Geologic Story of Yellowstone and Grand Teton National Parks*. Oxford University Press.

Tuttle, Sherwood D. 1997. *Yellowstone National Park in Geology of National Parks*. Kendall-Hunt Publishing Company, Dubuque, IA.

Watt, Fiona. *Usborne Guide: Earthquakes and Volcanoes*. Tulsa: EDC Publishing.

Websites

volcanoes.usgs.gov/lyvo

www.seis.utah.edu

Additional information available on numerous other websites.

Videos

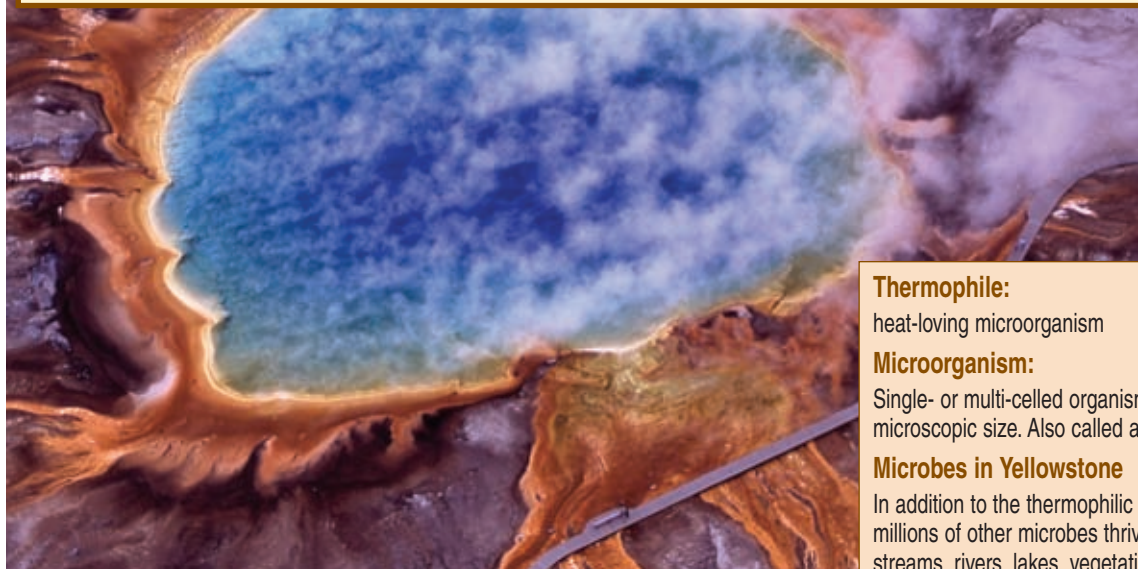
The Complete Yellowstone

Yellowstone: Imprints of Time

Yellowstone: A Symphony of Fire and Ice

LIFE IN EXTREME HEAT

4



The hydrothermal features of Yellowstone are magnificent evidence of Earth's volcanic activity. Amazingly, they are also habitats in which microscopic organisms called thermophiles—"thermo" for heat, "phile" for lover—survive and thrive.

Grand Prismatic Spring at Midway Geyser Basin (above) is an outstanding example of this dual characteristic. Visitors marvel at its size and brilliant colors. Along the boardwalk (lower right of photo), they cross a vast habitat for thermophiles. Nourished by energy and chemical building blocks available in the hot springs, microbes construct vividly colored communities throughout the park. Living with these microscopic life forms are larger examples of life in extreme environments, such as mites, flies, spiders, and plants.

People for thousands of years likely have wondered about these extreme habitats. The color of Yellowstone's superheated environments certainly caused geologist Walter Harvey Weed to pause and think, and even question scientists who preceded him. In 1889, he wrote:

There is good reason to believe that the existence of algae of other colors, particularly the pink, yellow and red forms so common in the Yellowstone waters, have been overlooked or mistaken for deposits of purely mineral matter.

However, he could not have imagined what a fantastic world truly exists in these waters of brimstone. Species, unseen to the human eye, thrive in waters as acidic as the liquid in your car battery and hot enough to blister your skin. Some create layers that look like molten wax on the surface of calcium-rich steaming pools. Still others, apparent to us through the odors they create, exist only in murky, sulfuric caldrons that stink worse than rotten eggs.

Today, many scientists study Yellowstone's thermophiles. Some of these microbes are similar to the first life forms capable of photosynthesis—using sunlight to convert water and carbon dioxide to oxygen, sugars, and other byproducts. These life forms, called cyanobacteria, began to create an atmosphere that would eventually support human life. Cyanobacteria are found in some of the colorful mats and streamers of Yellowstone's hot springs.

Thermophile:

heat-loving microorganism

Microorganism:

Single- or multi-celled organism of microscopic or sub-microscopic size. Also called a microbe.

Microbes in Yellowstone

In addition to the thermophilic microorganisms, millions of other microbes thrive in Yellowstone's soils, streams, rivers, lakes, vegetation, and animals. Some of them are discussed in other chapters of this book.

Bacteria (Bacterium)

Single-celled microorganisms without nuclei, varying in shape, metabolism, and ability to move.

Archaea (Archaeum)

Single-celled microorganisms without nuclei and with membranes different from all other organisms. Once thought to be bacteria.

Viruses

Non-living parasitic microorganisms consisting of a piece of DNA or RNA coated by protein.

Eukarya (Eukaryote)

Single- or multi-celled organisms whose cells contain a distinct membrane-bound nucleus.

Other life forms—the archaea (see page 54)—predated cyanobacteria and other photosynthesizers. Archaea can live in the hottest, most acidic conditions in Yellowstone; their relatives are considered among the very earliest of life forms on Earth.

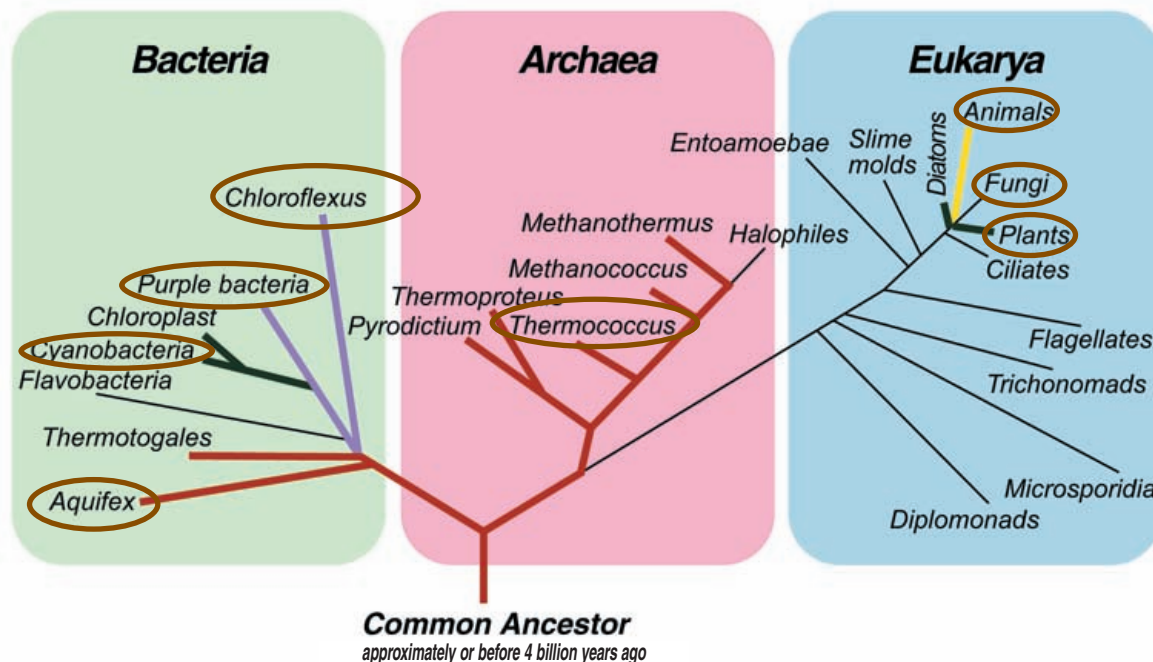
Yellowstone's thermophiles and their environments provide a living laboratory for scientists, who continue to explore these extraordinary organisms and how they relate to their environment. They know many mysteries of Yellowstone's extreme environments remain to be revealed.

Regardless of scientific advances, visitors and explorers in Yellowstone can still relate to something else Mr. Weed said about Yellowstone, more than a century ago:

The vegetation of the acid waters is seldom a conspicuous feature of the springs. But in the alkaline waters that characterize the geyser basins, and in the carbonated, calcareous waters of the Mammoth Hot Springs, the case is otherwise, and the red and yellow tinges of the algae combine with the weird whiteness of the sinter and the varied blue and green of the hot water to form a scene that is, without doubt, one of the most beautiful as well as one of the strangest sights in the world.

Thermophiles In the Tree of Life

In the last few decades, microbial research has led to a revised tree of life, far different from the one taught before. The new tree combines animal, plant, and fungi in one branch. The other two branches consist solely of microorganisms, including an entire branch of microorganisms not known until the 1970s—Archaea.



Yellowstone's hot springs contain species from the groups circled on the Tree of Life

Dr. Jack Farmer produced this image of the tree of life, which first appeared in GSA Today, July 2000. Used with permission.

Dr. Carl Woese first proposed this "tree" in the 1970s. He also proposed the new branch, Archaea, which includes many microorganisms formerly considered bacteria. The red line links the earliest organisms that evolved from a common ancestor. These are all hyperthermophiles, which thrive in water above 176°F (80°C), indicating life may have arisen in hot environments on the young Earth.

Relevance to Yellowstone

Among the earliest organisms to evolve on Earth were microorganisms whose descendants are found today in extreme high-temperature, and in some cases acidic, environments, such as those in Yellowstone. Their history exhibits principles of ecology and ways in which geologic processes might have influenced biological evolution.

Thermophilic Bacteria



Bacteria (bacterium)




single-celled microorganisms varying in shape, metabolism, and motility

The word “bacteria” is often associated with disease, but really only a few kinds of bacteria cause problems for humans. The other thousands of bacteria types, although all simple organisms, play a complex role in Earth’s ecosystems. In fact, cyanobacteria made our oxygen-rich atmosphere possible. They were the first photosynthesizers, more than 3 billion years ago. Without bacteria, we would not be here.

Almost any hot spring or geyser you see hosts bacteria. Some chemosynthesize, changing hydrogen or sulfur into forms other thermophiles can use. Most photosynthesize, providing oxygen to other thermophiles. All of

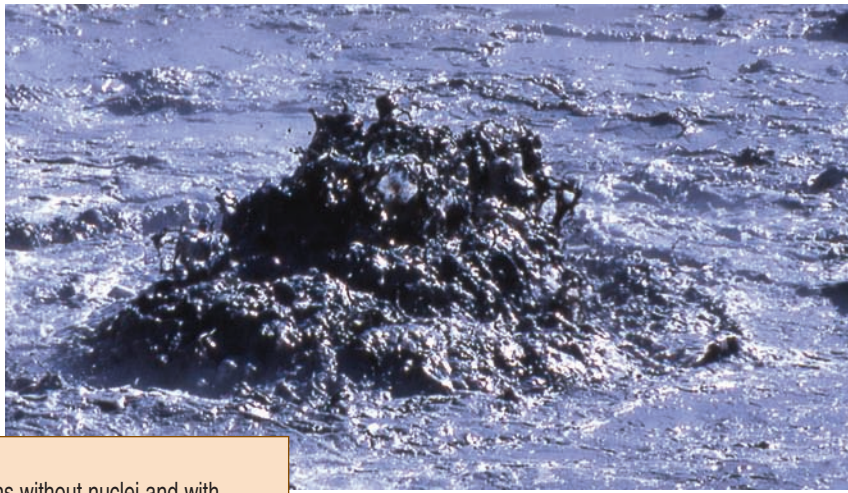
the cyanobacteria and green nonsulfur bacteria photosynthesize. Some fulfill both roles. For example, *Thermus sp.*—which are photosynthetic—also may be able to oxidize arsenic into a less toxic form.

Individual bacteria may be rod or sphere shaped, but they often join end to end to form long strands called filaments. These strands help hold thermophilic mats together, forming a vast community or mini-ecosystem. Other groups of bacteria form layered structures, which look like tiny towers, that can trap sand and other organic materials. (See bottom photo, page 58.)

	Name	pH & Temp	Description	Where found
	Cyanobacteria: <i>Calothrix</i> <i>Oscillatoria</i> <i>Phormidium</i> <i>Spirulina</i> <i>Synechococcus</i>	45–75°C 113–167°F usually alkaline	color: usually orange; can be yellow, blue-green, black metabolism: photosynthetic mobility: some can move to favorable light and temperatures within a mat form: usually long filaments entwined into mats with other thermophiles	Mammoth Hot Springs Upper, Midway, and Lower geyser basins West Thumb
	Green nonsulfur bacteria: <i>Aquifex</i> <i>Chloroflexus</i> <i>Thermus</i>	60–80°C 140–176°F usually alkaline	color: carotenoid pigments cause them to vary in pinks, yellows, and oranges metabolism: photosynthetic form: usually long filaments that entwine into mats with other thermophiles	Mammoth Hot Springs Upper, Midway, and Lower geyser basins West Thumb <i>Thermus sp.</i> at Norris, especially at Cistern Spring
	Sulfur-oxidizing bacteria: <i>Aquificales sp.</i>	60–86°C optimum >70°C	color: black, pink, or gray green, yellow, white metabolism: chemosynthesis, using hydrogen or sulfur form: filaments and mats	Lower Geyser Basin Mammoth Hot Springs: Angel Terrace

4

Thermophilic Archaea



Archaea (Archaeum)

single-celled microorganisms without nuclei and with membranes different from all other organisms. Once thought to be bacteria.

Archaea are the most extreme of all extremophiles—some kinds live in the frigid environments of Antarctica, others live in the boiling acidic springs of Yellowstone. These single-celled organisms have no nucleus, but have a unique, tough outer cell wall. This tough wall contains molecules and enzymes that may keep acid out of the organism, allowing it to live in environments of pH 3 or less. (Vinegar, for example, has a pH of less than 3.) Archaea also have protective enzymes within their cells.

Some scientists think present-day archaea have not changed much from their ancestors. This may be due to the extreme environments in which they live, which would allow little chance for successful changes to occur. If this is so, modern archaea may not be much different from the original forms—and thus provide an important link with Earth's earliest life forms.

Once thought to be bacteria, organisms in the domain Archaea actually may be more closely related to Eukarya—which includes plants

and animals.

Many kinds of archaea live in the hydrothermal waters of Yellowstone. For example, Grand Prismatic Spring at Midway Geyser Basin contains archaea. They are most well known in the superheated acidic features of Norris Geyser Basin and in the muddy roiling springs of the Mud Volcano area.

Whenever you see a hot, muddy, acidic spring, you are probably seeing the results of a thriving community of archaea called *Sulfolobus*. This is the archaea most often isolated and most well known by scientists. In sulfuric hydrothermal areas, it oxidizes hydrogen sulfide into sulfuric acid, which helps dissolve the rocks into mud. The *Sulfolobus* community in Congress Pool (Norris) is providing interesting new research directions for scientists: It is parasitized by viruses never before known on Earth. (See page 55.)

Name	pH & Temp	Description	Where found
Domain Archaea	pH: 0.9–5.8 upper temp.: >80°C/176°F	color: none metabolism: chemosynthesis, using hydrogen, sulfur, carbon dioxide form: unicellular, tough cell membrane	in many of Yellowstone's hydrothermal features
<i>Sulfolobus acidocaldarium</i> is the species most often isolated	pH 2–3, ideal <90°C/194°F	color: none metabolism: chemosynthesis; oxidizes sulfur and sulfur compounds into sulfuric acid form: spherical with lobes	Mud Volcano Norris, especially Congress Pool Roaring Mountain

Thermophilic Viruses



Viruses

non-living parasitic microorganisms consisting of a piece of DNA or RNA coated by protein

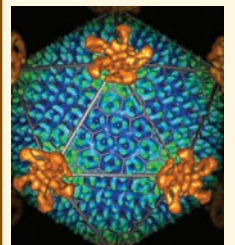
Like “bacteria,” the word “virus” often conjures up images of sickness and death. However, relatively few of the many types of viruses cause problems for humans. None of the thermophilic viruses in Yellowstone should cause problems for human health—our bodies are too cold, for one thing.

Unlike microorganisms in the three domains, viruses are not considered to be alive. They have no cell structure, only a protein “envelope” that encloses a piece of genetic material. They cannot reproduce on their own. Instead, a virus inserts itself into a host cell and uses that cell’s nutrients and metabolism to produce more viruses.

Scientists suspect many viruses exist in Yellowstone’s hydrothermal features because they would be a logical part of the thermophilic ecosystem. One kind was discovered in Congress Pool, at Norris Geyser Basin. It was infecting the archaeum *Sulfolobus*. Another kind of virus has been identified in pools near Midway Geyser Basin.

Name	pH & Temp	Description	Where found
Viruses (not in a domain)	pH: 0.9–5.8; optimum 2–3 55–80°C/ 131–176°F optimum 70–75°C	protein coats a core of genetic material cannot reproduce by itself reproduces by using the host cell’s metabolism not considered living predators of other microbes	in many of Yellowstone’s hydrothermal features
unnamed	acidic boiling	shape very similar to viruses that infect bacteria and animals, which could mean this group of viruses existed early in the development of life on Earth	unnamed pool near Midway Geyser Basin
unnamed	acidic boiling	parasitizes the archaeum, <i>Sulfolobus</i>	Norris, Congress Pool

this virus parasitizes
Sulfolobus



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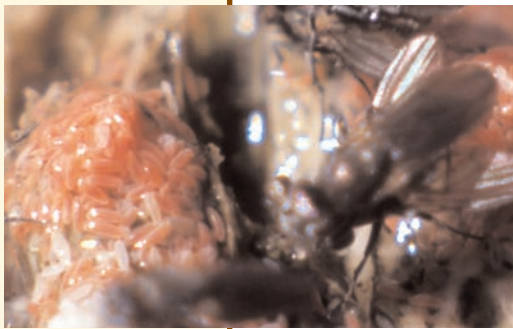
Thermophilic Eukarya

Eukarya (Eukaryote)

single- or multi-celled organisms whose cells contain a distinct membrane-bound nucleus



Zygogonium



ephydrid fly and egg mass



hot springs panic grass

Plants, animals, and mushrooms are the eukarya most of us know. Millions of unseen, microscopic members of this kingdom exist throughout our world, including in the extreme environments of Yellowstone.

Norris Geyser Basin (**photo above**) is one of the best places to see thermophilic algae. Bright green *Cyanidium caldarium* grows on top of orange-red iron deposits around Whirligig and Echinus geysers and their runoff channels. Waving streamers of *Zygogonium* are especially easy to see in Porcelain Basin, where their dark colors contrast with the white surface (**top photo at left**).



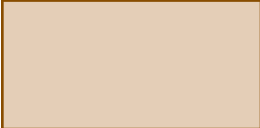



From the boardwalk crossing Porcelain Basin, you can also see larger eukarya, such as ephydrid flies. They live among the thermophilic mats and streamers, and eat, among other things, algae. The species that lives in the waters of Geyser Hill, in the Upper Geyser Basin, lays its eggs in pink-orange mounds, sometimes on the firm surfaces of the mats (**visible in center photo at left**). Part of the thermophilic food chain, ephydrid flies become prey for spiders, beetles, and birds.

Some microscopic eukarya consume other thermophiles. A predatory protozoan, called *Vorticella*, thrives in the warm, acidic waters of Obsidian Creek, which flows north toward Mammoth Hot Springs, where it consumes thermophilic bacteria.

Thermophilic eukarya include one form that is dangerous to humans: *Naegleria*, a type of amoeba, that can cause disease and death in humans if inhaled through the nose.

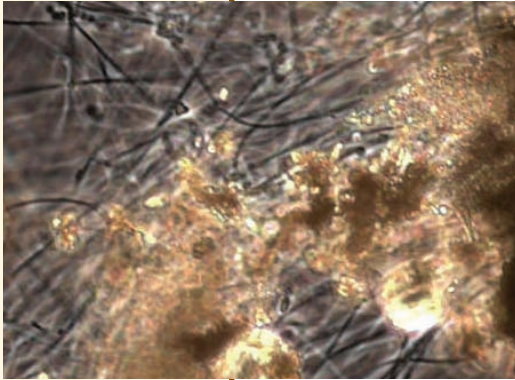
Although they aren't visible like mushrooms, several kinds of thermophilic fungi thrive in Yellowstone. *Curvularia protuberata* lives in the roots and leaves of hot springs panic grass (**bottom photo left**), which can grow on the edges of hot springs only with the aid of this fungus. The fungus contains the pigment melanin, which may somehow protect the plant from extreme heat. In return the fungus feeds on nutrients produced by the plant.

Of all the thousands (if not millions) of thermophilic species thriving in Yellowstone's extreme environments, the eukarya are the group that bridges the world of thermophilic microbes with the larger life forms—such as geese, elk, and bison—that thrive in ecological communities beyond the hot springs.

	Name	pH & Temp	Description	Where found
	Algae <i>Cyanidium caldarium</i>	pH 0.5–3 <56°C/133°F	color: bright green metabolism: photosynthetic form: coating on top of formations; mats	Roaring Mountain Norris, both basins
	<i>Zygonium</i>	35°C (95°F)	color: dark brown or purple metabolism: photosynthetic form: filaments and mats	Norris, especially Porcelain Basin
	Protozoa <i>Naegleria</i> (amoeba)	warm alkaline	predator; can infect humans when ingested through nose	Huckleberry Hot Springs Boiling River
	<i>Vorticella</i> (ciliate)		consumer; single-celled ciliate (feathery appendages swirl water, bringing prey)	Obsidian Creek
	Euglenids <i>Mutablis</i>	pH 1–2 <43°C/109°F	single-celled photosynthetic moves by waving one or two strands called flagella	
	Fungi <i>Curvularia protuberata</i>	<55°C/131°F	grows in roots and leaves of hot springs panic grass (<i>Dichanthelium lanuginosum</i>), enabling plant to survive high temperatures; in return the fungus feeds on sugars produced by the plant	
	Ephydrid fly <i>Ephydra sp.</i>	>pH 2 <43°C/109°F	nonbiting insect that eats microscopic algae as larvae and adult; prey for spiders, beetles, dragonflies, killdeer	Norris, especially Porcelain Basin Upper Geyser Basin, especially Geyser Hill
	Ross's bentgrass <i>Agrostis rossiae</i>	38°C/100°F	one of Yellowstone's two endemic plant species (see p. 66); may bloom in winter; dries out in summer's hot air temperatures	banks of Firehole River near Shoshone Lake
	Mostly warm springs spike rush, with some Tweedy's rush	warm acidic	forms thick floating mats, which also provide habitat for thermophilic algae and other thermophiles	Obsidian Creek

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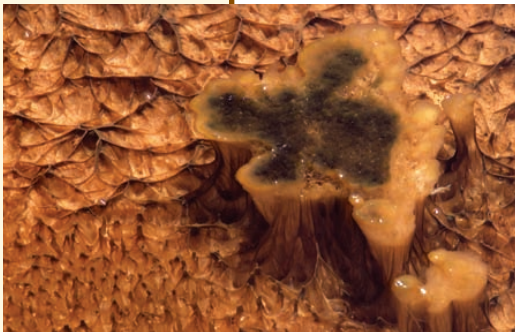
Thermophilic Communities



white filamentous bacteria, seen through a microscope



white filamentous bacteria



bacterial columns

Thermophilic communities are as diverse as the communities that humans live in. Community formations, colors, and locations vary depending on the types of microbes, the pH, and the temperature of their environments.

Millions of individual microbes can connect into long strands called filaments. Some bacteria (**photo left**) and algae form thin and delicate structures in fast moving water such as the runoff channels of hot springs and geysers. Other microbes form thick, sturdy structures in slower water or where chemical precipitates quickly coat their filaments.

A bacteria called *Thermocrinis* formed the structures in the **middle left photo**; this bacteria is descended from ancient bacteria that metabolized hydrogen and oxygen. Its filaments entwine, forming mats. Flowing water carries other microbes, miscellaneous organic matter, and minerals that become caught in the streamers and add to the mat.

Photosynthetic activity of cyanobacteria such as *Phormidium* form columns or pedestals (**bottom photo left**). Oxygen bubbles rise in the mat, forcing the microbes upward. The higher formations capture more organic matter and sediment than the lower mats, which help build the columns. Called stromatolites or microbialites, these structures are similar to ancient microbial communities still preserved in formations in some parts of the world.

Mats can be as thin as tissue paper or as thick as lasagna. Multiple layers of microorganisms comprise inch-thick mats. Dozens of types of microbes from all three domains can exist in these layers. Each microbial layer is a community, and each layer interacts with the other layers, forming a complex community full of millions of microorganisms and their life processes.

Visible and invisible changes occur in thermophile communities as light, temperature, and chemical concentrations change—both short term (within one day) and long term (seasonally). As day brightens to noon, cyanobacteria sensitive to light may move away from the surface; microbes less sensitive to light may move to the top layers of the mat. When light levels cause shifts in organisms, the community is responding to a *light gradient*.

Temperature and chemical gradients most often affect thermophilic communities in runoff channels of geysers and in shallow outflows from hot springs. In the **photo above**, the runoff channels from Pinwheel and Whirligig geysers meet. The outer edge of both are too hot for visible thermophile communities to develop. But as Pinwheel's water cools in the shallower channel edge, *Cyanidium* (an alga) can grow, forming a bright green community. Whirligig's runoff is hotter, which prevents *Cyanidium* from growing, but another type of



Chocolate Pots, on the Gibbon River, are an iron-rich community.

Thermophile community inhabitants are controlled, in part, by water temperature and pH. The chart at right provides general guidelines for what lives in which temperature.

thermophile thrives by oxidizing the abundant iron in the water, forming the orange community.

At the Chocolate Pots (**photo above**), which you can see from pullouts along the Gibbon River just north of Gibbon Meadows, iron-rich water flows from the vents. Three kinds of cyanobacteria—*Synechococcus*, *Chloroflexus*, and *Oscillatoria*—thrive in the iron-rich waters that flow from the vents. The bacterial filaments form mats, in which the mineral is captured. The iron may also be caught on the bacteria as the microbes move about within the mat. An olive green color indicates where the orange iron and green bacteria are enmeshed. Darker streaks indicate the presence of manganese. Scientists think the bacterial concentration may contribute to the iron concentrations at the Chocolate Pots, which are one hundred times more concentrated here than at other neutral hydrothermal features.

Communities formed by thermophilic microbes sustain communities of larger organisms within Yellowstone's hydrothermal areas, some of which were described on pages 56–57. These communities in turn affect even larger communities of the park's mammals. For example, bison and elk find food and warmth on the less extreme edges of thermophilic environments in winter (*photos at right*). In turn, coyotes, wolves, and bears seek prey in these areas—especially in late winter and early spring when bison and elk are weaker than any other time of year.

Whether it's the strike of a grizzly's paw or the shift of heat beneath the earth, these communities change through common and strange forces. Biologists continue to discover more about the individuals involved in thermophilic communities, and ecologists continue to follow the threads of these intricate webs.



93°C/199°F
Archaea

73°C/163°F
Cyanobacteria

62°C/144°F
Fungi

60°C/140°F
Algae

56°C/133°F
Protozoa

50°C/122°F
Mosses
crustaceans
insects

27°C/80°F
Trout

4

Thermophiles by Place & Color

Upper, Midway, & Lower Geyser Basins and West Thumb Geyser Basin



Characteristics

- pH 7–11
- underlain by rhyolitic rock
- water rich in silica, which forms sinter and geysers deposits

Thermophiles by Temperature

- >75°C/167°F, bacteria and archaea
- >75°C/167°F, *Thermocrinis* and other bacteria form streamers of pink, yellow, orange, or gray.
- <75°C/167°F, *Synechococcus*, *Phormidium*, and *Calothrix* (cyanobacteria) plus *Roseiflexus* (filamentous green bacterium) form mats that line cooler hot springs and runoff channels

Thermophiles by Color

- pink, yellow, orange, gray filaments—*Thermocrinis* bacteria
- orange mats—cyanobacteria, especially on sunny summer days (carotenoids protect the organisms from the bright sun)
- olive-green mats—cyanobacteria mixed with iron

Norris Geyser Basin & Mud Volcano Area



- pH 0–5
- underlain by rhyolite rock

- >75°C/167°F, *Sulfolobus*, an archaeum, and viruses that parasitize *Sulfolobus*
- >60°C/140°F, filamentous bacteria in yellowish streamers and mats
- <60°C/140°F, filamentous bacteria and archaea form red brown mats
- <56°C/133°F, *Zygonium*, other algae, and fungi form mats in runoff channels

- pink–pinkish-orange mats and streamers—*Thermus aquaticus* and other *Thermus* sp.
- green streamers and mats—*Cyanidium*
- orange—iron and/or arsenic, perhaps oxidized by thermophiles
- gray, muddy pools—*Sulfolobus*

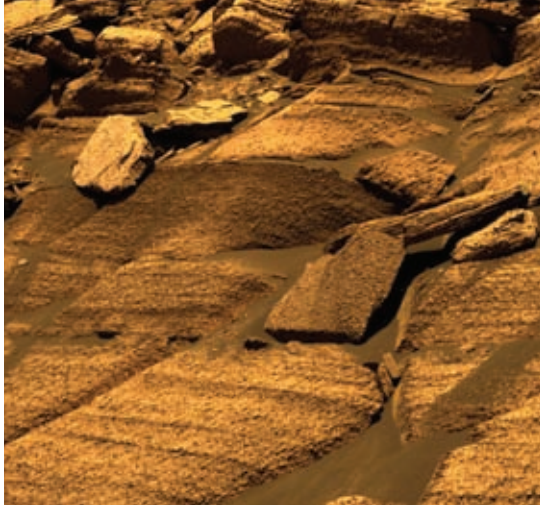
Mammoth Hot Springs



- pH 6–8 (neutral to slightly acidic)
- underlain by ancient limestone deposits
- water rich in calcium carbonate and sulfur

- 66–75°C/151–167°F, *Aquificales* (bacteria) filaments near hot springs vents
- <66°C/151°F, *Chloroflexus* (green nonsulfur bacteria) and cyanobacteria mats, and filamentous bacteria streamers
- <58°C/136°F, *Chromatium* (bacteria) form dark mats (uncommon)
- 25–54°C/77–129°F, *Chlorobium* (bacteria) mats; *Calothrix* streamers; *Synechococcus*

- Orange—*Chloroflexus* and cyanobacteria in summer
- Green—*Chloroflexus* and cyanobacteria in winter; *Chlorobium* in cooler water
- Cream—filamentous bacteria



These layers of rock on Mars have minerals and features developed by interactions between liquid water and rocks over extended periods of time. This evidence does not prove that life developed on Mars, but it brings the possibility one step closer to reality.

Photo and text adapted from www.nasa.gov, image by Nasa/JPL

From Earth to Mars—and Beyond?

Yellowstone's hydrothermal features and their associated communities of ther-

mophiles are studied by scientists who are searching for evidence of life on other planets. The connection is extreme environments. If life began in the extreme conditions thought to have been widespread on ancient Earth, it may well have developed on other planets—and might still exist today.

The chemosynthetic microbes that thrive in some of Yellowstone's hot springs do so by metabolizing inorganic chemicals, a source of energy that does not require sunlight. Such chemical energy sources provide the most likely habitable niches for life on Mars or on the moons of Jupiter—Ganymede, Europa, and Callisto—where uninhabitable surface conditions preclude photosynthesis. Chemical energy sources, along with extensive groundwater systems (such as on Mars) or oceans beneath icy crusts (such as on Jupiter's moons) could provide habitats for life.

Similar Signatures

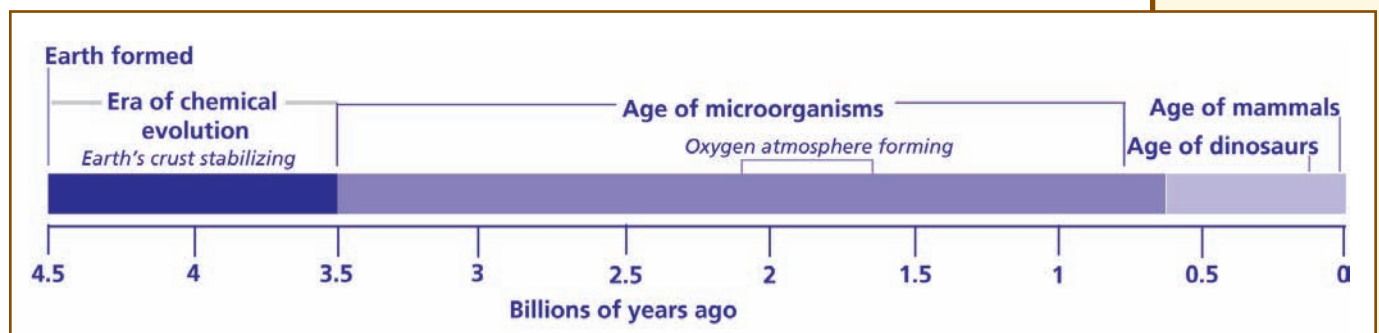
Thermophile communities leave behind evidence of their shapes as biological “signatures.” For example, at Mammoth Hot Springs, rapidly depositing minerals entomb thermophile communities. Scientists compare these modern signatures to those of ancient deposits elsewhere, such as sinter deposits in Australia that are 350 million years old. These comparisons help scientists better understand the environment and evolution on early Earth, and may give them an idea of what to look for on other planets.

Yellowstone National Park will continue to be an important site for studies at the physical and chemical limits of survival. These studies will give scientists a better understanding of the conditions that give rise to and support life, and how to recognize signatures of life in ancient rocks and on distant planets.

What's the Connection?

- Yellowstone's hydrothermal features contain modern examples of Earth's earliest life forms, both chemo- and photosynthetic, and thus provide a window into Earth's ancient past.
- Yellowstone hydrothermal communities reveal the extremes that life can endure, providing clues to environments that might harbor life on other worlds.
- Yellowstone environments show how mineralization preserves biosignatures of thermophilic communities, which could help scientists recognize similar signatures elsewhere.
- Based on the history of life on Earth, the search for life on other planets seems more likely to encounter evidence of microorganisms than of more complex life.

For additional information about the scientific value of thermophiles, see Chapter 9, “Bioprospecting.”



- Barns, Susan et al. 1996. Perspectives on archaeal diversity, thermophily, and monophyly from environmental rRNA sequences. *Proceedings Natl Acad. Sci.* 93: 9188–9193
- Boomer, Sarah et al. 2002. Molecular characterization of novel red green non-sulfur bacteria from five distinct hot spring communities in Yellowstone National Park. *Applied and Environmental Microbiology*. January: 346–355.
- Brock, Thomas D. 1978. *Thermophilic microorganisms and life at high temperatures*. Springer-Verlag, New York.
- 1998. Early days in Yellowstone Microbiology. *ASM News*. 64:137-140
- T. D. 1994 *Life at High Temperatures* Yellowstone Association/Mammoth, WY
- Dyer, Betsey Dexter 2003 *A Field Guide to Bacteria* Cornell University/Ithaca
- Carsten, Laura. 2001. Life in extreme environments. *Northwest Science and Technology*. Spring: 14–21.
- Farmer, Jack D. 2000. Hydrothermal Systems: Doorways to Early Biosphere Evolution. *GSA Today* 10(7): 1–9.
- Farmer, J. D., and D. J. Des Marais. 1999. Exploring for a record of ancient Martian life. *J. Geophys. Res.* 104.
- Fouke, Bruce et al. 2000. Depositional facies and aqueous-solid geochemistry of travertine-depositing hot springs. *J Sedimentary Research* 70(3): 565–585.
- Gihring, Thomas et al. 2001. Rapid arsenite oxidation by *T. aquaticus* and *T. thermophilus*: Field and laboratory investigations. *Environ. Sci. Technol.* 35:3857–3862.
- Madigan, Michael and Aharon Oren. 1999. Thermophilic and halophilic extremophiles. *Current Opinion in Microbiology* 2: 265–269.
- Pierson, Beverly and Mary Parenteau. 2000. Phototrophs in high iron microbial mats: microstructure of mats in iron-depositing hot springs. *Microbiology Ecology* 32: 181–196.
- Reysenbach, A-L. et al, eds. 2001. *Thermophiles: Biodiversity, Ecology, and Evolution*. Kluwer Academic Press/Plenum, New York.
- Reysenbach, A-L and Sherry Cady. 2001. Microbiology of ancient and modern hydrothermal systems. *Trends in Microbiology* 9(2): 80–86.
- Reysenbach, A-L, et al. 2000. Microbial diversity at 83°C in Calcite Springs, Yellowstone National Park. *Extremophiles* 4: 61–67.
- Sheehan, K.B. et al. 2005. *Seen and Unseen: Discovering the Microbes of Yellowstone* Falcon/Helena
- Sheehan, K.B. et al. 2004. *Yellowstone Under the Microscope*. The Globe Pequot Press/Gilford, CT.
- Walter, M. R. and D. J. Des Marais. 1993. Preservation of biological information in thermal spring deposits: developing a strategy for the search for fossil life on Mars. *Icarus* 101: 129–143.
- Ward, D.M. 1998. Microbiology in Yellowstone National Park. *ASM News* 64:141–146.
- Ward, D.M. et al. 1992. Modern phototrophic microbial mats: anoxygenic, intermittently oxygenic/anoxygenic, thermal, eucaryotic and terrestrial. In *The Proterozoic Biosphere: a Multidisciplinary Study*, J.W. Schopf and C. Klein, eds. Cambridge Univ. Press/Cambridge.
- Ward, D.M. and R.W. Castenholz. 2000. Cyanobacteria in geothermal habitats. In *Ecology of Cyanobacteria*. Kluwer Academic Publishers
- Ward, D.M. et al. 2002. Natural history of microorganisms inhabiting hot spring microbial mat communities: clues to the origin of microbial diversity and implications for micro- and macro-biology. In *Biodiversity of Microbial Life: Foundation of Earth's Biosphere*, J.T. Staley and A.-L. Reysenbach, eds. John Wiley and Sons/New York.

Websites

- www.windowsintowonderland.org, "Hot Colors: Windows into Hidden Worlds" (electronic field trip)
- www.microbeworld.org, the public website of the American Society for Microbiology
- www.tbi.montana.edu, website of the Thermal Biology Institute of Montana State University
- Additional information available on numerous websites. Search topics include thermophiles, extreme life, and astrobiology.

Additional Information from Yellowstone National Park

- Yellowstone National Park website, www.nps.gov/yell, includes an array of park information about resources, science, recreation, and issues.
- Yellowstone Science*, published quarterly, reports on research and includes articles on natural and cultural resources. Free; available from the Yellowstone Center for Resources, in the Yellowstone Research Library, or online at www.nps.gov/yell.
- Yellowstone Today*, published seasonally and distributed at entrance gates and visitor centers, includes features on park resources such as hydrothermal features.
- Area trail guides detail geology of major areas of the park. Available for a modest donation at Canyon, Fountain Paint Pot, Mammoth, Norris, Old Faithful, and West Thumb areas.
- Site Bulletins, published as needed, provide more detailed information on park topics. Free; available upon request from visitor centers.



Arrowleaf balsamroot

Yellowstone's vegetation is composed primarily of typical Rocky Mountain species. It is also influenced by flora of the Great Plains to the east and the Intermountain to the west. The exact plant community present in any area of the park reflects a complex interaction between many factors including the regional flora, the climate, the topography, and the local substrates/soils.

The vegetation of the park is interrelated with the geology of the park (*see Chapter 2*). The region's caldera explosions catastrophically destroyed vegetation. In addition, glaciers significantly altered the region during the ice ages. Today, the roughly 1100 native species of flowering plants in the park represent the species able to either persist in the area or recolonize after glaciers, lava flows, and other major disturbances. Unlike southwestern Wyoming or central Idaho, the Greater Yellowstone region has few endemic vascular plant species, primarily in the eastern portion of the Absaroka Mountains outside of Yellowstone. Within Yellowstone, only two endemics occur, Yellowstone sand verbenas (*Abronia ammophila*) and Ross' bentgrass (*Agrostis rossiae*).

Major Types

Montane Forests

Yellowstone is clothed in forests, covering roughly 80 percent of the park. Miles and miles of lodgepole pine forest characterize the park, especially within the Yellowstone Caldera. Also present in the park are extensive areas of forest dominated by subalpine

Vegetation Overview

- Vegetation in Yellowstone is typical of the Rocky Mountains.
- Elements of the Great Plains and Great Basin floras mix with Rocky Mountain vegetation in the vicinity of Gardiner and Stephen's Creek.
- The interaction of climate and geologic substrate controls distribution of vegetation in the park.
- Disturbances—fire, floods, insects, disease—occur periodically, affecting portions of the park.
- Hydrothermal areas support unique plant communities and rare species.
- Lodgepole pine alone comprises 80% of the forest canopy.
- Six other conifer tree species: white-bark pine, Engelmann spruce, sub-alpine fir, Douglas-fir, Rocky Mountain juniper, limber pine.

- Deciduous trees include quaking aspen and cottonwood.
- Shrubs include common juniper, sagebrush (many species), Rocky Mountain maple.
- Wildflowers number in the hundreds.
- Two endemics—Ross' bentgrass and Yellowstone sand verbenas.
- More than 200 exotics, including Timothy grass and Dalmatian toadflax.

Management

- Controlling exotics, which threaten native species, that are prevalent in developed areas; some are spreading into the backcountry.
- Surveying areas for sensitive or rare vegetation before disturbance such as constructing a new facility.

fir and Engelmann spruce, especially in areas such as the Absaroka Range that are underlain by andesites. These species can also be common in the understory where the canopy is entirely composed of lodgepole pine. Through time, in the absence of fire, the sub-alpine fir and Engelmann spruce will replace the lodgepole pine, leading to a canopy dominated by these species. At higher elevations such as the Absaroka Mountains and the Washburn Range, whitebark pine becomes a significant component of the forest. In the upper subalpine zone, whitebark pine, Engelmann spruce, and subalpine fir often grow in small areas separated by subalpine meadows. Severe conditions near treeline—wind and desiccation—cause distorted forms known as krumholtz where most of the 'tree' is protected below the winter snow.

Douglas-fir Forests

Douglas-fir forests occur at lower elevations, especially in the northern portion of the park. The thick bark of Douglas-fir trees allows them to tolerate low-intensity fire. Some of

Major Vegetation Types

Wildflowers

Wildflowers such as lupine and arnica often grow under the forest canopy, but the most conspicuous wildflower displays occur in the open meadows and sagebrush-steppe. The appearance of spring beauties, glacier lilies, and steer's head announce spring in the park. Soon colors splash the slopes, especially on the northern range—yellow from arrowleaf balsam-root, white from phlox, reds and oranges from paintbrush, and blue from penstemon and lupine. Goldenrod and gentians indicate the coming of autumn.

the trees in these forests are several hundred years old and show fire scars from a succession of low intensity ground fires. In contrast, lodgepole pine trees have very thin bark and can be killed by ground fires

Understory Vegetation

The understory vegetation differs according to precipitation regime, the forest type, and the substrate. Lodgepole pine forest is often characterized by a very sparse understory composed mostly of elk sedge (*Carex geyeri*), or grouse whortleberry (*Vaccinium scoparium*). Pinegrass (*Calamagrostis rubescens*) occurs frequently under Douglas-fir forest but is also common under other forest types, especially where the soil is better developed or moister. In some areas of the park such as Bechler and around the edges of the northern range, a more obviously developed shrub layer is composed of species such as Utah honeysuckle (*Lonicera utahensis*), snowberry (*Symphoricarpos spp.*) and buffaloberry (*Shepherdia canadensis*).

Sagebrush-Steppe

The northern range is composed of extensive stretches of sagebrush-steppe. Mountain big sagebrush (*Artemisia tridentata var. vaseyana*) dominates this community type, along with several other species and varieties of sagebrush. Several grass species, such as Idaho fescue (*Festuca idahoensis*), also dominate sagebrush-steppe. The northern range can be spectacular with wildflowers in late June and early July. Sagebrush-steppe also occurs in Hayden Valley, Pelican Valley, and Gardner's Hole.

Wetlands and Riparian Areas

Even though the park is dominated by forest and sagebrush-steppe, many other community types occur here. Wetlands are a conspicuous component in the area, with extensive areas of sedge bottoms and willow thickets. Subalpine meadows are rich in the number of different species of wildflowers and merge into alpine tundra on the highest peaks. Rivers, lakes, and ponds support aquatic vegetation in addition to the obvious inhabitants such as fish.

Hydrothermal Communities

Yellowstone is the best place in the world to see hydrothermal phenomenon such as geysers and hot springs. Fascinating and unique plant communities have developed in the expanses of thermally heated ground. Many of the species that occur in the geyser basins are actually species that tolerate tremendously different conditions, and thus grow all over the western United States. Other species, though, are typical of the central Rockies, or are regional endemics.

Vegetation Map (next page)

Lodgepole pine forests

- Dominates more than 80% of the total park forested area.
- Can be seral (developing) or climax.
- Climax forests underlain by rhyolite.

Douglas-fir forests

- Lower elevations (<7600 ft.) associated with the Lamar, Yellowstone, and Madison river drainages.
- Often less than 20 inches of annual precipitation.
- More frequent historic fire interval (25–60 year) than other forest types in the park.

Spruce-fir forests

- Engelmann spruce and subalpine fir dominate older forests.
- Usually found on moist and/or fertile substrates.
- Climax forests underlain by andesitic soils.

Whitebark pine forests

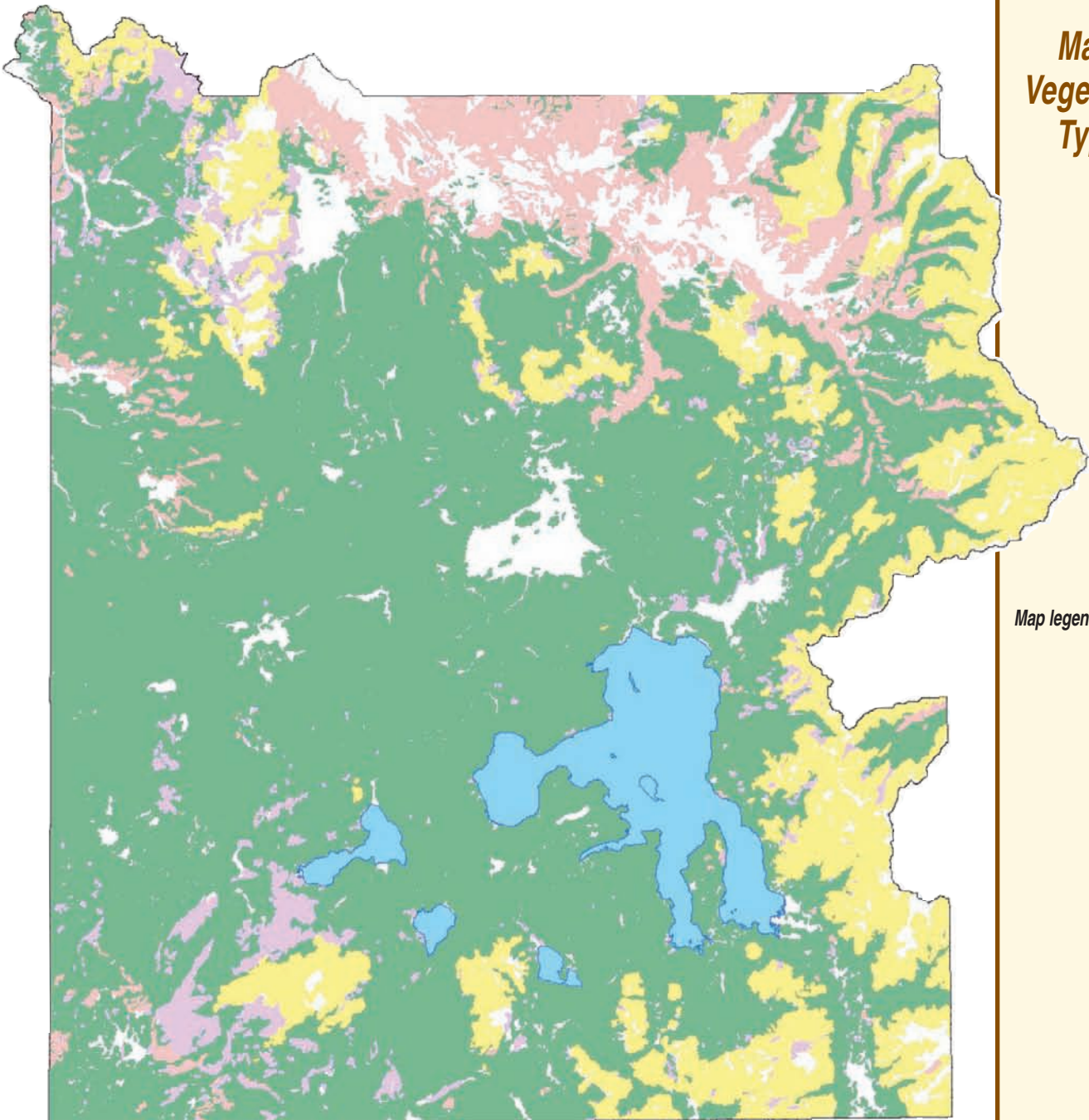
- Major overstory component at elevations above 8400 feet.
- Major understory component of lodgepole-dominated forests from 7,000 to 8,400 ft in elevation.
- Seeds are ecologically important food for a variety of wildlife species.

Non-forest

- Includes grasslands, sagebrush, alpine meadows, talus, and hydrothermal environments.
- Encompasses the moisture spectrum from dry sagebrush shrublands to wet alpine meadows.
- Provides the winter and summer forage base for ungulates.

Other types not shown on map

- Aspen—found in small clones interspersed among the sagebrush/forest ecotone (transition zone) along the Yellowstone, Madison, and Snake river drainages.
- Wetland—includes various grass, forb, rush, and sedge species.
- Riparian—typically streamside vegetation includes cottonwoods, willows, and various deciduous shrubs.



Map legend on p. 64

Effects of Disturbances

The park's vegetation appears at first glance to be static and unchanging, but must, in fact, respond to change. Hydrothermal plant communities demonstrate in very short periods of time that change is fundamental in any natural system. In a few days, the ground can heat up, perhaps triggered by an earthquake, and fry plants, while an adjacent area may be

turning cooler, allowing plants to invade a previously inhospitable place. The vegetation of the park today reflects the effects of many different types of natural disturbance such as forest fire (*see Chapter 6*), floods, landslides, insect infestations, blowdowns, and the continually changing climate.



Major Types of Trees

Lodgepole pine *Pinus contorta*

- Most common tree in park
- Needles in groups of twos
- May have serotinous cones
- Up to 75 feet tall

Limber pine *P. flexilis*

- Needles in groups of five
- Young branches are flexible
- Up to 75 feet tall
- Often on calcium-rich soil

Whitebark pine *P. albicaulis*

- Grows at higher elevations, above 7000 feet
- Needles in groups of five
- Purple-brown cones produce important food for squirrels, bears, Clark's nutcrackers
- Up to 75 feet tall

Engelmann spruce *Picea engelmannii*

- Often along creeks, or wet areas
- Sharp, square needles grow singly
- Cones hang down and remain intact, with no bract between scales
- Up to 100 feet tall

Subalpine fir *Abies lasiocarpa*

- Only true fir in the park
- Blunt, flat needles
- Cones grow upright, disintegrate on tree
- Up to 100 feet tall

Douglas-fir *Pseudotsuga menziesii*

- Resembles the fir and the hemlock, hence its generic name *Pseudotsuga*, which means "false hemlock"
- Cones hang down and remain intact, with 3-pronged bract between scales
- Thick bark resists fires
- Up to 100 feet tall

Rocky Mountain juniper

Juniperus scopulorum

- Needles scale-like
- Cones are small and fleshy
- Up to 30 feet tall

Cottonwood *Populus spp.*

- Several species and hybrids
- Up to 75 feet tall
- Thick, furrowed bark
- Seeds with tangled hairs—the "cotton"—dispersed by wind

Quaking aspen *Populus tremuloides*

- Sedimentary soils in damp areas
- Flexible stems quake and shiver in the breeze
- Trunks often rough and black due to browsing by elk and other animals
- Reproduces by cloning (most often), and by seeds (related to fire)

LOGEPOLE PINE

The lodgepole pine (*Pinus contorta*) is by far the most common tree in Yellowstone. Early botanical explorers first encountered the species along the West Coast where it is often contorted into a twisted tree by the wind, and thus named it *Pinus contorta* var. *contorta*. The Rocky Mountain variety, which grows very straight, is *Pinus contorta* var. *latifolia*. Various Native American tribes used this tree to make the frames of their tipis or lodges, hence the name "lodgepole" pine. Typically, lodgepole pine in Yellowstone is seldom more than 75 feet tall. The species is shade intolerant; any branches left in the shade below the canopy will wither and fall off the tree. Lodgepoles growing by themselves will often have branches all the way to the base of the trunk because sunlight can reach the whole tree.

Lodgepoles are the only pine in Yellowstone whose needles grow in groups of two. The bark is typically somewhat brown to yellowish, but a grayish-black fungus often grows on the shady parts of the bark, giving the tree a dark cast.

Like all conifers, lodgepole pines have both male and female cones. The male cones produce huge quantities of yellow pollen in June and July. This yellow pollen is often seen in pools of rainwater around the park or at the edges of lakes and ponds. The lodgepole's female cone takes two years to mature. In the first summer, the cones look like tiny, ruby-red miniature cones out near the end of the branches. The next year, after fertilization, the cone starts rapidly growing and soon becomes a conspicuous green. The female

cones either open at maturity releasing the seeds, or remain closed—a condition called serotiny—until subjected to high heat such as a forest fire. These cones remain closed and hanging on the tree for years until the right conditions allow them to open. Within a short period of time after the tree flashes into flame, the cones open up and release seeds over the blackened area, effectively dispersing seeds after forest fires. Trees without serotinous cones (like Engelmann spruce, subalpine fir, and Douglas-fir) must rely on wind, animals, or other agents to carry seeds into recently burned areas.

Lodgepole pines prefer a slightly acid soil, and will grow quickly in mineral soils disturbed by fire or by humans (such as a road cut). Their roots spread out sideways and do not extend deeply—an advantage in Yellowstone where the topsoil is only about 6 to 12 inches deep, but a disadvantage in high winds. Lodgepole pines are vulnerable in windstorms, especially individuals that are isolated or in the open.

Besides reseeding effectively after disturbance, lodgepole pines can grow in conditions ranging from very wet ground to very poor soil prevalent within the Yellowstone Caldera. This flexibility allows the species to occur in habitat that otherwise would not be forested.

Because lodgepole pines are dependent on sunny situations for seedling establishment and survival, the trees do not reproduce well until the canopy opens up significantly. In the Yellowstone region, this allows the lodgepole pine forest to be replaced by shade-loving seedlings of subalpine fir and Engelmann spruce where the soil is well-developed enough to support either of these species. In areas of nutrient poor soil, where Engelmann spruce and subalpine fir struggle, lodgepole pines will eventually be replaced by more lodgepole pine trees as the forest finally opens enough to allow young lodgepoles to become established.



Only Here

- Yellowstone is home to two endemic species—plants that grow nowhere else—Ross's bentgrass and Yellowstone sand verberna.
- Endemics occur in unusual or specialized habitats such as hydrothermal areas.
- Several other unusual species in Greater Yellowstone Area: warm springs spike rush, which grows in warm water; and Tweedy's rush, sometimes the only vascular plant growing in acidic hydrothermal areas.



Yellowstone sand verberna

Ross's bentgrass (*Agrostis rossiae*)

Ross's bentgrass only occurs on thermal ground along the Firehole River and near Shoshone Lake. This species seems to require locations providing the right combination of moisture and warmth that create a natural greenhouse. The temperature within an inch of the surface under a patch of this grass is usually roughly 100°F. As a result, this grass is one of the first species to green up in warm nooks and crannies of geyserite—sometimes as early as January. Inflorescences (flowers) may be present in February and March, but typically the plants do not produce viable seed that early. Full bloom occurs in late May and early June. As soon as temperatures rise in the early summer, the plants dry out due to the summer sun above and the thermal heat beneath. Ross's bentgrass is already dead and hard to find by July when most of the park's wildflowers are in full bloom.

Closely related species of grass also occur in the geyser basins. Hot springs tickle grass (*formerly A. scabra*) is common all through the interior of the park. This species is much more frequently encountered in the geyser basins than Ross's bentgrass and is similar. Ross's bentgrass is shorter, rarely growing taller than six inches and more typically only 2–3 inches. Another diagnostic characteristic of Ross's bentgrass is that the inflorescence never completely opens up.

Any plant growing in thermal areas must be able to deal with constant change. A successful plant in the geyser basins must be able to shift location relatively easily as one major thermal change or several changes could

eradicate the entire population. Apparently, Ross's bentgrass deals with this problem efficiently. Its seed dispersal mechanism has not been studied, but probably includes traveling on the muddy hooves of bison and elk who inhabit thermal areas during the winter. Exotic species pose the only known threat; as they spread in thermal areas, they eventually may outcompete Ross's bentgrass.

Yellowstone Sand Verberna (*Abronia ammophila*)

Yellowstone sand verberna occurs along the shore of Yellowstone Lake. Taxonomists debate the relationship of this population of sand verberna to other sand verbenas. Recent work suggests that Yellowstone sand verberna is distinct at least at the subspecific level, and is certainly reproductively isolated from the closest sand verberna populations in the Bighorn Basin of Wyoming.

Sand verbenas are a member of the four o'clock family, which is primarily a tropical family of flowering plants. Very few members of the family grow this far north. Little is known about the life history of Yellowstone sand verberna. It was described as an annual in the only monograph that has examined this genus in recent years, but it is a perennial. It grows close to the sand surface. Some individuals occur near warm ground, so the thermal activity in Yellowstone may be helping the survival of this species. The flowers are white and the foliage is sticky. Apparently, the sand verberna flowers from roughly mid-June until killing frosts in early September.

The full extent and impact of exotic plants in Yellowstone is unknown. Many grow in disturbed areas such as developments, road corridors, and thermal basins; they also are spreading into the backcountry. Several exotics, such as the common dandelion, have spread throughout the park.

Exotic plants can displace native plant species and change the nature of vegetation communities. These changes can profoundly effect the entire ecosystem. For example, exotics unpalatable to wildlife may replace preferred native plants, leading to changes in grazing activity. In turn, this stresses plants not adapted to grazing.

Controlling all the exotic species, some well-established, is unrealistic. The park focuses control action on species posing the most

Exotic Species

- More than 200 exotic plant species in park.
- Resource managers target the most threatening species for control or removal.

- Species include:
Dalmation toadflax
Spotted knapweed
Canada thistle
Ox-eye daisy
Houndstongue
Leafy spurge

serious threat or those most likely to be controlled.

The park uses Integrated Pest Management—chemical, biological, sociological, and mechanical methods—to control some of the exotic plants. The park also cooperates with adjacent state and county Weed Control Boards to share knowledge and technology related to exotic plant detection and control.

Dalmatian toadflax

Dalmatian toadflax *Linaria dalmatica*

- Northern portions of the park, especially around Mammoth.
- Highly invasive, replacing native plants.
- Intense biological and chemical control efforts during the late 1960s and early 1970s were unsuccessful.

Spotted knapweed *Centaurea maculosa*

- Along roadsides and in the vicinity of Mammoth.
- Aggressive species that, once established, forms a monoculture, which could displace native grasses on the ungulate winter and summer ranges.
- Aggressive control efforts underway to prevent a catastrophic change in park vegetation.

Canada thistle *Cirsium arvense*

- Throughout the park and adjacent national forests.
- Airborne seed enable it to spread widely throughout the park, invading wetlands.
- Forms dense monocultures, thus radically changing vegetation.

Ox-eye daisy *Leucanthemum vulgare*

- Mammoth and Madison areas, where it may have been planted in flower gardens.
- Can become dominant in meadows, is unpalatable to elk and other wildlife.

- Control efforts have substantially curtailed infestation; monitoring and evaluation continue.

Houndstongue *Cynoglossum officinale*

- Primarily Mammoth and East Entrance.
- May have been introduced by contaminated hay used by both the National Park Service and concessioners in their horse operations.
- Highly invasive, replacing native plants.
- Seeds easily attach to the coats of animals, and thus spread along animal corridors.

Leafy spurge *Euphorbia esula*

- Small patches in Bechler and along roadsides, so far being successfully controlled but spreading actively in Paradise Valley north of the park and outside Bechler on the Targhee National Forest.
- Becomes a monoculture, forcing out native vegetation.
- Extremely hard to control because of deep roots (up to 30 feet) and dense vegetation.



For More Information

Staff reviewers: Jennifer Whipple, Botanist; Roy Renkin

- Craighead, John J. et al. 1963. *A Field Guide to Rocky Mountain Wildflowers from Northern Arizona and New Mexico to British Colombia*. Boston: Houghton Mifflin.
- Cronquist et al. (ongoing, currently 5 volumes) *Intermountain Flora*. New York Botanical Garden.
- Despain, Don. 1990. *Yellowstone Vegetation: Consequences of Environment and History in a Natural Setting*. Boulder: Roberts Rinehart.
- Dorn, Bob. 2001. *Vascular Plants of Wyoming*. 3rd edition.
- Hitchcock & Cronquist. 1974. *Flora of the Pacific Northwest*. Seattle: U. Washington Press.
- Hitchcock et al. *Vascular Plants of the Northwest* (5 volumes). Seattle: U. Washington Press.
- Kershaw et al. 1998. *Plants of the Rocky Mountains*. Lone Pine Publishing.
- Preston, Richard J. 1968. *Rocky Mountain Trees: A Handbook of the Native Species with Plates and Distribution Maps*. New York: Dover.
- Romme, William H. and Dennis Knight. 1982. Landscape diversity: The concept applied to Yellowstone National Park. *Bioscience*. 32:8.
- Shaw, Richard J. 1964. *Trees and Flowering Shrubs of Yellowstone and Grand Teton National Parks*. Salt Lake City: Wheelwright Press.
- Shaw, Richard J. 1992. *Wildflowers of Yellowstone and Grand Teton National Parks*. Salt Lake City: Wheelwright Press.
- Sheley, Roger L. and Janet K. Petroff. 1999. *Biology and Management of Noxious Rangeland Weeds*. Corvallis: Oregon State University Press.
- Whitson, Tom L. et al. 2002. *Weeds of the West*. Western Society of Weed Science. Jackson, WY/Grand Teton Lithography.

Additional Information from Yellowstone National Park

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- Yellowstone Science*, published quarterly, reports on research and includes articles on natural and cultural resources. Free; available from the Yellowstone Center for Resources, in the Yellowstone Research Library, or online at www.nps.gov/yell.
- Yellowstone Today*, published seasonally and distributed at entrance gates and visitor centers, includes features on park resources such as hydrothermal features.
- Site Bulletins, published as needed, provide more detailed information on park topics such as bison management, lake trout, grizzly bears, and wolves. Free; available upon request from visitor centers.

FIRE IN YELLOWSTONE

6

Fire Ecology

Fire is a natural force operating in the Yellowstone ecosystem for thousands of years. Fire scars on old Douglas-fir trees in the northern range indicate an average of one fire every 25 to 30 years. Tree-ring research indicates different intervals for lodgepole pine forests, depending on soil: 150 years or more on andesitic soils; to 300 years on rhyolitic soils on the Yellowstone Plateau. Records kept since 1931 show that lightning starts an average of 22 fires each year.

The vegetation in the Greater Yellowstone Ecosystem has adapted to fire and in some cases is dependent on it. Some plant communities depend on the removal of the forest overstory to become established; they are the first to inhabit sites after a fire. Other plants growing on the forest floor are adapted to survive at a subsistence level for long periods of time until fires open the overstory.

Fire can limit trees in grasslands. Microhabitats suitable for tree seedling establishment are rare in a grassland, but if a seed reaches such a microhabitat during a favorable year, a tree may grow. Once the tree is growing, it begins to influence the immediate environment. More tree habitat is created and a small forest island eventually appears. Periodic fire kills the small trees before they have a chance to become islands, thus maintaining the grassland.

Older Douglas-fir trees are adapted to fire by having thick bark that resists damage by ground fires. In the past, in areas like the park's northern range, frequent ground fire kept most young Douglas-fir trees from becoming part of the overstory. The widely scattered, large, fire-scarred trees in some of the dense Douglas-fir stands in the valleys of the Lamar and Gardner rivers are probably remnants of these communities.

Lodgepole pines produce two types of cones, one of which opens after being heated to at



Arthur Fire, 2002

FIRE ECOLOGY

- Fires have always occurred periodically in the Yellowstone ecosystem.
- Lightning starts an average of 22 fires each year.
- Vegetation in this ecosystem is adapted to fire.
- Controlling fires alters the dynamics of the ecosystem.

least 113°F. These fire-dependent cones—called serotinous—ensure seedling establishment after a fire. Lodgepole seedlings also need an open canopy that allows plenty of sun through. This happens only if mature trees in a lodgepole stand are periodically thinned by disease, fire, or other natural agents. Such disturbances create a landscape more diverse in age, which reduces the probability of disease or fire spreading through large areas.

Fire influences the rate minerals become available to plants by rapidly releasing these nutrients from wood and forest litter. Fire's heat may also hasten the weathering and release of soil minerals. Following a fire, plants absorb this abundant supply of soluble minerals.

Fire suppression alters these natural conditions. Landscape diversity diminishes, forest size increases, and plant community structure and composition change. Species susceptible to fires become prominent; diseases spread over greater areas; litter and deadfall accumulate; and minerals remain locked up or are more slowly released.

Effects of Fire Control

- *Vegetation diversity decreases as communities age.*
- *Species that do not benefit from fire are favored.*
- *Insects and diseases are more likely to spread.*
- *Litter and dead-fall accumulate, increasing chances of extreme fire behavior.*

History

- For the first 100 years of the park's existence, managers believed fires had to be extinguished to preserve park resources.
- Scientific research revealed:
 - fires have occurred in Yellowstone for as long as there has been vegetation to burn
 - fire plays a role in creating the landscape
 - fire is a part of the ecosystem that park managers want to preserve
 - suppressing fires alters the natural landscape and diminishes diversity.
- 1972, Yellowstone began using natural fire management.

- Between 1972 and 2005, 397 natural, un-suppressed fires burned 66,354 acres—mostly in 3 dry years: 1979, 1981, 1988. (In 1988, natural fires were allowed to burn in early summer. See page 75.)
- The fires of 1988 brought about management changes (next section).

Current Fire Management Policy

The National Fire Plan emphasizes interagency cooperation in fire management. Appropriations for the plan include \$101 million for National Park Service projects and activities identified in the plan.



This four-wheel-drive fire truck was one of five that served Yellowstone from 1960 until 1996, including during the 1988 fires. The driver would head for the nearest river to refill the water tank.

Evolution of Fire Management

Fire suppression began with the arrival of the U.S. Army, which was placed in charge of protecting the park in 1886. The Army, which was in Yellowstone until 1918, successfully extinguished some fires, though it is difficult to determine what effect their efforts had on overall fire frequency or extent of fires. Their fire suppression was most effective on the northern range's grasslands. Reliable and consistent fire suppression began in the rest of the park when modern airborne firefighting techniques became available after World War II.

In 1972, Yellowstone was one of several national parks to initiate programs allowing some natural fires to run their courses. Two backcountry areas in the park (340,000 acres) were designated as locations where natural fires could burn.

In 1975, following initial successes of the program, an environmental assessment (EA) was prepared to expand the program to 1,700,000 acres in the park. It was approved early in 1976. Shortly thereafter Yellowstone National Park and Bridger-Teton National Forest entered into a cooperative program allowing naturally caused fires in the Teton Wilderness to burn across the boundary between the two federal units.

Yellowstone's fire management plan was gradually revised and updated in accordance with National Park Service guidelines and as research provided new information, such as:

- Tens of thousands of lightning strikes failed to ignite fire.
- 140 lightning-caused fires burned only a small area.
- More than 80 percent of the lightning starts went out by themselves.
- A total of 34,175 acres burned in the park as a result of natural fires.
- The largest natural fire burned about 7,400 acres. (Prior to this, the largest natural fire in the park's written history was in 1931 at Heart Lake. About 18,000 acres burned.)

- No human lives were lost, and no significant human injuries occurred due to fires.
- No park structures or special features were affected.

By 1985, cooperative agreements were in place among all Greater Yellowstone units to allow natural fires to burn across the public land boundaries.

A fire plan revision was begun in late 1986 and was in the final stages of approval by spring 1988. The plan's goals:

- To permit lightning-caused fires to burn under natural conditions.
- To prevent wildfire from destroying human life, property, historic and cultural sites, special natural features, or threatened and endangered species.
- To suppress all human-caused fires (and any natural fires whose suppression is deemed necessary) safely, cost-effectively, and in an environmentally sensitive manner.
- To prescribe burn when and where necessary and practical to reduce hazardous fuels.

The plan was reviewed again after the fires of 1988 (*see next section*) when the Secretaries of the Departments of the Interior and Agriculture appointed a Fire Management Policy Review Team. Its final report, issued in May 1989, reaffirmed the basic soundness of natural fire policies in national parks and wilderness areas and offered 15 recommendations to improve federal fire management programs. These recommendations were incorporated into the National Park Service's Wildland Fire Management Policy Guideline revised in June 1990 and into Yellowstone National Park's fire management plan of 1992.

National fire management plans continue to be reviewed after major fire seasons. For example, a major review of federal policies and programs followed the 1994 fire season when 34 people were killed in the western United States (none in Yellowstone, though). That review, completed in 1995, directs federal agencies to achieve a balance between suppression to protect life, property, and resources and "fire use" (the new term for natural fires that replaces prescribed natural fire) to regulate fuels and maintain healthy ecosystems. The report provides nine guiding principles and 13 policies to be incorporated into all wildland fire management actions.



Bringing water to the Arthur Fire (2002)

The National Fire Plan

During the 2000 fire season in the United States, almost 123,000 wildland fires burned more than 8.4 million acres and destroyed numerous structures. Subsequently, recommendations were developed on how to reduce the impacts of fire on rural communities and ensure sufficient firefighting resources for the future. That report, now known as the "National Fire Plan," identified five key points that continue to emphasize interagency approaches:

- *Firefighting: Continue to fight fires and be adequately prepared for the next year.*
- *Rehabilitation and Restoration: Restore landscapes and rebuild communities damaged by the wildfires of 2000.*
- *Hazardous Fuel Reduction: Invest in projects to reduce fire risk.*
- *Community Assistance: Work directly with communities to ensure adequate protection.*
- *Accountability: Be accountable and establish adequate oversight, coordination, program development, and monitoring for performance.*

The House and Senate approved an appropriations bill that included \$101 million for National Park Service projects and activities identified in the National Fire Plan, including those in Yellowstone.

The principles include:

- Firefighter and public safety is the first priority.
- Wildland fire is an essential ecological process and a natural change agent and will be incorporated into the planning process.

These principles and policies were incorporated into wildland fire management activities for the fire seasons beginning in 1996.

6

Fire Management

After the natural fire policy was suspended on July 15, 1988, all fires in the park were suppressed until the revised policy was approved in 1992. The table lists major fire years since that time. The map shows major fires since 2000 that burned close enough to park roads for visitors to see effects. They are:

- 2001**
Sulphur 3,750
- 2002**
Broad 9140
- 2003**
East Fire 18,050 acres
Grizzly 4,460 acres
+90% of Frank Island,
in Yellowstone Lake

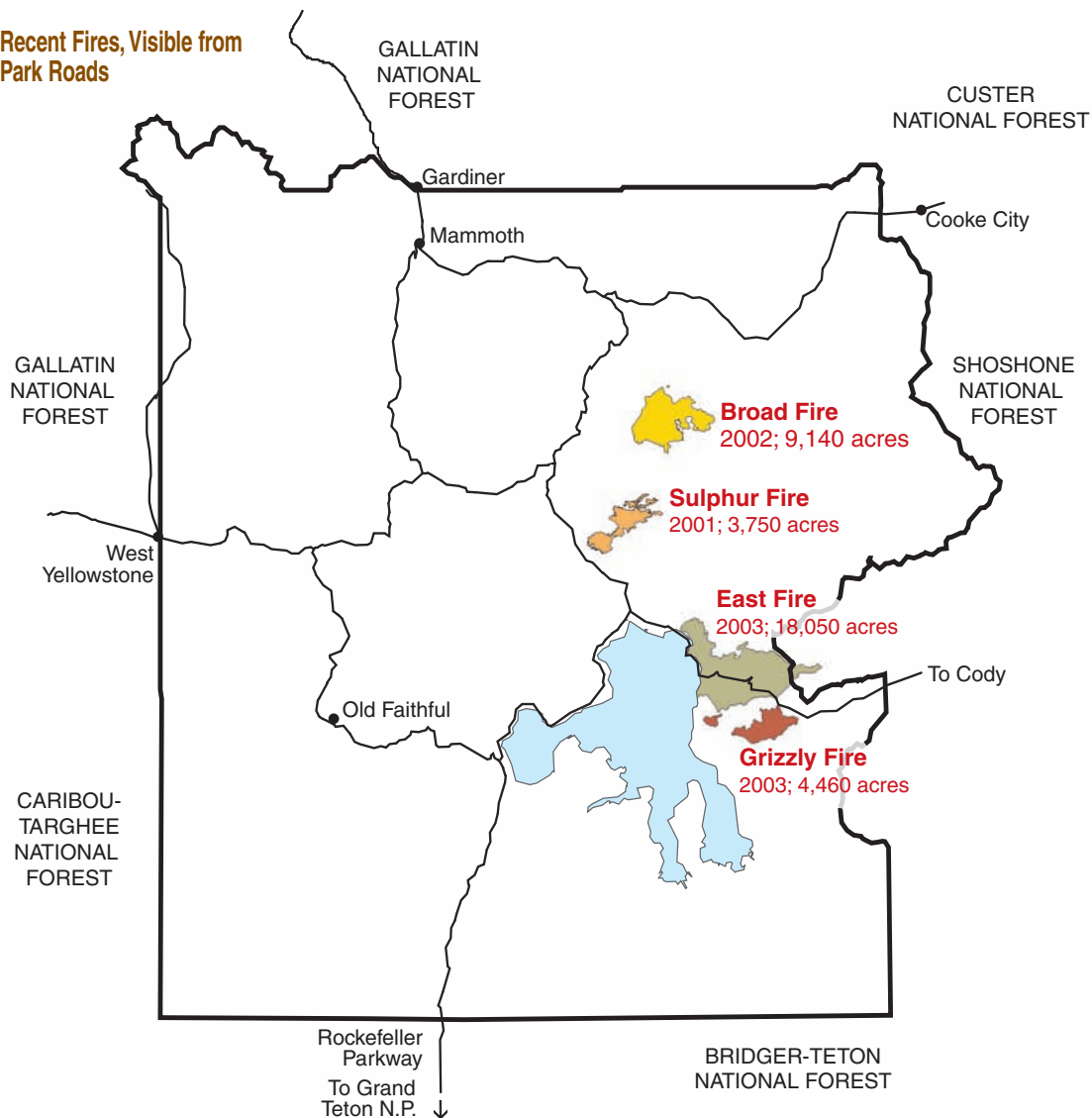
More wildland fire statistics at www.nifc.gov

Major Fire Years in Yellowstone Since 1994

Number of Fires

Year	Prescription	Suppressed	Acres Burned
1994	4	60	16,343
1996	13	11	3,263
2000	2	31	7,209
2001	16	21	7,987
2002	8	38	12,755
2003	7	71	28,849

Recent Fires, Visible from Park Roads



The Fires of 1988

The spring of 1988 was wet until June, when hardly any rain fell. Park managers and fire behavior specialists expected that July would be wet, though, as it had been historically (*see chart below right*). Eighteen lightning-caused fires were allowed to burn after evaluation according to the fire management plan. Eleven of these fires burned themselves out, behaving like many fires had in previous years.

Rains did not come in July as predicted. By late July, after almost two months of little rain, moisture content of grasses and small branches reached levels as low as 2 or 3 percent, downed trees were as low as 7 percent (kiln-dried lumber is 12 percent). A series of unusually high winds fanned flames that even in the dry conditions would not have moved with great speed.

Because of the extremely dry conditions, after July 15 no new natural fires were allowed to burn. (Exceptions were made for natural fires that started adjacent to existing fires, when the new fires were clearly going to burn into existing fires.) Even so, within a week the area of the fires in the park doubled to about 17,000 acres. After July 21, all fires were subjected to full suppression efforts as staffing would allow. (Human-caused fires had been vigorously suppressed from the beginning.) On July 27, during a visit to Yellowstone, the Secretary of the Interior reaffirmed that the natural fire program had been suspended, and all fires would be fought.

Fighting the Fires

An extensive interagency fire suppression effort was initiated in mid-July in the greater Yellowstone area in an attempt to control or contain the unprecedented series of wildfires. The extreme weather conditions and heavy, dry fuel accumulations presented even the most skilled professional firefighters with conditions rarely observed.

Statistics

- 9 fires caused by humans.
- 42 fires caused by lightning.
- 36% (793,880 acres) of the park was affected, mostly by surface burns.
- Fires begun outside of the park burned 63% or approximately 500,000 acres of the total acreage.
- About 300 large mammals perished as a direct result of the fires: 246 elk, 9 bison, 4 mule deer, 2 moose.
- \$120 million spent fighting the fires.
- 25,000 people employed in these efforts.

Fighting the Fires

- Until July 15, naturally-caused fires allowed to burn.
- After July 15, all fires were fought, regardless of their cause.
- Single largest fire-fighting effort in the history of the United States to date.
- Effort saved human life and property, but probably had little impact on the fires themselves.
- Rain and snow in September finally stopped the advance of the fires.

Results of the Fires

- Extensive review, some revision of fire management policy (*see previous section*).
- Extensive research on fire ecology (*see next section*).

THE YEAR THE RAINS FAILED Percent of Normal Rainfall Mammoth Hot Springs

	April	May	June	July	Aug.
1977	10	96	63	195	163
1978	91	126	42	99	46
1979	6	17	42	115	151
1980	33	152	55	143	199
1981	49	176	102	103	25
1982	169	74	89	118	163
1983	22	29	69	269	88
1984	44	84	66	297	121
1985	42	93	44	160	84
1986	145	47	64	212	75
1987	42	144	75	303	122
1988	155	181	20	79	10

Accepted firefighting techniques were frequently ineffective because fires spread long distances by “spotting,” a phenomenon in which wind lofts embers across unburned forest to start spot fires ahead of the main fire.

Moisture Content

When the moisture content of down and dead lodgepole pines is:

- 8 to 12%:
lightning will likely start fires that can spread rapidly
- 12 to 20%:
fires will burn actively and possibly spread rapidly
- >20%:
fires may start but few will burn significant acreage
- 24%:
few fires start

6

The Fires of 1988

Spotting up to a mile and a half away from the fires made the widest bulldozer lines useless and enabled the fires to jump rivers, roads, and even the Grand Canyon of the Yellowstone River.

Fires often moved two miles per hour, with common daily advances of five to ten miles, consuming even the most fire-resistant forest

types. The fast movement, coupled with spotting, made frontal attacks on the fires impossibly dangerous, as fire crews could easily be overrun or trapped between a main fire and its outlying spot fires. Even during the night, fires could not be fought. Normally, wildfires “lie down” at night as increased humidity and decreased temperature quiet them. But in 1988, the humidity remained low at night, and fire fighting was further complicated by the danger of falling trees.



The North Fork Fire threatened Old Faithful, Madison, Canyon, Norris, West Yellowstone, Mammoth Hot Springs, and the Tower–Roosevelt area.

Firefighting efforts were directed at controlling the flanks of fires and protecting lives and property in their paths. The fire experts on site generally agreed that only rain or snow could stop the fires. They were right: one-quarter inch of snow on September 11 stopped the advance of the fires.

By the last week in September, about 50 lightning-caused fires had occurred in or burned into the park, but only eight were still burning. More than \$120,000,000 had been spent in control efforts on fires in the greater Yellowstone area, and most major park developments—and a few surrounding communities—had been evacuated at least once as fires approached within a few miles. The fire suppression efforts involved many different federal and state agencies, including the armed forces. At the height of the fires, ten thousand people were involved. This was the largest such cooperative effort ever undertaken in the United States.

Confusion in the Media

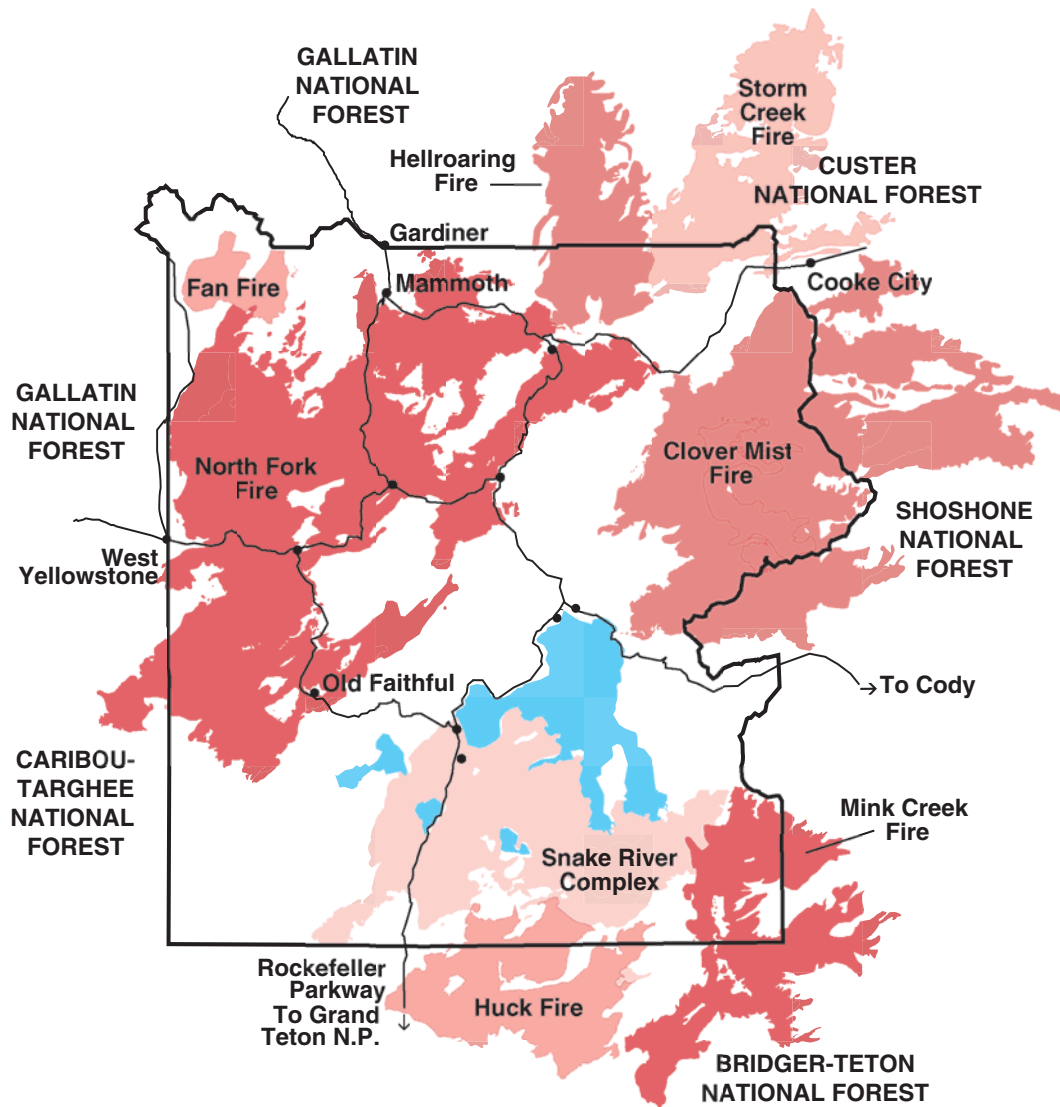
The Yellowstone area fires of 1988 received more national attention than any other event in the history of national parks. Unfortunately, many media reports were inaccurate or misleading and confused or alarmed the public. The reports tended to lump all fires in the Yellowstone area together as the “Yellowstone Park Fire”; they referred to these fires as part of the park’s natural fire program, which was not true; and they often contained oversimplification of events and exaggeration of how many acres had burned. In Yellowstone National Park itself, the fires affected—but did not “devastate”—793,880 acres or 36 percent of total park acreage.

A number of major fires, most notably the North Fork Fire, the Hellroaring Fire, the Storm Creek Fire, the Huck Fire, and the Mink Fire, started outside the park. These fires accounted for more than half of the total acres burned in the greater Yellowstone area, and included most of the ones that received intensive media attention. The North Fork Fire began in the Targhee National Forest and suppression attempts began immediately. The Storm Creek Fire started as a lightning strike in the Absaroka–Beartooth Wilderness of the Custer National Forest northeast of Yellowstone; it eventually threatened the Cooke City–Silver Gate area, where it received extended national television coverage.

Additional confusion resulted from the mistaken belief that managers in the Yellowstone area let park fires continue burning unchecked because of the natural fire plan—long after such fires were being fought. Confusion was probably heightened by misunderstandings about how fires are fought: if crews were observed letting a fire burn, casual observers might think the burn was merely being monitored. In fact, in many instances, fire bosses recognized the hopelessness of stopping fires and concentrated their efforts on the protection of buildings and developed areas.

The most unfortunate public and media misconception about the Yellowstone firefighting effort may have been that human beings can always control fire. These fires could not be controlled; their raw, unbridled power cannot be overemphasized. Firefighters were compelled to choose their fights very carefully, and they deserve great praise for working so successfully to save all but a few park buildings.

The Fires of 1988



The 1988 fires affected—but did not necessarily burn—thousands of acres. Many of the effects were positive, as research since that time has shown.

Burned Area Within Yellowstone National Park		
Burn Type	Acres	Percent of Park
• Crown fire: consuming the forest canopy, needles, and ground cover and debris	323,291	15%
• Mixed: mixture of burn types in areas where most of ground surface was burned	281,098	13%
• Meadows, sagebrush, grassland	51,301	2%
• Undifferentiated: variety of burn types	37,202	2%
• Undelineated: surface burns not detectable by satellite because under unburned canopy	100,988	4%
Total Burned Area	793,880	36%
Total Unburned Area	1,427,920	64%

Data from the Geographic Information Systems Laboratory, Yellowstone National Park, 1989;
Table adapted from Yellowstone in the Afterglow: Lessons From the Fires, Mary Ann Franke, 2000.

The Fires of 1988, Aftermath



The same scene in 1988 after the fires (left) and in 1989 (right)



Post-fire Response and Ecological Consequences

By late September, as the fires were diminishing, plans were underway in Yellowstone to develop comprehensive programs for all aspects of post-fire response. These included replacing, rehabilitating, or repairing damaged buildings, power lines, firelines, trails, campsites, and other facilities. Similarly, interpretive rangers developed programs to interpret the fires and their effects for visitors and for the general public. The park also cooperated with other agencies and state and local governments in promoting the economic recovery of communities near the park that were affected by the fires.

Scientists wanted to monitor the ecological processes following these major fires. The National Park Service cooperated with other agencies and independent researchers and institutions in developing comprehensive research directions for this unparalleled scientific opportunity.

Observations began while the fires were still burning, when it was apparent that the fires did not annihilate all life forms in their paths. Burning at a variety of intensities, sometimes as ground fires, sometimes as crown fires, the fires killed many lodgepole pines and other trees, but did not kill most other plants; they merely burned the tops off of them, leaving roots to regenerate.

Temperatures high enough to kill seeds occurred in less than one-tenth of one percent of the park. Only under logs and in deep litter accumulations, where the fire was able to burn for several hours, did lethal heat penetrate more deeply into the soil. Where water was available, new plant growth began within a few days. In dry soils, the rhizomes, bulbs, root crown, seeds, and other reproductive tissues had to wait until soil moisture was replenished the following spring.

The fires of 1988 created a mosaic of burns, partial burns, and unburned areas. This mosaic actually provides natural firebreaks, reducing the number of fire starts and limiting fire size over time while sustaining a greater variety of plant and animal species. Vegetation capable of sustaining another major fire will be rare for decades, except in extraordinary situations.

Though animal movements were sometimes affected dramatically by the passage of fires, relatively few animals died. However, portions of the northern range burned, which affected winter survival of grazing animals when coupled with summer drought conditions. In this and many other ways, fires dramatically altered the habitat and food production of Yellowstone for the short term.

What Has *NOT* Happened Since 1988

Many predictions were made about the fires' long-term consequences. No evidence exists that the following have come to pass:

- ✗ A long-term drop in park visitation.
- ✗ Flooding downstream of the park because of increased runoff on bare slopes.
- ✗ A decline in fish populations because increased erosion silts up the water.
- ✗ An increase in fish populations in smaller streams where deforestation and loss of shade could result in warmer water and higher nutrient levels.
- ✗ More rapid invasion of non-native plants into burned areas and corridors cleared as fire breaks.
- ✗ An increase in lynx following a boom in snowshoe hares as a result of changes in forest structure.
- ✗ Increased willow vigor and production of the defense compounds that deter its browsing by elk and moose.
- ✗ An increase in the elk population because of improved forage.
- ✗ A decline in the endangered grizzly bear population because of smaller whitebark pine seed crops.
- ✗ Another big fire season in Yellowstone because of all the fuel provided by so many dead and downed trees.
- ✗ Adoption of a program of prescribed burning to reduce the likelihood of future large fires in Yellowstone.



What *HAS* Changed

Although some long-term consequences of the fires remain to be seen, these changes have been caused entirely or in part by the fires of 1988:

- ✓ The replacement of thousands of acres of forest with standing or fallen snags and millions of lodgepole pine seedlings.
- ✓ The establishment of aspen seedlings in areas of the park where aspen had not previously existed.
- ✓ A decline in the moose population because of the loss of old growth forest.
- ✓ Shifts in stream channels as a result of debris flows from burned slopes.
- ✓ An increase in the public understanding and acceptance of the role of fire in wildland areas.
- ✓ A stronger program to reduce hazardous fuels around developed areas.

In 2000, The Yellowstone Center for Resources published Yellowstone in the Afterglow: Lessons from the Fires, by Mary Ann Franke. Some findings are summarized on the next pages.

6

Results of Fire Research Since 1988



Some grasses and flowers, such as fireweed (above), thrived only in the first years after the fires, while others such as pinegrass and showy aster have slowly but steadily increased.

Soils

Fertile soils with good water-holding capacity that had a dense, diverse vegetation before the fire were likely to respond quickly after the fire with a variety of species and nearly complete cover. Some soils in Yellowstone supported little vegetation before the fires and have continued to have little since then.

Areas that appear barren and highly erosive did not necessarily become that way because of fire.

Vegetation

As root systems of standing dead trees decay and lose their grip on the soil, the trees are gradually falling down, often with the help of a strong wind. However, many will remain upright for another decade or more.

Many forests that burned in 1988 were mature lodgepole stands, and this species recolonized most burned areas. Other species—such as Engelmann spruce, subalpine fir, and Douglas-fir—have also emerged.

The density of lodgepole pine seedlings in burned areas after the 1988 fires varied, depending on factors such as fire severity, elevation, abundance of serotinous cones, and seedbed characteristics. Density ranged from 80 seedlings per hectare in a high-elevation stand with no serotinous cones to 1.9 million seedlings per hectare in a low-elevation stand in which nearly half the trees had serotinous cones. (One hectare is approximately 2.5 acres.)

About 28 percent of the park's whitebark pine forest burned in 1988. This affects grizzly bears, for which whitebark pine seeds are an important food in fall. Seeds not consumed by grizzlies remain in caches of red squirrels and Clark's nutcracker. These buried seeds and the hardiness of whitebark pine seedlings on exposed sites give this tree an initial advantage in large burned areas over conifers dependent on wind to disperse seeds. However, this slow-growing and long-lived tree is typically more than a century old before producing cones. The young trees may die before reproducing if the interval between fires is too short or if faster-growing conifers overtake them. By 1995, whitebark pine seedlings had appeared in all 275 study plots,

though density was not significantly different between burned and unburned sites.

About one-third of the aspen in the northern range burned in the 1988 fires—but the aspen stands were not destroyed. Fire that killed adult stems also enhanced aspen reproduction. Like other disturbances, fire stimulates the growth of suckers from the aspen's extensive underground root system. (Suckers and root shoots produce clones of the "parent" aspen.) Fire also leaves bare mineral soil devoid of taller plants—perfect conditions for aspen seedlings. After the fires of 1988, aspen seedlings appeared throughout the park's burned areas. All the young trees, whether clones or seedlings, can be heavily browsed by elk and may not grow much beyond shrub height. But the fires indirectly helped protect some of these young trees: the trunks of fallen trees keep elk from reaching some young aspen.

Like trees, most other types of vegetation in the park were not killed by the fires; the portion above ground may have been burned off, but the roots were left to regenerate. The regrowth of plant communities began as soon as the fire was gone and moisture was available, which in some sites was within days. In dry soils, the seeds had to wait until moisture was replenished the following spring. New seedlings grew even in the few areas where the soil had burned intensely enough to become sterilized. Within a few years, grasslands had largely returned to their pre-fire appearance. Sagebrush also recovered rapidly.

Plant growth was unusually lush in the first years after the fires because of the mineral nutrients in the ash and increased sunlight on the forest floor. Moss an inch or more thick became established in burned soils, and may have been a factor in moisture retention, promoting revegetation and slowing erosion.

Wildlife

Most ungulate (hoofed) species were more affected by the drought and the relatively severe winter that followed than by the fires. Although none of their winter range burned, mule deer declined 19 percent and pronghorn 29 percent during the winter of 1988.

Elk mortality rose to about 40 percent in the winter of 1988–89, but scientists are unsure how much of this was due to reduced forage because of the fires. (At least 15 percent of the deaths were due to hunting seasons

outside the park.) Even without the fires, several factors would probably have led to high elk mortality that winter: summer drought, herd density, hunting harvest, and winter severity. The greatest impact of the fires would therefore be on the quantity and quality of forage available to elk in subsequent years. A two-year study following the fires found that the forage quality of three types of grasses was better at burned sites than unburned sites.

Of the 38 grizzly bears wearing radio transmitters when the fires began, 21 had home ranges burned by one or more of the fires: 13 of these bears moved into burned areas after the fire front had passed, three bears (adult females without young) stayed within active burns as the fire progressed, three bears remained outside the burn lines at all times, and two adult females could not be located. In a study from 1989–92, bears were found grazing more frequently at burned than unburned sites, especially on clover and fireweed. Even though bear feeding activity in some whitebark pine areas decreased as much as 63 percent, the fires had no discernible impact on the number of grizzly bears in greater Yellowstone.

Rodents probably had the highest fire-related mortality of any mammals. Although many could escape the fires in burrows, others died of suffocation as the fires came through. They also were more exposed to predators because they had lost the cover of grasses and other plants. But if the number of small mammals did temporarily decline while their predators multiplied, the increased number of predators would soon face a food shortage themselves, continuing the ongoing adjustment in the predator-prey ratio.

Most birds were not directly harmed by the fires and some benefited. For example, raptors hunted rodents fleeing the fires. But young osprey that were still in their nests died. Post-fire habitat changes helped some birds. Cavity-nesting birds, such as Barrow's goldeneye, flickers, and bluebirds, had many dead trees for their nests. Robins and flickers found ants and worms more easily. Boreal owls, however, lost some of the mature forests they need.

Aquatic Resources

In general, the amount of soil loss and sediment deposits in streams varied greatly, but in most cases was within the normal range.

About a quarter of the Yellowstone Lake and Lewis Lake watersheds and half of the Heart Lake watershed burned to some extent, but no significant changes have been observed in



nutrient enrichment, plankton production, or fish growth as a result. There was no apparent increase in streambank erosion or change in substrate composition or channel morphology that would affect cutthroat trout spawning habitat, nor does there appear to have been a decline in the number of spawning streams. No discernible fire-related effects have been observed in the fish populations or the angling experience in the six rivers that have been monitored regularly since 1988.

In other park watersheds, such as the Gibbon River, massive erosion and mudslides occurred during and after the heavy rains of the summer of 1989. Scientists don't know how much the fires of 1988 facilitated these events. However, by 1991, growth of plants had slowed this erosion.

Conclusion

In the years since the fires, visitors have marveled at the new vistas, the wildflower blooms, and the lush growth of new, young trees. Some visitors still feel that the Yellowstone they knew and loved is gone forever. But Yellowstone is not a museum—it is a functioning ecosystem in which fire plays a vital role.

The moose is the only large mammal whose population appears to have declined because of the 1988 fires. Willow and subalpine fir—winter food for moose—were reduced by the fires. Dense forest canopies were also gone, so snow accumulated more deeply. The combination of less food and deeper snow contributed to increased winter moose mortality.

For More Information

Staff reviewer: Phil Perkins, Fire Management Officer; Eric Miller, Fire Ecologist; Roy Renkin

- Barbee, Robert and Paul Schullery. 1989. Yellowstone: The smoke clears. *National Parks* 62:18–19.
- Blanchard, B.M. and R.R. Knight. 1996. Effects of wildfire on grizzly bear movements and foraging strategies in *Proc. Second Biennial Conf. on the Greater Yellowstone Ecosystem*. Fairfield, WA: Int. Assoc. Wildl. Fire.
- Franke, Mary Ann. 2000. *Yellowstone in the Afterglow: Lessons from the Fires*. YCR-NR-2000-3. NPS, Mammoth, WY.
- Greenlee, J., ed. *The Ecological Implications of Fire in Greater Yellowstone: Proceedings of the Second Biennial Conference on the Greater Yellowstone Ecosystem*. Fairfield, WA: Int. Assoc. Wildl. Fire.
- Houston, D.B. 1973. Wildfires in Northern Yellowstone National Park. *Ecology* 54: 1111–1117.
- Knight, D.H. and L.L. Wallace. 1989. The Yellowstone fires: issues in landscape ecology. *BioScience* 39:707–715.
- Littell, J.S. 2002. *Determinants of fire regime variability in lower elevation forest of the northern Yellowstone ecosystem*. M.S. thesis. Montana State University/Bozeman.
- Marston, D.B. 1983. Wildfires in Yellowstone National Park. *Ecology* 54(5): 1111–1117.
- Millsbaugh, S.H. et al. 2000. Variations in fire frequency and climate over the last 17,000 years in Yellowstone National Park. *Geology* 28(3): 211–214.
- Morrison, M. 1993. *Fire in Paradise: The Yellowstone Fires and the Politics of Environmentalism*. New York: Harper Collins.
- Nyland, R. D. 1998. Patterns of lodgepole pine regeneration following the 1988 Yellowstone fires. *Elsevier Forest Ecology and Management*. 111:23–33.
- Pyne, S.J. 1989. Letting wildfire loose: the fires of '88. *Montana the Magazine of Western Living*. 39(3): 76–79.
- Renkin, R.A. and D.G. Despain. 1992. Fuel moisture, forest type, and lightning-caused fire in Yellowstone National Park. *Canadian Journal of Forestry Research* 22(1):37–45.
- Romme, W. H. et al. 1997. A rare episode of sexual reproduction in aspen (*Populus tremuloides* Michx.) following the 1988 Yellowstone fires. *Natural Areas Journal* 17:17–25.
- Romme, W.H. 1982. Fire and landscape diversity in subalpine forest of Yellowstone National Park. *Ecological Monographs* 52(2):199–221.
- Romme, W.H. et al. 1995. Aspen, elk, and fire in northern Yellowstone National Park. *Ecology* 76(7):2097–2106.
- Varley, John D. and Paul Schullery. 1991. Reality and opportunity in the Yellowstone Fires of 1988. In *The Greater Yellowstone Ecosystem: Redefining American Heritage*, R. Keiter and M. Boyce, eds. New Haven: Yale University Press.
- Wuerthner, George. 1991. *Yellowstone and the Fires of Change*. Salt Lake City: Haggis House Publications.
- www.fire.nps.gov for information about the National Fire Plan

Additional Information from Yellowstone National Park

Yellowstone National Park website, www.nps.gov/yell, includes an array of park information about resources, science, recreation, and issues.

Yellowstone Science, published quarterly, reports on research and includes articles on natural and cultural resources. Free; available from the Yellowstone Center for Resources, in the Yellowstone Research Library, or online at www.nps.gov/yell.

Yellowstone Today, published seasonally and distributed at entrance gates and visitor centers, includes features on park resources such as hydrothermal features.

MAMMALS

- Yellowstone National Park is home to the largest concentration of mammals in the lower 48 states.
- 61 different mammals live here, including a wide variety of small mammals.
- Several hundred grizzly bears live in the greater Yellowstone area.
- Black bears are common.
- Gray wolves were restored in 1995; more than 100 live in the park now.
- Wolverine and lynx, predators requiring large expanses of undisturbed habitat, live here.
- Seven native species of ungulates—elk, mule deer, bison, moose, bighorn sheep, pronghorn, and white-tailed deer—live here, including one of the largest herds of elk in the United States.
- Non-native mountain goats have colonized the northwestern and northeastern portions of the park.

ORDER Carnivora

Habitat

Estimated Population

Family Ursidae

*Black Bear (<i>Ursus americanus</i>)	forests, meadows	500–650
*Grizzly Bear (<i>Ursus arctos horribilis</i>)	forests, meadows	280–610

Family Canidae

*Coyote (<i>Canis latrans</i>)	forests, meadows, grasslands	common
*Gray Wolf (<i>Canis lupus</i>)	forests, meadows	118
*Fox (<i>Vulpes vulpes</i>)	meadows	occasional

Family Felidae

*Bobcat (<i>Lynx rufus</i>)	forests, meadows	may be widespread
*Cougar (<i>Puma concolor</i>)	mountains, rocky areas	15–17
*Lynx (<i>Lynx canadensis</i>)	subalpine forests	few

Family Procyonidae

Raccoon (<i>Procyon lotor</i>)	rivers, cottonwoods	rare
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Family Mustelidae

Badger (<i>Taxidea taxus</i>)	sagebrush	common
Fisher (<i>Martes pennanti</i>)	forests	rare, if present
**Marten (<i>Martes martes</i>)	coniferous forests	common
Mink (<i>Mustela vison</i>)	riparian forests	occasional
**River Otter (<i>Lutra canadensis</i>)	rivers, lakes, ponds	common
Striped Skunk (<i>Mephitis mephitis</i>)	riparian to forest	rare
**Long-tailed Weasel (<i>Mustela frenata</i>)	willows to spruce/fir forests	common
**Short-tailed Weasel (ermine) (<i>Mustela erminea</i>)	willows to spruce/fir forests	common
**Wolverine (<i>Gulo gulo</i>)	alpine, coniferous forests	rare

*indicates a species described in the species accounts that begin on page 93, following “Small Mammals.”

**indicates a species described on pages 86–92 under “Small Mammals.”

Species described under “Small Mammals” are alphabetized by their common name on this list.

7A

Mammals

ORDER Artiodactyla

Family Cervidae

*Elk (Wapiti) (<i>Cervus elaphus</i>)	meadows, forests	15,000–25,000 in summer
*Moose (<i>Alces alces shirasi</i>)	riparian, forests	<500
*Mule Deer (<i>Odocoileus hemionus</i>)	forests, grasslands, shrub lands	2,300–2,500
*White-tailed Deer (<i>O. virginianus</i>)	forests, grasslands, shrub lands	occasional

Family Bovidae

*Bison (<i>Bison bison</i>)	meadows, grasslands	>3,500
*Bighorn Sheep (<i>Ovis canadensis</i>)	cliffs, mountain slopes	250–275
Mountain Goat (non-native) (<i>Oreamnus americanus</i>)	alpine meadows, rocky slopes	175–225

Family Antilocapridae

*Pronghorn (<i>Antilocapra americanus</i>)	sagebrush, grasslands	200–250
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ORDER Chiroptera

Family Vespertilionidae

Big Brown Bat (<i>Eptesicus fuscus</i>)	roost in cliffs, attics; feed around water	rare
Little Brown Bat (<i>Myotis lucifugus</i>)	roost in cliffs, attics; feed around water	common
Long-eared Bat (<i>M. evotis</i>)	roost in cliffs, attics; feed around water	common
Big-eared Bat (<i>Plecotus townsendi</i>)	roost in cliffs, attics; feed around water	common

ORDER Lagomorpha

Family Leporidae

**Snowshoe Hare (<i>Lepus americanus</i>)	forests, willows	common
White-tailed Jackrabbit (<i>Lepus townsendii</i>)	sagebrush, grasslands	common
Desert Cottontail (<i>Sylvilagus audubonii</i>)	shrub lands	common
Mountain Cottontail (<i>S. nuttallii</i>)	shrub lands	common

Family Ochotonidae

**Pika (<i>Ochotona princeps</i>)	rocky slopes	common
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ORDER Insectivora

Family Soricidae

Dusky Shrew (<i>Sorex monticolus</i>)	moist meadows, forests	common
Masked Shrew (<i>S. cinereus</i>)	moist meadows, forests	common
Water Shrew (<i>S. palustris</i>)	moist meadows, forests	common
Preble's Shrew (<i>S. preblei</i>)	moist meadows, forests	rare, if present
Dwarf Shrew (<i>S. nanus</i>)	moist meadows, forests	rare

ORDER Rodentia**Family Castoridae**

*Beaver (<i>Castor canadensis</i>)	ponds, streams	500
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Family Sciuridae

**Least Chipmunk (<i>Tamias minimus</i>)	forests	common
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Uinta Chipmunk (<i>T. umbrinus</i>)	forests	common
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Yellow Pine Chipmunk (<i>T. amoenus</i>)	forests	common
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**Yellow-bellied Marmot (<i>Marmota flaviventris</i>)	rocky slopes	common
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**Golden-mantled Ground Squirrel (<i>Spermophilus lateralis</i>)	forests, rocky slopes	common
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Northern Flying Squirrel (<i>Glaucomys sabrinus</i>)	forests	occasional
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**Red Squirrel (<i>Tamiasciurus hudsonicus</i>)	forests	common
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**Uinta Ground Squirrel (<i>Spermophilus armatus</i>)	sagebrush, meadows	common
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Family Geomyidae

**Northern Pocket Gopher (<i>Thomomys talpoides</i>)	sagebrush, meadows, forests	common
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Family Cricetidae

Deer Mouse (<i>Peromyscus maniculatus</i>)	grasslands	common
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Western Jumping Mouse (<i>Zapus princeps</i>)	riparian	occasional
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Muskrat (<i>Ondatra zibethicus</i>)	streams, lakes, ponds	common
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Heather Vole (<i>Phenacomys intermedius</i>)	sagebrush to forests	occasional
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Long-tailed Vole (<i>Microtus longicaudus</i>)	moist meadows	common
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Meadow Vole (<i>M. pennsylvanicus</i>)	moist meadows	common
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**Montane Vole (<i>M. montanus</i>)	moist meadows	common
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Red-backed Vole (<i>Clethrionomys gapperi</i>)	dense forests	common
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Water Vole (<i>M. richardsoni</i>)	riparian	occasional
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Bushy-tailed Woodrat (<i>Neotoma cinerea</i>)	rocky slopes	common
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Family Erethizontidae

Porcupine (<i>Erethizon dorsatum</i>)	forests, sagebrush, willows	common
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7A

Small Mammals

Species accounts appear in alphabetical order by their common name.

Numerous small mammals live in Yellowstone National Park. The park's interpretive rangers chose the following species to describe because visitors are likely to see them or inquire about them. Descriptive photos and illustrations exist in numerous books about these species; see "For More Information" on pages 130–132 for suggested titles.

GOLDEN-MANTLED GROUND SQUIRREL

Spermophilus lateralis



Identification

- 9–12 inches long, 7.4–11 ounces.
- Adult head and shoulders are reddish-brown, their "mantle."

- Often mistaken for a least chipmunk (described below); distinguished by larger size, more robust body, shorter tail, and lateral stripes that do not extend onto the sides of the head.

Habitat

- Found throughout Yellowstone at all elevations in rocky areas, edges of mountain meadows, forest openings, tundra.
- 87% of diet consists of fungi and leaves of flowering plants; other foods include buds, seeds, nuts, roots, bird eggs, insects, and carrion.
- Predators include coyotes, weasels, badgers, hawks.

Behavior

- Hibernate from October to March or April.
- Breeding occurs shortly after both males and females emerge from hibernation; one litter of 5 young per year.



LEAST CHIPMUNK

Tamias minimus

Identification

- 7.5–8.5 inches long, 1.2 ounces.
- Smallest member of the squirrel family; one of three chipmunk species in the park.
- Alternating light and dark stripes on its back and sides, with the outermost stripe on the

sides being dark; underside tends to be white and its tail has black-tipped hairs with a reddish undertone.

- Often mistaken for golden-mantled ground squirrel (described above); distinguished by smaller size, longer tail, and lateral stripes that extend onto the sides of the head.

Habitat

- Prefers sagebrush valleys, shrub communities, and forest openings.
- Eats primarily plant material, especially seeds and other fruits, but will also eat conifer seeds and some insects.
- Preyed on by various hawks and probably foxes and coyotes.

Behavior

- In Yellowstone, this species hibernates but also stores some food and probably arouses frequently during the winter.
- Breeding begins as snowmelt occurs usually late March until mid-May; one litter of 5–6 young per year.
- Little is known about their vocalizations but they do have "chipping" (which may be an alarm) and "clucking" calls.
- Can be identified by quick darting movements and it seems to carry its tail vertically when moving.

LONG-TAILED WEASEL*Mustela frenata***Identification**

- Typical weasel shape: a very long body, short legs, pointed face, long tail.
- 13–18 inches long, 4.8–11 ounces.
- Fur is light brown above and buff to rusty orange below in summer; all white in winter, except for tail, which is black-tipped all year.
- Males 40% larger than females.

Compare to marten (below) and short-tailed weasel, page 90.

Habitat

- Found in forests, open grassy meadows and marshes, and near water.
- Eat voles, pocket gophers, mice, ground and tree squirrels, rabbits; to a lesser degree birds, eggs, snakes, frogs, and insects.

Behavior

- Breeding occurs in early July and August; one litter of 6–9 young per year.
- Solitary animals except during breeding and rearing of young.

MARTEN*Martes americana***Identification**

- 18–26 inches long, 1–3 pounds.
- Weasel family; short limbs and long bushy tail; fur varies from yellow to brown to black; irregular, yellowish to bright orange throat patch.
- Smaller than a fisher; lighter in color, orange bib rather than white.

Compare to long-tailed weasel (above) and short-tailed weasel, page 90.

Habitat

- Found in conifer forests with dense canopy and understory of fallen logs and stumps; will use riparian areas, meadows, forest edges and rocky alpine areas.
- Eat primarily small mammals such as red-backed voles, red squirrels, snowshoe hares, flying squirrels, chipmunks, mice and shrews; also to a lesser extent birds and eggs, amphibians and reptiles, earthworms, insects, fruit, berries, and carrion.

Behavior

- Solitary except in breeding season (July & August); delayed implantation; 1–5 young born in mid-March to late April.
- Active throughout the year; hunts mostly on the ground.
- Rest or den in hollow trees or stumps, in ground burrows or rock piles, in excavations under tree roots.



7A

Small Mammals

MONTANE VOLE

Microtus montanus

Identification

- 5–7.6 inches long, 1.2–3.2 ounces.
- Brownish to grayish-brown, occasionally grizzled; ventral side is silvery gray; relatively short tail is bi-colored.

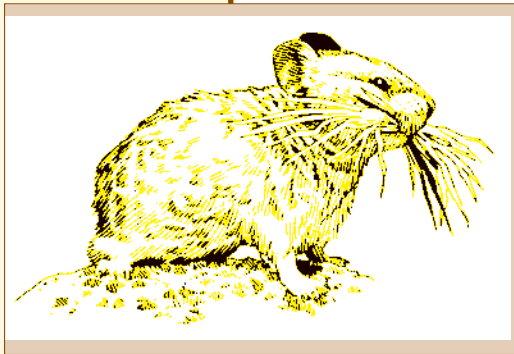
Habitat

- Found at all elevations in moist mountain meadows with abundant grass and grassy sagebrush communities; also common in riparian areas.

- Grass is their primary food.
- Probably the most important prey species in the park; eaten by coyotes, raptors, and other animals.

Behavior

- Active year-round maintaining tunnels in the winter; also dig shallow burrows.
- Typically breeds from mid-February to November; up to 4 litters of 2–10 young per year.



PIKA

Ochotona princeps

Identification

- 7–8.4 inches long, 5.3–6.2 ounces (about the size of a guinea pig).
- Tailless, gray to brown with circular ears.

Habitat

- Found on talus slopes and rock falls at nearly all elevations in the park.
- Eat plant foods such as grasses, sedges, aspen, lichen, and conifer twigs.
- Predators include coyotes, martens, and hawks.

Behavior

- Active year-round; darts around on rocks; travels through tunnels under snow.
- Breeds in spring; two litters per year.
- Often heard but not seen; makes a distinct shrill whistle call or a short “mew.”
- Scent marks by frequently rubbing cheeks on rocks.
- Late summer it gathers mouthfuls of vegetation to build “haystacks” for winter food; defends haystacks vigorously.
- Haystacks often built in same place year after year; have been known to become three feet in diameter.
- Like rabbits and hares, pika eat their own feces.

**POCKET GOPHER***Thomomys talpoides***Identification**

- 6–10 inches long, 2.6–6.3 ounces.
- Very small eyes and ears; brown or tan smooth fur; short tail; long front claws for burrowing; large external pouches for carrying food.

Habitat

- Only restriction in range seems to be topsoil depth, which limits burrowing.
- Preyed upon by owls, badgers, grizzly bears, coyotes, weasels, and other predators.
- Snakes, lizards, ground squirrels, deer mice, and other animals use their burrows.

- In the top 6–8 inches below the surface they forage for forbs, some grasses and underground stems, bulbs and tubers.

Behavior

- Transport food in their cheek pouches to underground cache.
- Grizzly bears will sometimes dig up these caches, including an unsuspecting gopher.
- Do not hibernate, but instead burrow into the snow; often fill tunnels with soil forming worm-like cores that remain in the spring after snow melts.
- Breed in May and April; one litter of 5 young per year.
- Burrow systems are elaborate and often bi-level; can be 400–500 feet long.
- Very territorial; only one per burrow.

RED SQUIRREL*Tamiasciurus hudsonicus***Identification**

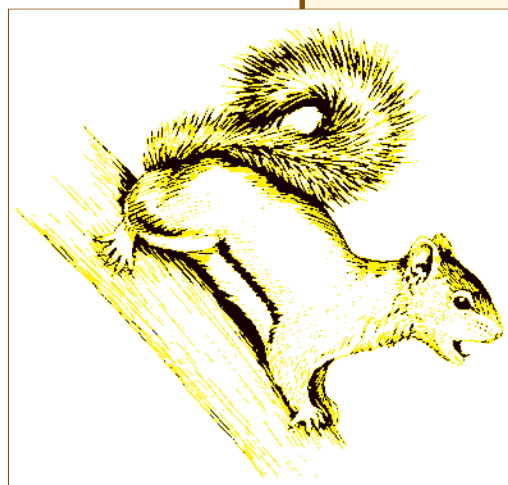
- 11–15 inches long, 6.7–7 ounces.
- Brownish-red on its upper half; dark stripe above white ventral side; light eye ring; bushy tail.
- Quick, energetic.
- Loud, long chirp to advertise presence; much more pronounced in the fall.

Habitat

- Spruce, fir, and pine forests; young squirrels found in marginal aspen habitat.
- Eat conifer seeds, eat terminal buds of conifer trees, fungi, some insects; sometimes steal young birds from nests.
- Preyed on by coyotes, grizzly bears, hawks.

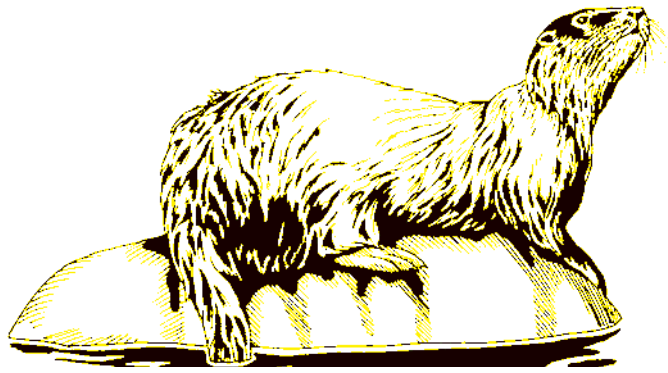
Behavior

- Breeds February–May, typically March and April; one litter of 3–5 young.
- One of the park's most territorial animals; territorialism ensures winter food supply.
- In fall, cuts cones from trees and caches them in middens, which are used for years and can be 15 by 30 feet; grizzlies search out these middens in whitebark pine habitat to obtain the nuts.



7A

Small Mammals



RIVER OTTER

Lutra canadensis

Identification

- 40–54 inches long, 10–30 pounds.
- Sleek, cylindrical body; small head; tail nearly one third of the body and tapers to a point; feet webbed; claws short; fur is dark dense brown.
- Ears and nostrils close when underwater; whiskers aid in locating prey.

Habitat

- Most aquatic member of weasel family; rarely found far from water.
- Eats crayfish and fish; also frogs, turtles, sometimes young muskrats or beavers.

Behavior

- Active year-round.
- Breeds in late March through April; one litter of two young per year.
- Females and offspring remains together until next litter; may temporarily join other family groups.
- Can swim underwater up to 6 miles per hour and for 2–3 minutes at a time.
- Not agile or fast on land unless they find snow or ice, then can move rapidly by alternating hops and slides; can reach speeds of 15 miles per hour.
- Mostly crepuscular but have been seen at all times of the day.

SHORT-TAILED WEASEL (ERMINE) *Mustela erminea*

Identification

- 8–13 inches long, 2.1–7 ounces.
- Typical weasel shape: very long body, short legs, pointed face, long tail.
- Males about 40% larger than females.
- Fur is light brown above and white below in summer; all white in winter except for tail, which is black-tipped all year.

Compare to long-tailed weasel and marten, page 87.

Habitat

- Eat voles, shrews, deer mice, rabbits, rats, chipmunks, grasshoppers, and frogs.
- Found in willows and spruce forests.



Behavior

- Breeding takes place in early to mid-summer; 1 litter of 6–7 young per year.
- Can leap repeatedly three times their length.
- Will often move through and hunt in rodent burrows.

SNOWSHOE HARE*Lepus americanus***Identification**

- 14.5–20 inches long, 3–4 pounds.
- Large hind feet enable easy travel on snow; white winter coat offers camouflage; gray summer coat.
- Transition in seasonal fur color takes about 70–90 days; seems to be triggered in part by the day length.

Habitat

- Found throughout Yellowstone in coniferous forests with dense understory of shrubs, riparian areas with many willows, or low areas in spruce-fir cover.
- Rarely ventures from dense forest cover except to feed in forest openings.
- Eats plants.

- Preyed upon by lynx, bobcats, coyotes, foxes, some hawks, and great horned owls.

Behavior

- Breed from early March to late August.
- Young are born with hair, grow rapidly and are weaned within 30 days.
- Mostly nocturnal; their presence in winter is only advertised by a network of well-worn trails in the snow.
- Docile except during the breeding season when they chase each other, drum on the ground with the hind foot, leap into the air, and occasionally battle each other.

**UINTA GROUND SQUIRREL***Spermophilus armatus***Identification**

- 11–12 inches long, 7–10 ounces.
- Grayish back and rump with fine white spots on back; nose and shoulders are tan to cinnamon; tail is grayish underneath.

Habitat

- Found in disturbed or heavily grazed grasslands, sagebrush meadows, and mountain meadows up to 11,000 feet.
- Eats grasses, forbs, mushrooms, insects, and carrion (including road-killed members of its own species).
- Preyed on by long-tailed weasels, hawks, coyotes, badgers.

Behavior

- Hibernate as early as mid-July through March.
- Breeds in early spring; one litter of 6–8 young per year.
- Young, after they leave the burrow, are vulnerable to long-tailed weasels and hawks.
- During cool spring weather, Uinta ground squirrels active at all times of day, as the weather warms activity more limited to morning, late afternoon, and evening.

During the winter, Uinta ground squirrels are sometimes active near the Albright Visitor Center at Mammoth Hot Springs and the hotel. Perhaps they are aroused from hibernation due to ground temperatures rising as hydro-thermal activity increases in the vicinity. No one knows for sure.

WOLVERINE*Gulo gulo***Identification**

- 28–42 inches long, 13–36 pounds.
- Largest member of weasel family; compact and strongly built, broad head, short legs; black to dark brown with white on chest may extend as bands onto sides; shaggy appearance due to long guard hairs.

Habitat

- Found in undisturbed conifer forests and alpine tundra; rarely seen; considered an indicator of true wilderness.
- Eats burrowing rodents, birds, eggs, beavers, squirrels, marmots, mice, and vegetation; has also been known to take

large prey such as deer or elk when snow is deep.

Behavior

- Primarily nocturnal, active year-round.
- Breeds April to October; 1 litter of 2–4 young each year.
- Den under log jams, uprooted trees, caves.
- Solitary except when breeding.

Research

In 2005, researchers began a 5-year field study to gather information about this species in east Yellowstone National Park and the adjoining Shoshone National Forest. Animals will be live-trapped and fitted with radio collars equipped with Global Positioning Systems.

**YELLOW-BELLIED
MARMOT***Marmota flaviventris***Identification**

- 20–28 inches long; 3.5–11 pounds.
- One of the largest rodents in Yellowstone.
- Reddish-brown upper body; yellowish belly; small ears; prominent active tail.

Habitat

- Found from lowest valleys to alpine tundra, usually in open grassy communities and almost always near rocks.
- Feed on grasses and forbs in early summer; switch to seeds in late summer, occasionally will eat insects.

- Preyed on by coyotes, grizzlies, and golden eagles.

Behavior

- Hibernate up to 8 months, emerging from February to May depending on elevation; may estivate in June in response to dry conditions and lack of green vegetation and reappear in late summer.
- Breeds within two weeks of emerging from hibernation; average 5 young per year.
- Active in morning, late afternoon, and evening.
- Colonies consist of one male, several females, plus young of the year.
- Vocalizations include a loud whistle (early settlers called them “whistle pigs”), a “scream” used for fear and excitement; a quiet tooth chatter that may be a threat.
- Males are territorial; dominance and aggressiveness demonstrated by waving tail slowly back and forth.





In Yellowstone, about 50 percent of black bears (*Ursus americanus*) are black in color, others are brown and cinnamon. Black bears stand about 3 feet high at the shoulder. Males weigh 210–315 pounds; females weigh 135–160 pounds. They have fair eyesight and an exceptional sense of smell.

Black bears eat almost anything, including grass, berries, fruits, tree cambium, bird eggs, nuts, insects, fish, and carrion. Their short, curved claws enable them to climb trees, but do not allow them to dig for roots or ants as well as a grizzly bear can (grizzlies have longer, less-curved claws).

During fall and early winter, bears spend most of their time feeding, in a predenning period known as “hyperphagia.” In November they locate or excavate a den on north-facing slopes between 5,800–8,600 feet. There, they hibernate until late March.

Most scientists consider bears to be true hibernators. Some hibernating animals experience an extreme drop in metabolism with a cooling of body temperature and near stoppage of respiration and circulation. Bears undergo these changes to a less dramatic extent than some other species, and they can be easily roused from hibernation.

Males and females without cubs are solitary, except during the mating season, which is May to early July. They may mate with a number of individuals, but occasionally a pair stays together for the entire period. Both genders usually begin breeding at age four.

After fertilization, the barely developed blastocyst (egg) does not immediately implant in the uterus, a process called “delayed implantation.” If the bear is healthy when she dens for the winter, implantation and development will begin; if not, her body will abort the blastocyst. Total gestation time is 200 to 220 days, but only during the last half of this period does fetal development occur.

As of March 2006 . . .

Number in Yellowstone
500–650, estimate

Where to see
Tower and Mammoth areas, most often

Behavior & Size

- Males weigh 210–315 pounds, females weigh 135–160 pounds; adults stand about 3 feet at the shoulder.
- May live 15–20 years.
- Home range: male, 6–124 square miles, female, 2–45 square miles.
- Can climb trees; adapted to life in forest and along forest edges.
- Food includes rodents, insects, elk calves, cutthroat trout, pine nuts, grasses and other vegetation.
- Mates in spring; gives birth the following winter to 1–3 cubs.
- Considered true hibernators.

History

- Like grizzlies, used to be fed at dumps within the park.
- For years, black bears were fed by visitors from vehicles.
- Both of these actions resulted in bears losing fear of humans and pursuing human food, which resulted in visitor injuries, property damage, and the need to destroy “problem bears.”

Management Status

- 2000, study begun to find out how black bears fit into the mix of northern range predators; six black bears have been radio-collared.

See “Grizzly & Black Bear Management” in Chapter 9.

Birth occurs in mid-January to early February; the female becomes semiconscious during delivery. Usually two cubs are born. At birth, the cubs are blind, toothless, and almost hairless. After delivery the mother continues to sleep for another two months while the cubs alternately suckle and sleep.

After emerging from the den, the cubs and their mother roam over her home territory. The animals have no regular summer den, but they often dig shallow depressions—day beds—near abundant food sources. In the fall, the cubs den with their mother. The following spring, the cubs and mother separate.

When faced with a threat, black bears are likely to retreat up a tree or flee outright, rather than reacting aggressively. However, any bear, particularly a female with cubs, may attack when surprised at close range. And black bears are more likely than grizzlies to stalk a human—although this is rare. Whether it’s a grizzly or a black bear, always give these animals a wide berth.

7A

Bear, Grizzly



size and as their claws grow longer, they have a harder time climbing. Stories that bears cannot swim or run downhill are also wrong. Grizzlies can sprint up to 45 miles per hour.

As of March 2006 . . .

Number in Yellowstone

Estimated 280–610 bears

Where to see

Dawn and dusk in the Hayden and Lamar valleys, on the north slopes of Mt. Washburn, and from Fishing Bridge to the East Entrance.

Behavior & Size

- Males weigh 300–700 pounds, females weigh 200–400 pounds; adults stand about 3½ feet at the shoulder.
- May live 15–20 years.
- Home range: male, 813–2,075 square miles, female, 309–537 square miles.
- Agile; can run up to 45 mph.
- Can climb trees but curved claws and weight make this difficult.

- Adapted to life in forest and meadows.
- Food includes rodents, insects, elk calves, cutthroat trout, roots, pine nuts, grasses, and large mammals.
- Mates in spring; gives birth the following winter; 2–3 cubs, rarely 4.
- Considered true hibernators.

Status

- Yellowstone is one of only two major areas south of Canada still inhabited by grizzly bears.
- In 1975, the grizzly bear was listed as a threatened species under the Endangered Species Act.
- In 2005, the process to delist the grizzly bear began.

Current Management

See “Grizzly & Black Bear Management” in Chapter 9.

The grizzly bear (*Ursus arctos horribilis*) is a subspecies of brown bear that once roamed the mountains and prairies of the American West. Today, the grizzly bear remains in a few isolated locations in the lower 48 states, including Yellowstone.

The name “grizzly” comes from the frequent presence of silver-tipped or “grizzled” hairs on the animals’ coats. However, the coloration of black and grizzly bears is so variable that it alone is not a reliable means of telling the two species apart. Particularly when bears are not fully grown or when seen only briefly or at a long distance, it can be difficult to correctly identify one bear species from another.

It is commonly said that grizzly bears cannot climb trees. This is not true, especially when the bears are small. As grizzlies increase in

Bears are generally solitary, although they may tolerate other bears when food is not limited. Mating season occurs from mid-May to mid-July, and bears may mate with multiple partners during a single season. Females do not breed until at least age 4 or 5. Bears experience “delayed implantation,” meaning that the embryos do not begin to develop until late November or December. This appears to be a strategy allowing the mother bear to save up energy until entering her winter den, where the cubs are born in late January or February. A litter of one to three cubs is common, litters of four cubs occur occasionally. Male bears take no part in raising cubs and may pose a threat to younger bears. A mother grizzly will usually keep her cubs with her for two winters following their birth, after which time she (or a prospective suitor) chases the subadult bears away so she can mate again. Female cubs frequently establish their home range in the vicinity of their mother, but male cubs must disperse farther in search of a home.

They can be effective predators, especially on such vulnerable prey as elk calves and spawning cutthroat trout. They also scavenge meat when available, such as from winter-killed carcasses of elk and bison, from road-killed wildlife, and from wolves and cougars. They eat small mammals (such as pocket gophers) and insects (such as ants and army cutworm moths that summer on high-elevation talus slopes), both of which provide important, high-protein food. A grizzly’s long claws and strong shoulders enable it to efficiently dig for roots, bulbs, corms, and

Bear, Comparison

tubers, and rodents and their caches. They also eat a wide variety of plants, including whitebark pine nuts, berries, sedges, grasses, glacier lilies, dandelions, yampas and biscuit-roots, horsetails and thistles. They will eat human food and garbage where they can get it. This is why managers emphasize that keeping human foods secure from bears increases the likelihood that humans and bears can peacefully co-exist in greater Yellowstone.

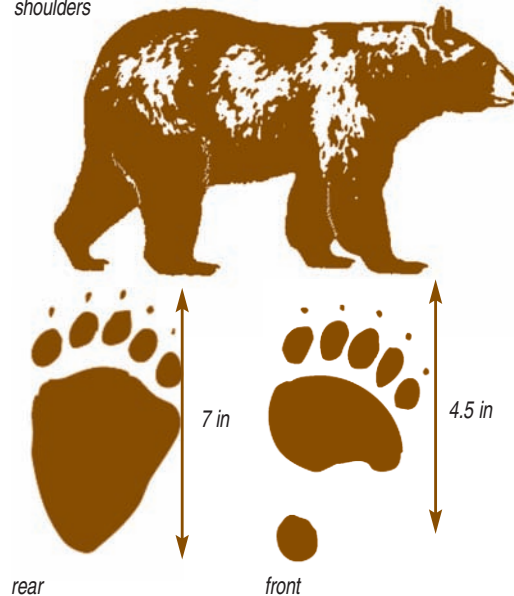
Grizzlies have a social hierarchy in which adult male bears dominate the best habitats and food sources, generally followed by mature females with cubs, then by other single adult bears. Subadult bears, who are just learning to live on their own away from mother's protection, are lowest on the social ladder and most likely to be living in poor-quality habitat or in areas nearer roads and developments. Thus, young adult bears are most vulnerable to danger from humans and other bears, and to being conditioned to human foods. Food-conditioned bears are removed from the wild population.

Bears spend most of their time feeding, and this effort increases during "hyperphagia," the predenning period in autumn. They locate or excavate dens on densely vegetated, north-facing slopes between 6,562–10,000 feet. Bears enter their winter dens between mid-October and early December. Although grizzlies are considered true hibernators (*see black bear description for more on this*), they do sometimes awaken and leave their dens during the winter.

Black Bear

rump higher than shoulders

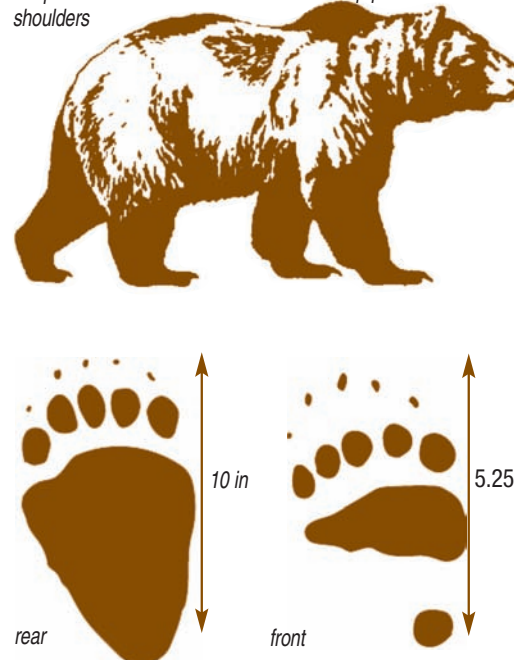
no hump



Grizzly Bear

rump lower than shoulders

hump present



7A

Beaver



As of March 2006 . . .

Number in Yellowstone

Minimum estimate: 500 in 85 colonies

Where to see

Beavers often have lodges in Willow Park (between Mammoth and Norris), Beaver Ponds (Mammoth area), Harlequin Lake (Madison area), and the Gallatin River along U.S. 191. In the backcountry, they often have lodges in the upper Yellowstone River (Thorofare region), Bechler River, and Slough Creek. They may also be seen occasionally in the Lamar, Gardner, and Madison rivers.

Behavior & Size

- Active at night; seldom seen during day.
- If live on rivers, may build bank dens instead of lodges.
- One lodge may support 6–13 beavers that are usually related; this group is called a colony.
- 35–40 inches long, including tail.
- Weighs 30–60 pounds.
- Average life span: 5 years.

Other Info

- Beaver are native to Yellowstone.
- Yellowstone's beaver escaped most of the trapping that occurred in the 1800s due to the region's inaccessibility.
- The most recent survey for beaver in Yellowstone was conducted in 2005.

willows for construction and for food. In areas where preferred woody plants are only present in very small densities or are absent, beavers may feed solely on submerged vegetation such as pond lilies.

Beaver are famous as dam builders, and examples of their work can be seen from the roads in the park. An old dam is visible at Beaver Lake between Norris and Mammoth. Most dams are on small streams where the gradient is mild, and the current is relatively placid during much of the year. Colonies located on major rivers or in areas of frequent water level fluctuations, such as the Lamar River, den in holes in the riverbank.

Male and female beaver look alike—thick brown fur, paddle-shaped tail, weigh 30–60 pounds, and are about 35 to 40 inches long, including tail. When hunched over their food, beaver can resemble round river rocks.

Because beaver are most active at night, visitors seldom see them. But these animals do not necessarily avoid areas of moderate to high levels of human use. Several occupied lodges in Yellowstone are close to popular backcountry trails and/or campsites. Every year, beaver are seen along main park roadways. The nocturnal habits of beaver seem to be enough to separate them from human use of the same area.

People who wait near known beaver activity areas may be rewarded with the sight of them swimming smoothly along or clambering onto the bank to gnaw at trees and willows. But they may just as likely hear the sound of a startled or surprised beaver—the sharp sound of the beaver slapping its tail on the water before it submerges to seek safety.

Since 1989, park staff have periodically surveyed riparian habitat in Yellowstone to determine current presence and distribution of beaver (*Castor canadensis*). These surveys confirm that beaver live throughout Yellowstone National Park but are concentrated in the southeast (Yellowstone River delta area), southwest (Bechler area), and northwest portions (Madison and Gallatin rivers) of the park. They are also making a comeback in Slough Creek due to new willow growth and because they were reintroduced upstream in the Gallatin National Forest. These areas are likely important habitat because of their waterways, meadows, and the presence of preferred foods such as willow, aspen, and cottonwood.

Beaver, however, are not restricted to areas that have their preferred foods. Essentially no aspen exist in some areas where beaver sign is most abundant, such as in the Bechler River. The same is true in other areas where beaver periodically live, such as Heart Lake, Grizzly Lake, the lower Lamar River and Slough Creek area, Slide Lake, and the lower Gardner River. In these areas, beaver use

Bighorn Sheep



Millions of bighorn sheep (*Ovis canadensis*) once lived in the western United States. By 1900, though, bighorn numbers were reduced to a few hundred due to market hunting. In 1912, naturalist Ernest T. Seton reported bighorns in the park had increased to more than 200, and travelers could find them around Mt. Everts or Mt. Washburn.

Bighorn sheep inhabit high, rocky country. The bottoms of their feet are concave, enabling them to walk and run over rocks very easily. Their tan-colored fur camouflages them against cliff rocks.

Both males and females have horns. For the first two years of its life, the horns of a male are similar to the small, slightly curved horns of a female. By the time a male is six or seven years old, the horns form the better part of a circle. The bone interior of the horn does not extend out very far; the outer parts of the horns are hollow and may be damaged during the rut (mating season). Broken or splintered tips are never replaced, and the horn continues to grow from the base throughout the animal's life.

The rut begins in November. Males challenge one another in dramatic battles, snorting and grunting and rising onto their hind legs, then racing toward each other and crashing their heads and horns together. Their extra thick skull protects their brain during these jarring encounters. At the end of the two-month rut, males are often battered and bruised.

Although they are sure-footed in a steep and rocky environment, bighorns do have accidents. They fall off cliffs, slip on ice, and can become caught in avalanches. In Yellowstone, they also have been struck by lightning and hit by automobiles.

As of March 2006 . . .

Number in Yellowstone
250–275

Where to See

- Summer: slopes of Mount Washburn, along Dunraven Pass.
 - Year-round: Gardner Canyon between Mammoth and the North Entrance.
- Also: On cliffs along the Yellowstone River opposite Calcite Springs; above Soda Butte; in backcountry of eastern Absarokas.

Behavior and Size

- Adult male (ram) up to 300 pounds, including horns that can weigh 40 pounds.
- Average life span: males, 9–12 years; females 10–14 years.
- Adult female (ewe) up to 200 pounds.
- Both sexes have horns.

- Feed primarily on grasses; forage on shrubby plants in fall and winter.
- Mating season begins in November.
- One to two lambs born in May or June.

Management

- Bighorns exhibit some habituation to humans; be alert to them along the road; never feed them.
- Early accounts that reported large numbers of bighorn sheep in Yellowstone have led to the speculation that they were more numerous before the park was established.
- A chlamydia (pinkeye) epidemic in 1982 reduced the northern herd by 60%.
- Other unknown factors may be limiting the population now.

Population and Management

After a chlamydia (pinkeye) epidemic in 1982, the population of bighorns on the northern range has not recovered to previous levels. Because no sign of the disease is present, other factors may be limiting population growth.

Researchers have also studied bighorn sheep habitat use and the effect of human activity along the Gardiner–Mammoth road. About 65 percent of all sheep observations occur atop McMinn Bench of Mt. Everts, which has been proposed as an alternate route for the road. Moving the road to this location would affect at least 2 ewe groups and 2–3 ram groups.

On the morning of November 12, 2001, cougar researchers found the fresh carcasses of a cougar and a bighorn ram at the base of Mt. Norris. Evidence at the top of the cliff indicated that the cougar had attacked the ram and both had fallen to their deaths.

7A

Bison



As of March 2006 . . .

Number

approximately 3,500

Where to see

- Year-round: Hayden and Lamar valleys.
- Summer: grasslands of the park.
- Winter: hydrothermal areas and along the Madison River.

Behavior & Size

- Male (bull) weighs up to 2,000 pounds, female (cow) weighs up to 1,000 pounds.
- May live 12–15 years.
- Three herds: Northern (Lamar Valley), Mary Mountain (Hayden-Firehole valleys), Pelican Valley.
- Feed primarily on grasses and sedges.
- Mate in late July through August; give birth to one calf in late April or May.
- Can be aggressive, are very agile, and can run up to 30 miles per hour.

History

- Yellowstone National Park is the only place in the lower 48 states to have a continuously free-ranging bison population since prehistoric times.
- In the 1800s, market hunting, sport hunting, and a U.S. Army campaign nearly resulted in the extinction of the bison.
- By 1902, poachers reduced Yellowstone's small herd to about two dozen animals.
- The U.S. Army, who administered Yellowstone at that time, protected these bison from further poaching.
- Bison from private herds augmented the native herd.
- For decades, bison were intensively managed due to belief that they, along with elk and pronghorn, were over-grazing the park.
- By 1968, intensive manipulative management (including herd reductions) of bison ceased and natural ecological processes began.

Current Issues

See Chapter 9 for articles on management & brucellosis.

the cow being slightly more curved and slender than the bull's.

Bison are animals of the grasslands; they eat primarily grasses and sedges. Their massive hump supports strong muscles that allow the bison to use its head as a snowplow in winter, swinging side to side to sweep aside the snow.

Cows, calves, and some younger bulls comprise a herd. Mature bulls, however, spend most of the year alone or with other bulls. The exception is during the rut, or mating season. At this time, in late July and August, bulls seek out females. They display their dominance by bellowing, wallowing, and engaging in fights with other bulls. Once a bull has found a female who is close to estrus, he will stay by her side until she is ready to mate. Then he moves on to another female.

After a gestation period of 9 to 9½ months, single reddish-brown calves are born in late April and May. Calves can keep up with the herds about 2–3 hours after birth and they are well protected by their mothers and other members of the herd. However, wolves and grizzly bears have killed bison calves.

Adult bison have had no large predators for many decades, although the restoration of wolves in Yellowstone is changing that—wolves kill some adult bison each year. Scientists have also recently seen grizzly bears hunting bison successfully. Dead bison provide an important source of food for scavengers and other carnivores.

Many insects feed upon the bison, and bison will rub against trees, rocks, or in dirt wallows in an attempt to rid themselves of insect pests. Birds such as the magpie “ride” a bison in order to feed on insects in its coat. The cowbird will also follow close behind a bison, feeding on insects disturbed by its steps.

For many years scientists considered Yellowstone's bison to be a subspecies known as the mountain bison. Most scientists no longer make this distinction, and consider all bison to be one species, *Bison bison*.

The bison is the largest land mammal in North America. Bulls are more massive in appearance than cows, and more bearded. For their size, bison are agile and quick, capable of speeds in excess of 30 mph. Each year, bison injure park visitors who approach too closely.

Bison are sexually mature at age 2. Although female bison may breed at younger ages, older males (>7 years) participate in most of the breeding. In Yellowstone, life span averages 12–15 years, few individuals live as long as 20 years. Both sexes have horns, those of

In North America, both “bison” and “buffalo” refer to the American bison (Bison bison). Generally, “buffalo” is used informally; “bison” is preferred for more formal or scientific purposes.

History

From 30 to 60 million bison may have roamed North America in the 1800s. Their historic range spread from the Pacific to the Appalachians. As a result of over-hunting, they disappeared east of the Mississippi by 1832.

While bison were found throughout most of the country, their main habitat was the Great Plains. For millennia bison had roamed there in herds that often numbered three to five million animals. Plains tribes developed a culture that depended on bison. Almost all parts of the bison provided something for the Native American's way of life—food, tools, shelter, or clothing. No part of the animal was wasted; even the dung was burned for fuel. Hunting bison required skill and cooperation to herd and capture the animals. After tribes acquired horses from the Spanish in the 1600s, they could travel farther to find bison and hunt the animals more easily.

But European American settlers moving west during the 1800s changed the balance. Market hunting, sport hunting, and a U.S. Army campaign in the late 1800s nearly caused the extinction of the bison.

Yellowstone was the only place in the lower 48 states where a population of wild, free-ranging bison persisted. The U.S. Army, which administered Yellowstone at that time, protected these few dozen bison from poaching as best they could. The protection of bison in Yellowstone and their subsequent recovery is one of the great triumphs of the American conservation movement. (*See Chapter 1.*)

Management History

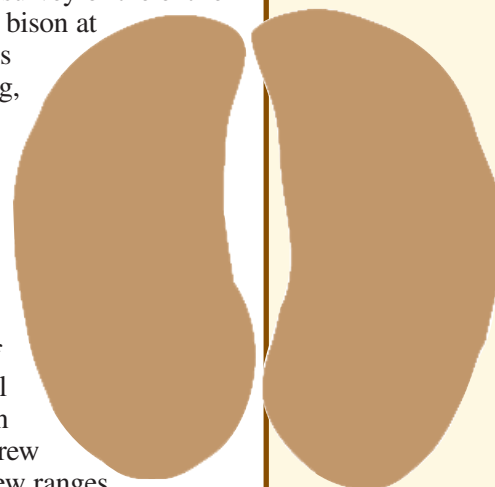
Despite protection, Yellowstone's bison were reduced by poaching to less than two dozen animals in 1902. Fearing the demise of the wild herd, the U.S. Army brought 21 bison from ranches to Yellowstone. In 1906–07, the Buffalo Ranch in Lamar Valley was constructed and began operation to increase the number of bison in the park. Various management strategies were used until the mid-1930s to increase the herd size, which grew to more than 1,000 animals. During that period, the park's surviving native bison herd in Pelican Valley also slowly increased.

Policy began to shift in the 1930s to the preservation of bison in a more natural state with less artificial manipulation. The introduced bison were released and allowed to move freely throughout the park and intermingle with the native bison. However, bison were still managed, albeit sporadically, through culling.

In January 1954, an aerial survey of the entire park placed the number of bison at 1,477. Because of concerns about possible over-grazing, subsequent management reductions were carried out, and an aerial count in March 1967 indicated 397 bison in the entire park.

In 1968, manipulative management of bison was replaced by the strategy of allowing natural ecological processes to operate. Bison population subsequently grew and bison began to seek new ranges inside and outside the park. Because humans now occupy much of what used to be bison habitat outside the park, conflicts inevitably occur. Bison can be a threat to human safety and can cause considerable damage to fences, crops, landscaping, and other private property. And, of significant concern to livestock producers, some Yellowstone bison are infected with the disease brucellosis.

Because of brucellosis, the bison are not welcome outside the park even though other ungulates that may also harbor the brucellosis organism are. Through the 1980s and 1990s, this issue has grown steadily into one of the most heated and complex of Yellowstone's resource controversies. For more information about brucellosis and the bison management plan, see Chapter 9, "Bison Management."



7A

Cats: Bobcat & Lynx

The cats of Yellowstone are seldom seen and little known. Of the three living in the park, cougars are better studied and are discussed in their own section. The little information available on bobcats and lynx is summarized below.



Bobcat *Lynx rufus*

Number in Yellowstone

Unknown, but probably widespread.

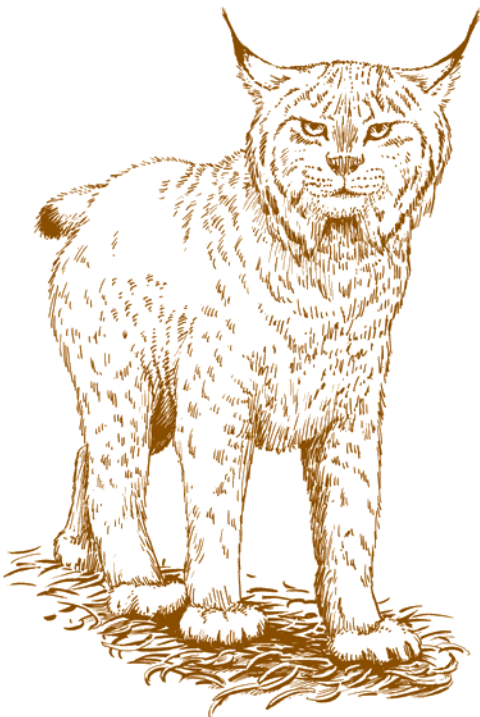
Where to see

- Rarely seen; most reports from northern half of the park.
- Typical habitat: rocky areas, conifer forests, and sagebrush.

Behavior and Size

- Adult: 15–30 pounds; 24–49 inches long.

- Color ranges from red-brown fur with indistinct markings to light buff with dark spotting; short tail; ear tufts.
- Distinguish from lynx: black rings discontinuous around tail, shorter ear tufts, smaller track (2").
- Solitary, active between sunset and sunrise.
- Eats rabbits, hares, voles, mice, red squirrels, birds such as wrens, sparrows, grouse; may take young deer and adult pronghorn.



Lynx

Lynx canadensis

Number in Yellowstone

Few; 111 known observations in entire park history.

Where to see

- Very rarely seen.
- Typical habitat: cold conifer forests.
- Recent research indicates presence throughout Yellowstone.

Behavior and Size

- Adult: 16–35 pounds, 26–38 inches long.
- Gray brown fur with white, buff, brown on throat and ruff; tufted ears; short tail; hind legs longer than front.
- Distinguish from bobcat: tail tip solid black; longer ear tufts; larger track.
- Wide paws with fur in and around pads; allows lynx to run across snow.
- Track: 4–5 inches.
- Solitary, nocturnal; usually beds during the day.
- Eats primarily snowshoe hares, especially in winter; also rodents, rabbits, birds, red squirrels, and other small mammals.

Research

A four-year research project to document the number and distribution of lynx in the park was recently completed. Researchers consistently confirmed lynx presence in the central and eastern portions of the park.



7A

Cougar

The cougar (*Puma concolor*), also called the mountain lion, is the largest member of the cat family in North America. Cougars live throughout the park in summer, but their secretive nature results in few sightings. The northern range of Yellowstone is prime habitat for cougars because snowfall is light and prey always available. Cougars follow their main prey as they move to higher elevations in summer and lower elevations in the winter.

Adult male cougars are territorial and may kill other adult males in their home range. Male territories may overlap with several females. In non-hunted populations, such as in Yellowstone, the resident adult males living in an area the longest are the dominant males. These males sire most of the litters within a population; males not established in the same area have little opportunity for breeding.

Although cougars may breed and have kittens at any time of year, most populations have a peak breeding and birthing season. In northern latitudes, including Yellowstone, males and females breed primarily February through May. Males and females without kittens search for one another by moving throughout their home ranges and communicating through visual and scent markers called scrapes. A female scrape conveys her reproductive status. A male's scrape advertises his presence to females and warns other males that an area is occupied. After breeding, the males leave the female.

In Yellowstone, most kittens are born in June, July, August, and September. Female cougars

As of March 2006 . . .

Number in Yellowstone

15–17 resident adults on the northern range; others in park seasonally.

Where to see

Seldom seen.

Behavior and size

- Adult males weigh 140–165 pounds; females weigh about 100 pounds; length, including tail, 6.5–7.5 feet.
- Average life span: males, 8–10 years; females, 12–14 years
- Preferred terrain: rocky breaks and forested areas that provide cover for hunting prey and for escape from competitors such as wolves and bears.
- Prey primarily on elk and mule deer, plus porcupines and other small mammals.
- Bears frequently displace cougars

from their kills.

- Male cougars may kill other male cougars within their territory.
- Adult cougars and kittens have been killed by wolves.
- Litters range from 2–3 kittens; 50% survive first year.

Research

Research is underway to assess effects of wolf restoration on cougars.

Interaction with humans

- Very few documented cougar–human confrontations have occurred in Yellowstone.
- If a big cat is close by: Stay together in a hiking group; carry small children; make noise. Do not run, do not bend down to pick up sticks. Act dominant—stare in the cat's eyes and show your teeth while making noise.

den in a secure area with ample rock and/or vegetative cover. Kittens are about one pound at birth and gain about one pound per week for the first 8–10 weeks. During this time, they remain at the den while the mother makes short hunting forays and then returns to nurse her kittens. When the kittens are 8–10 weeks old, the female begins to hunt in a larger area. After making a kill, she moves the kittens to the kill. Before hunting again, she stashes the kittens. Kittens are rarely involved in killing until after their first year.

7A

Cougar



Between 1988 and 2004, researchers documented 409 known or probable cougar kills:

*301 elk
62 mule deer
12 bighorn sheep
10 pronghorn
8 coyotes
7 marmots
4 porcupines
1 red fox
1 mountain goat
1 golden eagle*

Most kittens leave their area of birth at 14 to 18 months of age. Approximately 99 percent of young males disperse 50 to 400 miles; about 70–80 percent of young females disperse 20 to 150 miles. The remaining proportion of males and females establish living areas near where they were born. Therefore, most resident adult males in



Yellowstone are immigrants from other populations, thus maintaining genetic variability across a wide geographic area.

Yellowstone's cougars are not hunted within the park. Thus, their life span may be 12–14 years for females and 8–10 years for males. Cougars living in areas where they are hunted have much shorter life spans.

In Yellowstone, cougars prey upon elk (mostly calves) and deer. They stalk the animal then attack, aiming for the animal's back and killing it with a bite to the base of the skull or the throat area.

A cougar eats until full, then caches the carcass for later meals. Cougars spend an average of 3–4 days consuming an elk or deer kill and 4–5 days hunting for the next kill. Cougars catch other animals—including red squirrels, porcupines, marmots, grouse, and moose—if the opportunity arises.

Cougars are solitary hunters who face competition for their kills from other large mammals. Even though a cached carcass is harder to detect, it sometimes is found by scavengers and competitors such as bears and wolves. In Yellowstone, black and grizzly bears will take over a cougar's kill. Coyotes will try, but can be killed by the cougar instead. Wolves displace cougars from their kills less than 5 percent of the time according to recent observations.

Management History

In the early 1900s, cougars were killed as part of predator control in the park. By 1925, the remaining population was estimated to be 12 individuals. Reports of cougars in Yellowstone have increased steadily from 1 each year between 1930 and 1939 to about 16 each year between 1980 and 1988. However, increases in visitor travel in Yellowstone and improvements in record keeping during this period probably contributed to this trend.

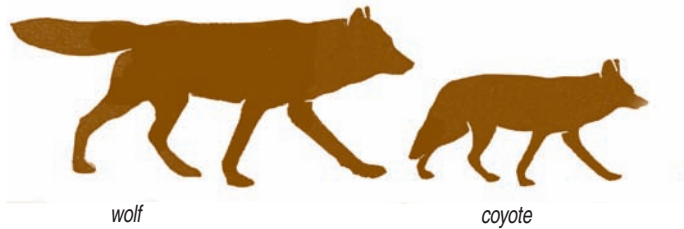
In 1987, the first study of cougar ecology began in Yellowstone National Park. The research documented population dynamics of cougars in the northern Yellowstone ecosystem inside and outside the park boundary, determined home ranges and habitat requirements, and assessed the role of cougars as a predator in the ecosystem.

In 1998, the second phase of cougar research began. Researchers have collared 87 cougars, including 50 kittens in 22 litters. Currently, 4 cougars are radio-collared and will be monitored through 2006, the last year of the study. Between 1988 and 2005, researchers documented 467 known or probable cougar kills. Elk comprised the majority: 75 percent; 52 percent were calves, 36 percent were cows, and 9 percent were bulls. Cougars killed about one elk or deer every 9.4 days and spent almost 4 days at each kill.

Very few cougar/human confrontations have occurred in Yellowstone. However, observations of cougars, particularly those close to areas of human use or residence, should be reported.

Note: The cougar photo above was taken under controlled research conditions by researchers who study Yellowstone's cougars. It is of a kitten that has just been treed. Now an adult, it continues to be tracked by researchers as part of the long-term cougar study in Yellowstone.

Coyote



wolf

coyote

Coyotes (*Canis latrans*) are intelligent and adaptable. Like wolves, coyotes have been killed because they sometimes preyed on livestock and, in the park's early days, they were perceived as threats to ungulate populations. Unlike wolves, however, coyotes were successful in resisting efforts to exterminate them. Up until the 1940s, wildlife managers in Yellowstone also considered the coyote a threat to survival of elk and other ungulates. Since then, research has shown the chief foods of the coyote are voles, mice, rabbits, other small animals, and carrion. Coyotes do hunt for elk calves in the spring, but only when the calves are young.

Often mistaken for a wolf, the coyote is much smaller with a slighter build—resembling a shepherd dog in general appearance. Its coat colors range from tan to buff, sometimes gray, and with some orange on its tail and ears. Males are slightly larger than females.

During the 20th century, coyotes partially filled the niche left vacant by the removal of wolves from the park earlier in the century. This may explain, in part, why coyotes are more social in Yellowstone National Park than elsewhere. Most of the coyotes on the northern range live and hunt in packs of 6–7 animals, with an alpha male and female, and subordinate individuals (usually pups from previous litters).

Coyotes defend their territories by vocalization and scent-marking with their urine and feces. They also use scent-marking to communicate with each other about their location and breeding status.

Until recently, coyotes faced few predators in Yellowstone other than cougars, who will kill coyotes feeding on cougar kills. Since wolves were restored, however, dozens of coyote pups and adults have been killed by wolves—primarily when feeding on other animals killed by wolves. On the northern range, wolves have caused a 30–50 percent reduc-

As of March 2006 . . .

Number in Yellowstone

Total unknown, but numerous. In the northern range, scientists know the coyote population has decreased 30–50% since wolves were restored to Yellowstone due to direct mortality and changes in coyote denning behaviors and success.

Where to see

Meadows, fields, other grassland areas.

Behavior & Size

- Weigh 25–35 pounds, 16–20 inches high at the shoulder.
- Average life span 6 years; up to 13 years in Yellowstone National Park.
- Home range: 6–42 square miles.
- Primarily eat mice, voles, ground squirrels, pocket gophers, birds, carrion, elk calves, some adult elk.
- 5–7 pups are born in May in dens.

- Preyed upon by wolves.

Management

- Like other predators, coyotes were often destroyed in the early part of the 20th century because they sometimes preyed on livestock.
- Coyotes continued to thrive because their adaptability enabled them to compensate for the destruction efforts.
- Elimination of wolves probably resulted in high coyote population densities; wolves' absence opened a niche that coyotes could occupy in Yellowstone.
- NPS staff monitors coyotes and uses cracker-shell rounds, pepper spray, or other negative stimuli to discourage coyotes that have lost their wariness of humans.

tion in the resident coyote population through direct mortality and changes in coyote denning behaviors and success.

Coyotes also face threats from humans. They quickly learn habits like roadside feeding. This may lead to aggressive behavior toward humans and can increase the risk of the coyote being poached or hit by a vehicle. Several instances of coyote aggression toward humans have occurred here, including one that involved an actual attack.

Beginning in 1988, park staff increased monitoring of coyotes along park roadsides and began to experiment with scaring unwary coyotes from visitor-use areas with cracker-shell rounds, bear repellent spray, or other negative stimuli. Those animals that continue to pose a threat to themselves or to humans are moved to other areas of the park or killed. Signs, interpretive brochures, and park staff continue to remind visitors that coyotes and other park wildlife are wild and potentially dangerous and should never be fed or approached.



7A

Deer

Mule deer and white-tailed deer can be told apart by their coloration, antler shape, tail, behavior, and where they live.

All species of deer use their hearing, smell, and sight to detect predators such as coyotes or cougars. They probably smell or hear the approaching predator first; then may raise their heads high and stare hard, rotating ears forward to hear better. If a deer hears or sees movement, it flees.

Mule deer are common in Yellowstone, living throughout the park in almost all habitats; white-tailed deer are uncommon, restricted to streamside areas of the northern range.



Mule deer *Odocoileus hemionus*

Number in Yellowstone

Summer: 2,300–2,500

Winter: less than 100

Where to see

- Summer: throughout the park.
- Winter: North Entrance area.

Behavior and Size

- Male (buck): 150–250 pounds; female (doe): 100–175 pounds; 3½ feet at the shoulder.
- Summer coat: reddish; winter coat: gray-brown; white rump patch with black-tipped tail; brown patch on forehead; large ears.

- Males grow antlers from April or May until August or September; shed them in late winter and spring.
- Mating season (rut) in November and December; fawns born late May to early August.
- Lives in brushy areas, coniferous forests, grasslands.
- Bounding gait, when four feet leave the ground, enables it to move more quickly through shrubs and rock fields.
- Eats shrubs, forbs, grasses; conifers in spring.
- Predators include wolf, coyote, cougar, bear.

White-tailed Deer *O. virginianus*

Number in Yellowstone

Scarce

Where to see

Along streams and rivers in northern part of the park.

Behavior and Size

- Adults 150–250 pounds; 3½ feet at the shoulder.
- Summer coat: red-brown; winter coat: gray-brown; throat and inside ears with whitish

patches; belly, inner thighs, and underside of tail white.

- Waves tail like a white flag when fleeing.
- Males grow antlers from May until August; shed them in early to late spring.
- Mating season (rut) peaks in November; fawns born usually in late May or June.
- Eats shrubs, forbs, grasses; conifers in spring.
- Predators include wolf, coyote, cougar, bear.



Elk (*Cervus elaphus*) are the most abundant large mammal found in Yellowstone. European American settlers used the word “elk” to describe the animal, which is the word used in Europe for moose (causing great confusion for European visitors). The Shawnee word “wapiti,” which means “white deer” or “white-rumped deer,” is another name for elk. The North American elk is considered the same species as the red deer of Europe.

Bull elk are probably the most photographed animals in Yellowstone, due to their huge antlers. Bull elk begin growing their first set of antlers when they are about one year old. Antler growth is triggered in spring by a combination of two factors: a depression of testosterone levels and lengthening daylight. The first result of this change is the casting or shedding of the previous year’s “rack.” Most bulls drop their antlers in March and April. New growth begins soon after.

Growing antlers are covered with a thick, fuzzy coating of skin (the blood vessels of which are depositing the bone that makes up the antler) commonly referred to as “velvet.” Usually around early August, further hormonal changes signal the end of antler growth, and the animal begins scraping the velvet off, polishing and sharpening the antlers in the process.

The antler growing period is shortest for yearlings (about 90 days) and longest for healthy, mature individuals (about 140 days). Roughly 70 percent of the antler growth takes

As of March 2006 . . .

Number in Yellowstone

- Summer: 15,000–25,000 elk in eight different herds.
- Winter: Approximately 10,000–15,000.
- Largest herds:
Northern: 9,000–12,000 in winter
Firehole–Madison: 250–500 year-round.

Where to see

Summer: Gibbon Meadows, Elk Park, and Lamar Valley.
Autumn, during “rut” or mating season: northern range, including Mammoth Hot Springs; Norris; Madison River.
Winter: migrate south to the Jackson Hole Elk Refuge in Jackson, Wyoming, or north to the northern range and around Gardiner, Montana; 250–500 along the Firehole and Madison rivers.

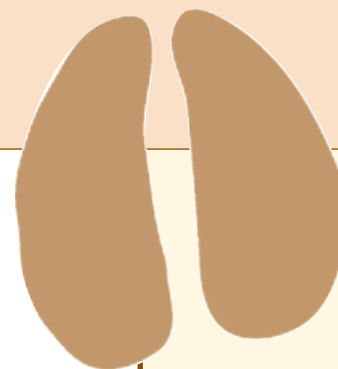
Behavior and Size

- Male (bull) weighs about 700 pounds and is about 5 feet high at the shoulder; female (cow) weighs about 500 pounds and is slightly shorter; calf is about 30 pounds at birth.
- Average life span: 13–18 years.
- Bulls have antlers, which they begin growing in the spring and usually drop in March or April.
- Feed on grasses, sedges, other herbs and shrubs, bark of aspen trees, conifer needles, burned bark, aquatic plants.
- Mating season (rut) in September and October; calves born in May to late June.

See article on the northern range, Chapter 9.

place in the last half of the period, when the antlers of a mature elk will grow $\frac{2}{3}$ of an inch each day. The antlers of a typical healthy bull are 55–60 inches long, just under six feet wide, and weigh about 30 pounds per pair.

Bulls retain their antlers through the winter. When antlered, bulls usually settle disputes by wrestling with their antlers. When antlerless, they use their front hooves (as cows do), which is more likely to result in injury to one of the combatants. Because elk spend the winter in herds with other bulls or with gender-mixed herds, retention of antlers means fewer injuries sustained overall. Also, bulls with large antlers that are retained longer are at the top of elk social structure, allowing them preferential access to feeding sites.



7A

Elk

Elk Antler Details

- Antlers usually symmetrical, but asymmetry and malformations occur.
- The average, healthy, mature bull has six tines on each antler, and is known as a “six point” or “six by six.”
- Can occur on female elk.
- One-year-old bulls grow simple spikes 10–20 inches, sometimes forked.
- Two-year-old bulls usually have four to five points on slender antlers.
- Three-year-old bulls have the same number of points, but thicker antlers.
- Four-year-old and older bulls typically have six points; antlers are thicker and longer each year.
- Eleven- or twelve-year old bulls often grow the heaviest antlers; after that age, the size of antlers generally diminishes.



Mating Season

The mating season (rut) generally occurs from early September to mid-October. Elk gather in mixed herds—lots of females and calves, with a few bulls nearby. Bulls bugle to announce their availability and fitness to females and to warn and challenge other bulls. When answered, bulls move toward one another and sometimes engage in battle for access to the cows. They crash their antlers together, push each other intensely, and wrestle for dominance. While loud and extremely strenuous, fights rarely cause serious injury. The weaker bull ultimately gives up and wanders off.

Calves are born in May and June. They are brown with white spots and have little scent, providing them with good camouflage from predators. They can walk within an hour of birth, but they spend much of their first week to ten days bedded down between nursings. Soon thereafter they begin grazing with their mothers, and join a herd of other cows and calves. Up to two-thirds of each year's calves may be killed by predators. Elk calves are food for black and grizzly bears, wolves, coyotes, cougars, and golden eagles. female

elk that reach maturity can live 17–18 years; rare individuals may live 22 years.

Habitat

Climate is an important factor affecting the size and distribution of elk herds here. While nearly the entire park provides summer habitat for 15,000–25,000 elk, winter snowfalls force elk and other ungulates to leave most of the high elevation grasslands of the park. The number of elk that winter in the park averages 10,000–15,000.

The northern range, with more moderate temperatures and less snowfall than the park interior, can support large numbers of wintering elk. The northern Yellowstone herd is one of the largest herds of elk in the United States. The herd winters in the area of the Lamar and Yellowstone river valleys from Soda Butte to Gardiner, Montana. It also migrates outside of the park into the Gallatin National Forest and onto private lands.

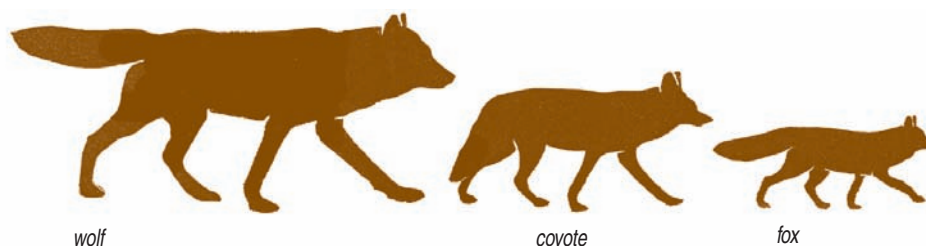
Only one herd lives both winter and summer inside the park. The Madison–Firehole elk herd of 250–500 animals has been the focus of a research study since November 1991. Researchers are examining how environmental variability affects ungulate reproduction and survival. Prior to wolf restoration, the population was naturally regulated by severe winter conditions to a degree not found in other, human-hunted elk herds. The elk are also affected by high fluoride and silica levels in the water and plants they eat, which affect enamel formation and wear out teeth quickly—thus shortening their lives. The average life span is 13 years; elk on the northern range live approximately 18 years. This herd has both relatively high survival of animals older than calves and high reproduction rates. Information gained in this study will be useful in comparing unhunted and hunted elk populations.

Researchers also examined elk use of areas burned in the wildfires of 1988. They found that elk ate the bark of burned trees. Fires had altered the chemical composition of lodgepole pine bark, making it more digestible and of higher protein content than live bark. While the burned bark was not the highest quality forage for elk, it is comparable to other low-quality browse species. Researchers speculate that elk selected burned bark because it was readily available above the snow cover in winter.

See also Chapter 9, “Northern Range Issue.”

Horns vs. Antlers

Antlers, found on members of the deer family, grow as an extension of the animal's skull. They are true bone, are a single structure, and, generally, are found only on males. Horns, found on pronghorn, bighorn sheep, and bison, are a two-part structure. An interior portion of bone (an extension of the skull) is covered by an exterior sheath grown by specialized hair follicles (similar to human fingernails). Antlers are shed and regrown yearly while horns are never shed and continue to grow throughout an animal's life. However, one exception is the pronghorn, which sheds and regrows its horn sheath each year.



The red fox (*Vulpes vulpes*) has been documented in Yellowstone since the 1880s. In relation to other canids in the park, red foxes are the smallest. Adult foxes weigh 9–12 pounds; coyotes average 28 pounds in Yellowstone; and adult wolves weigh closer to 100 pounds. Red foxes occur in several color phases, but they are usually distinguished from coyotes by their reddish yellow coat that is somewhat darker on the back and shoulders, with black “socks” on their lower legs. “Cross” phases of the red fox (a dark cross on their shoulders) have been reported a few times in recent years near Canyon and Lamar Valley. Also, a lighter-colored red fox has been seen at higher elevations.

Foxes feed on a wide variety of animal and plant materials. Small mammals such as mice and voles, rabbits, and insects comprise the bulk of their diet. Carrion seems to be an important winter food source in some areas. The many miles of forest edge and extensive semi-open and canyon areas of the park seem to offer suitable habitat and food for foxes. They are widespread throughout the northern part of the park with somewhat patchy distribution elsewhere in the park. Foxes are more abundant than were previously thought in Yellowstone, yet they are not often seen. They are nocturnal, usually solitary, and travel along edges of meadows and forests.

Foxes can become habituated to humans usually due to being fed. One fox in the summer of 1997 was trapped and relocated three times from the Tower Fall parking area because visitors fed it human food. The fox was relocated between 10 and 60 miles away from Tower but twice it returned. Finally the fox came to Mammoth where it was fed again and as a result was destroyed. While this story gives us interesting information about the homing instinct of fox, it also points out the importance of obeying rules to avoid inadvertently causing the death of one

As of March 2006 . . .

Number in Yellowstone

Unknown

Where to see

- Lamar Valley, Canyon Village area
- Typical habitat: edges of sagebrush/grassland and forests

Behavior and Size

- Adult: 9–12 pounds; average 43 inches long.
- Average life span: 3–4 years.
- Several color phases; usually red fur with white-tipped tail, dark legs; slender, long snout.
- Rarely howls or sings.
- Distinguish from coyote by size, color, and bushier tail.
- Solitary or in mated pairs.
- Prey: voles, mice, rabbits, other small animals.
- Other food: carrion and some plants.
- Predators include coyotes.



of Yellowstone’s animals.

A little known fact about red foxes is that most of them in the Lower 48 states, especially in the eastern and plains states, were introduced from Europe in the 18th and 19th centuries for fox hunts and fur farms. The foxes that survived the hunt or escaped the fur farms proliferated and headed westward. In addition to this introduced subspecies of red fox, three native subspecies exist at high elevations in the Sierra (*V. v. nectar*), Cascade (*V. v. cascadiensis*), and Rocky (*V. v. macroura*) mountains and are collectively called mountain foxes. Little is known about any of these subspecies.

7A

Fox

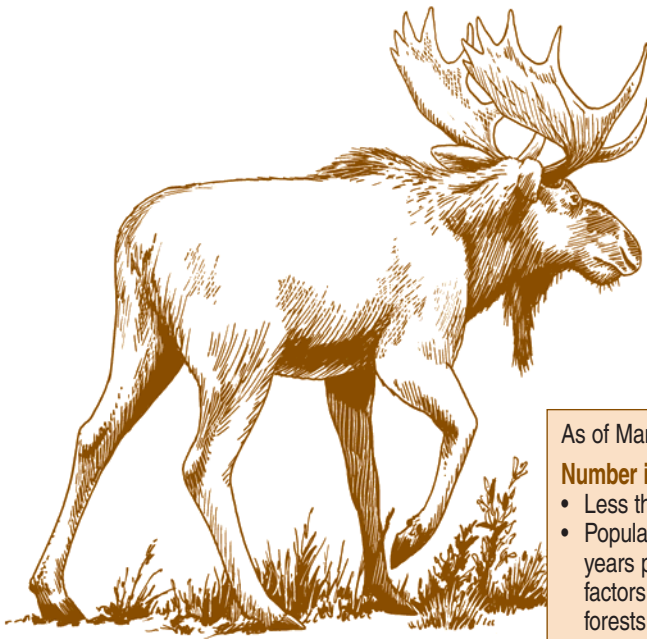
A research project conducted between 1994–1998 determined at least two subpopulations of foxes live in the Greater Yellowstone Ecosystem. At about 7,000 feet in elevation, there seemed to be a dividing line with no geographical barriers separating these foxes. The genetic difference between these foxes was similar to mainland and island populations of foxes in Australia and their habitat use was different as well. In addition, their actual dimensions, such as ear length and hind foot length, were adapted to some degree for colder environments with deep snow and long winters.

Ever since red fox sightings were first recorded in Yellowstone National Park, a novel coat color has been seen at high elevations. This yellowish or cream color most often occurs above 7,000 feet in areas such as Cooke City and the Beartooth Plateau.

During the past century, especially within the past few decades, the number of fox sightings has increased greatly. This could be due to better documentation of sightings through the rare animal sighting reports that began in 1986. In addition, an increase in visitors means more chances to see foxes. There may also be a gradual increase in the number of foxes now that the wolf has returned to Yellowstone.

Wolves and coyotes are more closely related both genetically and physically than wolves and foxes, and wolves are successfully competing with coyotes, causing a decline in the coyote population. This may have caused an increase in the number of fox sightings in core wolf areas such as the Lamar Valley.

Moose



Moose (*Alces alces shirasi*) are the largest members of the deer family in Yellowstone. A male (bull) moose can weigh nearly 1,000 pounds and stand more than 7 feet at the shoulder. Both sexes have long legs that enable them to wade into rivers and through deep snow, to swim, and to run fast. Despite its size, a moose can slip through the woods without a sound. Moose, especially cows with calves, are unpredictable and have chased people in the park.

Both sexes are dark brown, often with tan legs and muzzle. Bulls can be distinguished from cows by their antlers. Adults of both sexes have “bells”—a pendulous dewlap of skin and hair that dangles from the throat and has no known function.

In summer, moose eat aquatic plants like water lilies, duckweed, and burweed. But the principle staples of the moose diet are the leaves and twigs of the willow, followed by other woody browse species such as gooseberry and buffaloberry. An adult moose consumes approximately 10–12 pounds of food per day in the winter and approximately 22–26 pounds of food per day in the summer.

Some moose that summer in the park migrate in winter to lower elevations west and south of Yellowstone where willow remains exposed above the snow. But many moose move to higher elevations (as high as 8,500 feet) to winter in mature stands of subalpine fir and Douglas-fir. Moose can also move easily in these thick fir stands because the

As of March 2006 . . .

Number in Yellowstone

- Less than 500.
- Population has declined in last 40 years perhaps due to a number of factors such as loss of old growth forests surrounding the park, hunting outside the park, burning of winter habitat (spruce-fir forests) in 1988.

Where to see

Marshy areas of meadows, lake shores, and along rivers.

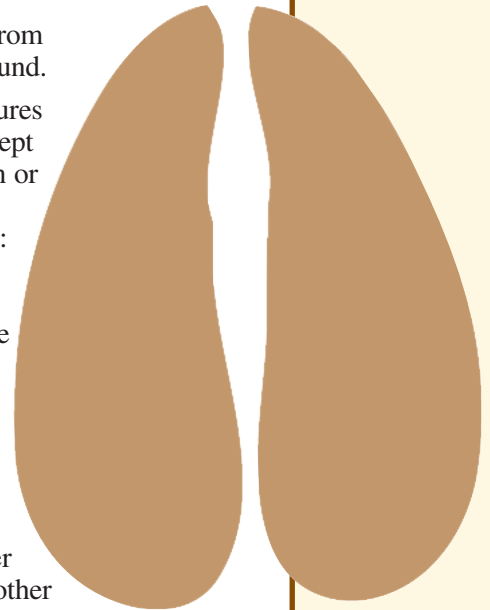
Behavior & Size

- Largest member of deer family.
- Adult male (bull) weighs close to 1,000 pounds; female (cow) weighs up to 900 pounds; 5½ to 7½ feet at the shoulder.
- Browses on willows and aquatic plants in summer; willows where available in winter or on conifers above 8,500 feet.
- Usually alone or in small family groups.
- Mating season peaks in late September and early October; one or two calves born in late May and June.
- Lives up to 20 years.

branches prevent snow from accumulating on the ground.

Moose are solitary creatures for most of the year, except during the mating season or rut. During the rut, both bulls and cows are vocal: the cows may be heard grunting in search of a mate, and bulls challenge one another with low croaks before clashing with their antlers. A bull on the offensive tries to knock its opponent sideways. If such a move is successful, the challenger follows through with another thrust of its antlers. The weaker animal usually gives up before any serious damage is done; occasionally the opponent's antlers inflict a mortal wound.

Bulls usually shed their antlers in late November or December, although young bulls may retain their antlers as late as March. Shedding their heavy antlers helps them conserve energy and promote easier



7A

Moose



winter survival. In April or May, bulls begin to grow new antlers. Small bumps on each side of the forehead start to swell, then enlarge until they are knobs covered with a black fuzz (called velvet) and fed by blood which flows through a network of veins. Finally the knobs change into antlers and grow until August. The antlers are flat and palmate (shaped like a hand). Yearlings grow six to eight inch spikes; prime adult bulls usually grow the largest antlers—as wide as 5 feet from tip to tip. Then the bull rubs and polishes his antlers on small trees in preparation for the rut.

Cows are pregnant through the winter; gestation is approximately eight months. When ready to give birth, the cow will drive off any previous year's offspring that may have wintered with her and seek out a thicket. She gives birth to one or more calves, each weighing 25–35 pounds.

A calf walks a few hours after birth and stays close to its mother. Even so, a moose calf often becomes prey for bears or wolves and less frequently of cougars or coyotes.

History

Moose were reportedly very rare in northwest Wyoming when the park was established in 1872. Subsequent protection from hunting and wolf control programs may have contributed to increased numbers, but suppression of forest fires probably was the most important factor in their population increase. Moose depend on mature fir forests for winter survival. By the 1970s, an estimated 1,000 moose inhabited the park.

The moose population declined following the fires of 1988. Many old moose died during the winter of 1988–89, probably as a combined result of the loss of good moose forage and a harsh winter. Unlike moose habitat elsewhere, northern Yellowstone does not have woody browse species that will come in quickly after a fire and extend above the snowpack to provide winter food. Therefore, the overall short-term effect of the fires was probably detrimental to moose populations. Their current population and distribution are unknown.

Today, moose are most likely seen in the park's southwestern corner and in the Soda Butte Creek, Pelican Creek, Lewis River, and Gallatin River drainages.

The North American pronghorn (*Antilocapra americana*) is not a true antelope, which are found in Africa and southeast Asia. The pronghorn is the surviving member of a group of animals that evolved in North America during the past 20 million years. Use of the term “antelope” seems to have originated when the first written description of the animal was made during the 1803–1805 Lewis and Clark Expedition.

The pronghorn has true horns, similar to bison and bighorn sheep. The horns are made of modified, fused hair that grows over permanent bony cores, but they differ from those of other horned animals in two major ways: the sheaths are shed and grown every year and they are pronged. (A number of other horned mammals occasionally shed their horns, but not annually.) Adult males (bucks) typically have 10–16 inch horns that are curved at the tips. About 70 percent of the females (does) also have horns, but they average 1–2 inches long and are not pronged. The males usually shed the horny sheaths in November or December and begin growing the next year’s set in February or March. The horns reach maximum development in August or September. Females shed and regrow their horns at various times.

Pronghorn are easy to distinguish from the park’s other ungulates. Their deer-like bodies are reddish-tan on the back and white underneath, with a large white rump patch. Their eyes are very large, which provides a large field of vision. Males also have a black cheek patch.

Females that bred the previous fall commonly deliver a set of twins in May or June. The newborn fawns are a uniform grayish-brown and weigh 6–9 pounds. They can walk within 30 minutes of birth and are capable of out-running a human in a couple of days. The young normally stay hidden in the vegetation while the mother grazes close by. After the fawns turn three weeks old they begin to

As of March 2006 . . .

Number in Yellowstone
200–250

Where to see

- Summer: Lamar Valley; some may be near the North Entrance near Gardiner, Montana.
- Winter: between the North Entrance and Reese Creek.

Behavior and Size

- Male (buck) weighs 100–125 pounds; female (doe) weighs 90–110 pounds; adult length is 45–55 inches and height is 35–40 inches at shoulder.
- Average life span: 7–10 years.
- Young (fawns) born in late May–June.
- Live in grasslands.
- Can run for several miles at 45 mph
- Eat sagebrush and other shrubs, forbs, some grasses.
- Both sexes have horns; males are pronged.

History

- Prior to European American settlement of the West, pronghorn population estimated to be 35 million.
- Early in the 19th century, pronghorn abundant in river valleys radiating from Yellowstone; settlement and hunting reduced their range and numbers.
- Park management also culled pronghorn during the first half of the 20th century due to overgrazing concerns.

Research Concerns

- Pronghorn are designated species of special concern in the park.
- Since 1991, the population has dropped approximately 50%; research is underway to determine why; possible causes include predation and loss of winter range.
- This small population could face extirpation from random catastrophic events such as a severe winter or disease outbreak.



follow the females as they forage. Several females and their youngsters join together in nursery herds along with yearling females.

Pronghorn form groups most likely for increased protection against predators. When one individual detects danger, it flares its white rump patch, signaling the others to flee. The pronghorn is well adapted for outrunning its enemies—its oversized windpipe and heart allow large amounts of oxygen and blood to be carried to and from its unusually large lungs. Pronghorn can sustain sprints of 45–50 mph. Such speed, together with keen vision, make the adults difficult prey for any natural predator. Fawns, however, can be caught by coyotes, bobcats, wolves, bears, and golden eagles.

The pronghorn breeding season begins mid-September and extends through early October. During the rut the older males “defend” groups of females (called a harem). They warn any intruding males with loud snorts and wheezing coughs. If this behavior does not scare off the opponent, a fight may erupt. The contenders slowly approach one another until their horns meet, then they twist and shove each other. Eventually, the weaker individual will retreat. Although the fights may be bloody, fatalities are rare.

The most important year-round foods are shrubs like sagebrush and rabbitbrush; they eat succulent forbs during spring and summer. They can eat lichens and plants like locoweed, lupine, and poisonvetch that are toxic to some ungulates. Their large liver (proportionately, almost twice the size of a domestic sheep’s liver) may be able to remove plant toxins from the blood stream. Grasses appear to be the least-used food item, but may be eaten during early spring when the young and tender shoots are especially nutritious.

During winter, pronghorn form mixed-sex and -age herds. In spring, they split into smaller bands of females, bachelor groups of males

between 1–5 years old, and solitary older males. The small nursery and bachelor herds may forage within home ranges of 1,000 to 3,000 acres while solitary males roam smaller territories (60 to 1,000 acres in size).

Pronghorn, including two-thirds of the individuals in Yellowstone, migrate between different winter and summer ranges to more fully utilize forage within broad geographic areas.

History

During the early part of the 19th century, pronghorns ranked second only to bison in numbers, with an estimated 35 million throughout the West. The herds were soon decimated by conversion of rangeland to cropland, professional hunters who sold the meat, and ranchers who believed that pronghorns were competing with livestock for forage. Today, due to transplant programs and careful management, pronghorns again roam the sagebrush prairies in herds totaling nearly one-half million animals.

Pronghorn in Yellowstone have not fared as well. The park’s pronghorn population declined in the 1960s and again in the 1990s. Research in 1991 found that the average fawn life span that year was about 35 days and nearly all collared pronghorn fawns were apparently killed by coyotes. This mortality rate closely followed the decline in total fawn numbers measured during weekly surveys of the entire park. In 1999 another cooperative study was initiated to determine fawn productivity and mortality rates. Other factors include declining amount and quality of winter range as private lands are taken out of agriculture.

Research continues to search for answers to the population decline. This small population is susceptible to extirpation from random catastrophic events such as a severe winter or disease outbreak.



Wolves ranged widely throughout North America in pre-Columbian times. Worldwide, all wolves, except the red wolf (*Canis rufus*) of the southeastern United States, are the same species (*Canis lupus*).

Wolves are highly social animals and live in packs. In Yellowstone, the average pack numbers eleven animals; some are more than twice that size. (In areas of abundant wolves, about 25 percent of the packs will have more than eight members.) The pack is a highly evolved and complex social family, with leaders (the alpha male and alpha female) and subordinates, each having individual personality traits. Packs generally command territory that they mark by urine scenting and defend against intrusion by other wolves (individuals or packs).

Wolves consume a wide variety of prey, large and small. However, the evolution of packs and their structure allows efficient hunting of large prey while still competing with coyotes (and, to a lesser extent, foxes) for smaller meals. In Yellowstone, 90 percent of their winter prey is elk: 40 percent calves, 30–35 percent cows, 10–22 percent bulls. (Wolves kill older cows; the average age is 14. Hunters kill cows that average six years of age.) In winter, a wolf pack will kill an average of 9–14 elk per month. Deer comprise 25 percent of their prey in summer. Wolves also occasionally kill adult bison.

On the other hand, wolves have provided a bounty of food for a variety of animals in Yellowstone. When wolves kill an elk, it is a beginning rather than an ending. Ravens arrive almost immediately. Coyotes arrive soon after, waiting nearby until the wolves are sated. Bears are not so patient and will attempt to chase the wolves away, and are usually successful. Many other animals—from magpies to foxes—dine on the remains.

From their confined beginnings in a few pens, the wolves have expanded their population

As of March 2006 . . .

Number in Yellowstone area

- 325 wolves live in 45 packs in the greater Yellowstone area.
- 11 of those packs with 118 individuals den in the park—a drop of one-third in one year (see below).

Where to see

They inhabit most of the park now, look at dawn and dusk.

Behavior & Size

- 26–36 inches high at the shoulder, 4–6 feet long from nose to tail tip; males weigh 100–130 pounds, females weigh 80–110 pounds.
- Home range: 18–540 square miles; varies with pack size, food, season.
- Typically live 3–4 years in wild.
- Three color phases: gray, black, and white; gray is the most common;

white is only in the high Arctic; and black is common only in the Rockies.

- Prey primarily on hoofed animals. In Yellowstone, 90% of their winter diet is elk; more deer in summer; also eat a variety of smaller mammals like beavers.
- Mate in February; give birth to average of five pups in April after a gestation period of 63 days; young emerge at 10–14 days; pack remains at the den for 3–10 weeks unless disturbed.
- Human-caused death is the highest mortality factor for wolves; the leading natural cause is wolves killing other wolves.

Current Management

See Chapter 9, “Wolf Restoration.”

and range, and now are found throughout the Greater Yellowstone Ecosystem.

Until 2005, the wolf population continued to increase in the park—to the extent that they might have saturated the available territory. However, in 2005, a disease (probably either parvovirus or distemper) killed one-third of the pups. Studies are underway to confirm the cause of death.

History

In the 1800s, westward expansion brought settlers and their livestock into direct contact with native predator and prey species. Much of the wolves’ prey base was destroyed as agriculture flourished. With the prey base removed, wolves began to prey on domestic stock, which resulted in humans removing wolves from most of their historic range. (Other predators such as bears, cougars, and coyotes were also killed to protect livestock and “more desirable” wildlife species, such as deer and elk.) By the early 1900s, wolves had been almost entirely eliminated from the 48 states.

Disease update

Wolves kill each other and other carnivores, such as coyotes and cougars, usually because of territory disputes or competition for carcasses. In 2000, however, the subordinate female wolves of the Druid pack exhibited behavior never seen before: they killed their pack’s alpha female; then they carried her pups to a central den and raised them with their own litters.

7A

Wolf



Today, it is difficult for many people to understand why early park managers would have participated in the extermination of wolves. After all, the Yellowstone National Park Act of 1872 stated that the Secretary of the Interior “shall provide against the wanton destruction of the fish and game found within said Park.” But this was an era before people, including many biologists, understood the concepts of ecosystem and the interconnectedness of species. At the time, the wolves’ habit of killing prey species was considered “wanton destruction” of the animals. People who poisoned every carcass they passed in the backcountry (loading strychnine into carcasses was the easiest way to kill wolves) did so believing they were supporting the Yellowstone National Park Act. Between 1914 and 1926, at least 136 wolves were killed in the park; by the 1940s, wolves were rarely reported.

In the 1960s, National Park Service policy regarding human management of Yellowstone’s wildlife populations changed to a policy of allowing those populations to manage themselves. Many suggested at the time that for such regulation to succeed, the wolf had to be a part of the picture.

Also in the 1960s and 1970s, a national awareness of environmental issues and consequences led to the passage of many laws

designed to correct the mistakes of the past and help prevent similar mistakes in the future. One such law was the Endangered Species Act, passed in 1973. The U.S. Fish and Wildlife Service is required by this law to restore endangered species that have been eliminated, if possible. (National Park Service policy also calls for restoration of native species where possible.)

Wolves & Humans

As wolf numbers increase, they will encounter more humans. Wolves are not normally a danger to humans, unless humans habituate them by providing them with food. No wolf has attacked a human in Yellowstone, but a few attacks have occurred in other places. Almost all were from wolves that had become conditioned to human foods. Like coyotes, wolves can quickly learn to associate campgrounds, picnic areas, and roads with easy food. This often leads to aggressive behavior toward humans.

What You Can Do

- Never feed a wolf or any other wildlife. Do not leave food or garbage outside unattended. Make sure the door is shut on a garbage can or dumpster after you deposit a bag of trash.
- Treat wolves with the same respect you give any other wild animal. If you see a wolf, do not approach it.
- Never leave small children unattended.
- If you have a dog, keep it leashed.
- If you are concerned about a wolf—it’s too close, not showing sufficient fear of humans, etc., do not run. Stop, stand tall, watch what the wolf is going to do. If it approaches, wave your arms, yell, flare your jacket, and if it continues, throw something at it. Group up with other people, continue waving and yelling.
- Report the presence of wolves near developed areas or any wolf behaving strangely.

To date, four wolves in Yellowstone National Park have become habituated to humans. One of them was killed north of the park because it was not afraid of people at a ranch.

See Chapter 2 for how wolves are affecting the ecosystem and Chapter 9, “Wolf Restoration,” for more details about their management.

Records of bird sightings have been kept in Yellowstone since its establishment in 1872; these records document 320 species of birds to date, of which approximately 148 species are known to nest in the park. This is remarkable considering the harsh conditions that characterize the area.

Many birds, such as American robins and common ravens, are found throughout the park. Other species live in specific habitats. For example, belted kingfishers are found near rivers and streams while Steller's jays are found in moist coniferous forests.

Spring is a good time to look for birds. Migration brings many birds back to the park from their winter journeys south; other birds are passing through to more northern nesting areas. Songbirds are singing to establish and defend their territories; and many ducks are in their colorful breeding plumages, which makes identification easier.

Watch for birds on early morning walks from mid-May through early July. At all times, but especially during the nesting season, birds should be viewed from a distance. Getting too close can stress a bird (as it can any animal) and sometimes cause the bird to abandon its nest.

Most birds migrate to lower elevations and more southern latitudes beginning in September. At the same time, other birds pass through Yellowstone. Fall transients include tundra swans and ferruginous hawks. Some birds do stay in Yellowstone year-round, including the common raven, Canada goose, blue grouse, gray jay, red-breasted nuthatch, American dipper, and mountain chickadee. And a few species, such as rough-legged hawks and bohemian waxwings, migrate here for the winter.

Brief descriptions of some of Yellowstone's significant bird species follow.

As of March 2006 . . .

Number in Yellowstone

- 320 bird species have been documented in Yellowstone.
- Approximately 148 of these species nest in the park.

Other Info

- One endangered bird species previously occurred in the greater Yellowstone area: the whooping crane.
- One threatened bird species occurs in the park: the bald eagle.
- The peregrine falcon nests here. Formerly an endangered species, it was delisted in 1999.

Species monitored:

American white pelicans, trumpeter swans, ospreys, common loons, harlequin ducks, great gray owls, and colonial nesting birds.

Current Management

Yellowstone is an active participant in the Western Working Group of Partners in Flight, an international effort to protect migrant land birds in the Americas, because more than 100 bird species spend the winter in Mexico and Central America. There, they are threatened by loss of habitat, pesticide use, and increasing human development and pressure.



Visitors often ask, "What is the black and white bird with the long tail?" They have seen the black-billed magpie, a gregarious bird found throughout the West. In the right light, its dark feathers appear a shiny blue-black or green-black.



Bald Eagle *Haliaeetus leucocephalus*

Identification

- Large, dark bird; adult (four or five years old) has completely white head and tail.
- Females larger than males, as is true with most predatory birds.
- Immature bald eagles show varying amounts of white; they can be mistaken for golden eagles.

Habitat

Habitat can be a clue to which eagle you are seeing:

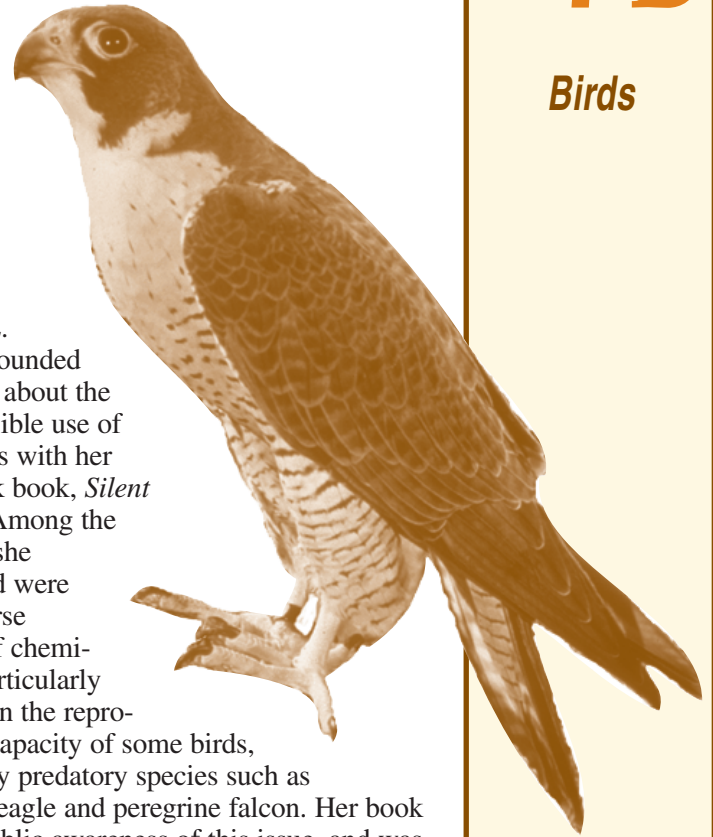
- Bald eagles are usually near water where they feed on fish and waterfowl.
- Golden eagles hunt in open country for rabbits and other small mammals.
- Exception: Both feed on carcasses in the winter, sometimes together.

Behavior

- Bald eagles nest in large trees close to water.
- In severe winters, eagles may move to lower elevations such as Paradise Valley, north of the park, where food is more available. On these wintering areas, resident eagles may be joined by migrant bald eagles and golden eagles.
- Feed primarily on fish, except in winter when fish stay deeper in water.
- In winter, they eat more waterfowl.
- Eat carrion in winter if it is readily available.
- Form long-term pair bonds.
- Some remain on their territories year-round, while others return to their nesting sites by late winter.
- Two to three eggs (usually two) laid from February to mid-April.
- Both adults incubate the eggs, which hatch in 34 to 36 days.
- At birth, eaglets are immobile, downy, have their eyes open, and are completely dependent upon their parents for food.
- When 10–14 weeks old, they can fly from the nest.
- Some young migrate in fall to western Oregon and Washington.
- Many adults stay in the park year-round.

Status

- Listed as threatened on the endangered species list, but recovery appears to be well underway.
- As of 1989, recovery objectives had been reached in the Greater Yellowstone Ecosystem.
- In 1995, the U.S. Fish and Wildlife Service downlisted the bald eagle from endangered to threatened in four of five regions, including the Pacific Northwest, which includes Yellowstone, due to the significant population gains made.
- Some eagle territories are experiencing nest instability due to large numbers of trees that are falling as a result of the 1988 fires.
- In the park, 34 eagle nests produced 26 eaglets in 2005.



Peregrine Falcon *Falco peregrinus*

Because of the peregrine's great speed and low population numbers, sightings in Yellowstone are uncommon.

Identification

- Slightly smaller than a crow.
- Black "helmet" and a black wedge below the eye.
- Uniformly gray under its wings. (The prairie falcon, which also summers in Yellowstone, has black "armpits.")
- Long tail, pointed wings.

Habitat

- Near water, meadows, cliffs.
- Nests on large cliffs overlooking rivers or valleys where prey is abundant.

Behavior

- Resident in the park March through October, when its prey—songbirds and waterfowl—are abundant in park.
- Lays 3–4 eggs in late April to mid-May.
- Young fledge in July or early August.
- Migrates as far south as Mexico.
- Dives at high speeds (can exceed 200 mph) and strikes prey in mid-air.

Status

- Yellowstone was a site for peregrine reintroductions in the 1980s.
- Reintroductions were discontinued after 1988 because the peregrine population was increasing on its own.
- The peregrine was removed from the federal endangered/threatened species list in 1999 because of its widespread recovery.
- In 2005, 30 nesting pairs fledged 44 young.

In 1962, Rachel L. Carson sounded an alarm about the irresponsible use of pesticides with her landmark book, *Silent Spring*. Among the dangers she described were the adverse effects of chemicals—particularly DDT—on the reproductive capacity of some birds, especially predatory species such as the bald eagle and peregrine falcon. Her book raised public awareness of this issue, and was one of the catalysts leading to the United States banning of the most damaging pesticides.

The peregrine falcon was among the birds most affected by the toxins. It was listed on the endangered species list and a reintroduction program was spearheaded by groups such as the non-profit Peregrine Fund of Boise, Idaho. Subsequently, the peregrine has made a comeback in much of its former range and was delisted in 1999.



Osprey *Pandion haliaeetus*

Identification

- Slightly smaller than bald eagle.
- Mostly white belly, white head with dark streak through eye.
- Narrow wings with dark patch at bend or “wrist.”

Habitat

- Usually near lakes (such as Yellowstone Lake), river valleys (such as Hayden and Lamar valleys), and in river canyons (such as the Gardner Canyon and the Grand Canyon of the Yellowstone River).

Behavior

- Generally returns to Yellowstone in April; departs for warmer climates by September.
- Builds nest of sticks in large trees or on pinnacles close to water.
- Lays 2–3 eggs in May to June.
- Eggs hatch in 4–5 weeks.
- Young can fly when 7–8 weeks old.
- Feed almost entirely on fish.
- Often hovers 30–100 feet above water before diving for a fish.
- In the air, arranges the fish with its head pointed forward to reduce its resistance to air.

Status

- Like many other birds of prey, osprey populations declined due to pesticides in the mid-20th century.
- Its populations rebounded during the latter part of the 20th century.
- In Yellowstone, the osprey population fluctuates, with 58 nests producing 17 young in 2005 and a high of 100 nests and 101 fledglings in 1994.
- Osprey in Yellowstone are being monitored, along with other fish-eating wildlife, to find out if populations of non-native lake trout will affect them (*see Chapter 9*).

Trumpeter Swan *Cygnus buccinator*

Identification

- Largest wild fowl in North America.
- White feathers, black bill with a pink streak at the base of the upper mandible.
- During migration, can be confused with the tundra swan, which is smaller, lacks the pink mandible stripe, sometimes has a yellow spot in front of eye, and a rounder head.

Habitat

- Slow moving rivers or quiet lakes.
- Nest is a large, floating mass of vegetation.

Behavior

- Feed on submerged vegetation and aquatic invertebrates.
- Low reproduction rates; in 2005, 1 cygnet fledged from one nest.
- Can fail to hatch eggs if disturbed by humans.
- Lay 4–6 eggs in June; cygnets fledge in late September or early October.
- Usually in pairs with cygnets in summer; larger groups in winter.

Status

- North American population recovering from decades of habitat destruction, hunting, and poaching.
- Declining in the Greater Yellowstone Ecosystem: 300–350 resident swans; as of autumn 2004, only 17 adult swans reside in Yellowstone National Park.
- Winter population in the region varies from 2,000–4,000; in the park, varies between less than one hundred to several hundred individual swans.
- Limiting factors in Yellowstone appear to be flooding of nests and predation by coyotes.
- The swan pair that used the floating nesting platform at Seven Mile Bridge on the Madison River lost the male to predation in 2001. In 2004, the female re-mated; but she and her mate were killed by predators.



Trumpeter swans in North America neared extirpation in the early 1900s due to human encroachment, habitat destruction, and the commercial swan-skin trade. Small populations survived in isolated areas such as Yellowstone. Red Rock Lakes National Wildlife Refuge, west of the park, was set aside in the 1930s specifically for the trumpeter swan. In the 1950s, a sizeable population of swans was discovered in Alaska. Today, more than 20,000 trumpeters exist in North America.

In Yellowstone, however, resident trumpeter swans have rarely numbered more than 20 individuals in recent years. Winter numbers vary from 60 to several hundred. Reproduction rates are low.

One threat was eliminated recently. Mute swans were introduced in the 1960s by landowners in Paradise Valley, north of the park. These non-native swans threatened to displace native trumpeter swans in the region. However, beginning in 1989, mute swans were replaced on private lands with captive-raised trumpeter swans.

Now 13 adult trumpeter swans reside in Paradise Valley, and three pairs successfully reared seven young in 2005. These swans have contributed to the park's population of trumpeter swans.

In fall and winter, look closely at a swan—it could be a trumpeter, which is native to the park, or a tundra, which is passing through. The swan above, which has a yellow spot near the eye, is a tundra swan. Trumpeter swans have a thin pink stripe at the base of their upper mandible.

7B

Birds



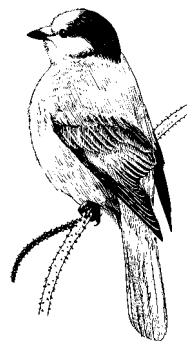
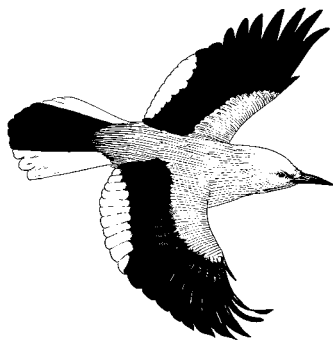
Sandhill cranes (left) nest in Yellowstone each summer. Their guttural calls announce their presence long before most people see them—their gray feathers blend in well with their grassland habitat. The all-white whooping crane, one of the world's most endangered birds, was the subject of recovery efforts in the Greater Yellowstone Ecosystem from 1975 until 2002. The last remaining whooping crane frequented the Centennial Valley of Montana (west of Yellowstone National Park). It was declared dead in the spring of 2002, marking the end of the experimental recovery efforts in Greater Yellowstone.

American white pelicans (right) spend the summer mainly on Yellowstone Lake and the Yellowstone River. These large white birds are often mistaken for trumpeter swans until their huge yellow beak and throat pouch are seen. Their black wing tips separate them from swans, which have pure white wings.



Ravens frequent parking lots, and have learned to unzip and unsnap packs. Do not allow them access to your food.

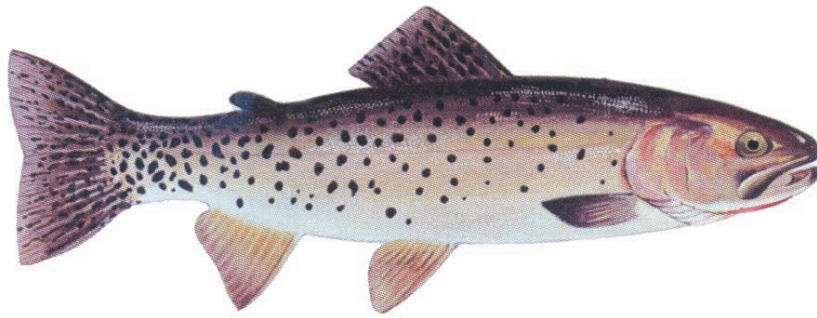
Some ravens have also learned to follow wolves during hunting forays. They wait in trees or on the ground, until wolves finish at a carcass. Other animals—such as coyotes, bald eagles, golden eagles, black-billed magpies, and red fox—also may be waiting nearby.



Several raven relatives live in Yellowstone, including the Clark's nutcracker (left) and gray jay (right). Like the raven, they often show up where people are eating. Do not feed them. They have plenty of natural food available in the forests where they live.



The dark gray American dipper (left) can be seen bobbing beside and diving into streams and rivers. The dipper, also called the water ouzel, dives into the water and swims in search of aquatic insects. Thick downy feathers and oil from a preening gland enable this bird to survive the cold waters of Yellowstone.



Yellowstone contains one of the most significant, near-pristine aquatic ecosystems found in the United States. More than 634 lakes and ponds comprise approximately 107,000 surface acres in Yellowstone—94 percent of which can be attributed to Yellowstone, Lewis, Shoshone, and Heart lakes. Some 1,000 rivers and streams make up approximately 2,463 miles of running water.

This may appear to be prime fish habitat, but waterfalls and other physical barriers prevent fish from colonizing the smaller headwater streams and isolated lakes. When Yellowstone became a national park, almost 40 percent of its waters were barren of fish—including Lewis Lake, Shoshone Lake, and the Firehole River above Firehole Falls. That soon changed.

Early park managers transplanted fish into new locations, produced more fish in hatcheries, and introduced non-native species. Today, about 40 lakes have fish; the others either were not planted or have reverted to their original fishless condition.

The ranges and densities of the park's native trout and grayling have been substantially altered during the past century due to exploitation and introduction of non-native species. Non-native species in the park include rainbow trout, brown trout, brook trout, lake trout, and lake chub.

Despite changes in species composition and distribution, large-scale habitat degradation has not occurred in the park. Water diversions, water pollution, and other such impacts on aquatic ecosystems have rarely occurred here. Consequently, fish and other aquatic inhabitants continue to provide important food for grizzly and black bears, bald eagles, river otters, mink, ospreys, pelicans, loons, grebes, mergansers, ducks, terns, gulls, kingfishers, and herons.

As of March 2006 . . .

Number in Yellowstone

- Native species: 11
 - 3 sport fish: cutthroat trout (3 sub-species), Arctic grayling, mountain whitefish
 - 8 non-game fish: 4 minnows: long-nose dace, speckled dace, redbelly shiner, Utah chub; 3 suckers: long-nose sucker, mountain sucker, Utah sucker; mottled sculpin
- Non-native: 5 species—brook trout, brown trout, lake trout, rainbow trout, lake chub

History

- When the park was established, many of its waters were fishless.
- Park waters were stocked with native and non-native fish until the mid-1950s.
- Stocking changed the ecology of many Yellowstone waters as non-native fish displaced or interbred with native species.

Status

- By the 1960s, Yellowstone's trout populations were in poor condition and the angling experience had declined, prompting a major change in fisheries management.
- By the late 1980s, native trout had recovered in some areas under restrictions that allow catching wild fish in a natural setting but prohibit killing native sport fish.
- In 2001, fishing regulations changed to require the release of all native sport fishes caught in park waters.
- Four native fish at risk: fluvial form of Arctic grayling, westslope cutthroat trout, Yellowstone cutthroat trout, Snake River cutthroat trout.
- Threats to the fisheries:
 - 1) Lake trout illegally introduced into Yellowstone Lake and its tributaries.
 - 2) Whirling disease now present in Yellowstone Lake, the Firehole River, and Pelican Creek.
 - 3) New Zealand mud snails.

See Chapter 9, "Aquatic Invaders."

For about 30 years until 1996, the U.S. Fish and Wildlife Service maintained an aquatic research and monitoring program in the park. Current National Park Service fisheries managers focus on the same objectives: to manage aquatic resources as an important part of the park ecosystem, preserve and restore native fishes and their habitats, and provide anglers with the opportunity to fish for wild fish in a natural setting.

The Volunteer Angler Report

Anglers contribute to the park's fisheries database by filling out the Volunteer Angler Report card, which is issued with each fishing license. For some park waters, these reports are the only data available. This information helps managers monitor the status of fisheries throughout the park.

Fishing in Yellowstone National Park

About 75,000 of the park's three million visitors fish each year. Angling is an anomaly in a park where the primary purpose is to preserve natural environments and native species in ways that maintain natural conditions. Yet fishing has been a major visitor activity here for more than 100 years. Fishing is a major industry in the Greater Yellowstone Ecosystem, and park anglers spend more than \$4 million annually on their sport. Angler groups have supported management actions, such as closing the Fishing Bridge to fishing in the early 1970s, and have helped fund research on aquatic systems.

Observing fish in their natural habitat is also a popular activity for visitors. Fisheries biologists monitored non-consumptive use of aquatic resources for about a decade (ending in 1992) at Fishing Bridge and LeHardys Rapids. The total number of visitors each year to LeHardys Rapids, where spawning cutthroat can be observed jumping the rapids, was about 134,000. Visitors at Fishing Bridge, where fish can be seen in the waters below the bridge, numbered nearly 290,000 in 1988.

Fishing Regulations

Strict regulations allow ecological processes to function with minimal interference from humans and preserve fish populations for the animals that depend on them. Complete regulations are at all ranger stations and visitor centers. In summary:

- Fishing is allowed only during certain seasons (usually late May through October).
- A permit is required (revenue stays in the park to support park programs).
- Terminal tackle must be lead-free (lead poisoning is a serious threat to waterfowl).
- Bait fishing is prohibited, except for children under 12 in a few areas (to prevent the introduction of non-native fish into park waters and because of an increased risk of death to fish caught with bait).
- All native sport fish—cutthroat trout, fluvial Arctic grayling, and mountain whitefish—must be released.
- Lake trout must be killed if caught in Yellowstone Lake and its tributaries.

- Certain waters may be closed to protect rare or endangered species, nesting birds, or to provide undisturbed vistas.

Changes in Yellowstone Waters

- Historically, only Yellowstone cutthroat trout and longnose dace populated Yellowstone Lake. Today, these two species are still present, but the longnose sucker, lake chub, redbreasted sunfish, and the lake trout have been introduced into the lake.
- Most of the Firehole River historically was fishless because Firehole Falls blocked fish from moving upstream. Today, anglers can fish for rainbow trout, brown trout, brook trout, and Yellowstone cutthroat trout in the thermally influenced stream.
- Historically, the Madison and Gibbon rivers (below Gibbon Falls) were inhabited by westslope cutthroat trout, Arctic grayling, mountain whitefish, mottled sculpin, mountain sucker, and longnose dace. Today, some of those species survive (some in extremely depleted numbers) and brown trout, rainbow trout, and brook trout have been added to the mix.
- When Heart Lake was first sampled for fish, Yellowstone cutthroat trout, mountain whitefish, speckled dace, redbreasted sunfish, Utah sucker, Utah chub, and the mottled sculpin were found.
- Lewis and Shoshone lakes were historically fishless because of waterfalls on the Lewis River. Today, the lakes support lake trout, brown trout, brook trout, Utah chub, and redbreasted sunfish.
- The lower Lamar River and Soda Butte Creek historically were home to Yellowstone cutthroat trout, longnose dace, longnose sucker, and mountain sucker. Today, those species survive, and rainbow trout was stocked in the drainage.

Cutthroat Trout

Oncorhynchus clarki

- Native to the Rocky Mountains.
- Three subspecies in Yellowstone: Yellowstone cutthroat, Snake River cutthroat, and the westslope cutthroat (described below).
- The Yellowstone cutthroat originally occurred in the Yellowstone River, its tributaries, and in the Falls River.
- The Snake River cutthroat is limited to the Snake River drainage.
- Require cold, clean water in streams or lakes.
- Deep waters—even small lakes—provide a winter refuge.
- Spawn in rivers or streams in early May through mid-July.
- Most important foods are aquatic insects — mayflies, stoneflies, caddisflies, etc.—plus terrestrial insects that fall into the water.
- Also eat smaller fish, fish eggs, small rodents, frogs, algae and other plants, and plankton.

While the Yellowstone cutthroat trout is essentially a Pacific drainage species, it has (naturally) traveled across the Continental Divide into the Atlantic drainage. One possible interconnection between the two oceans in the Yellowstone area is Two Ocean Pass, south of the park in the Teton Wilderness. Here, it's possible for a fish to swim across the Continental Divide at the headwaters of Pacific Creek and Atlantic Creek and, thus, swim from the Pacific to the Atlantic via the Snake and Yellowstone rivers.

Management

Yellowstone Lake and Yellowstone River together contain the largest population of native cutthroat trout in the world. For many years, the fish in Yellowstone Lake have been intensively monitored and studied. In the 1960s, fisheries managers determined that angler harvest was excessive and negatively impacting the fishery. Increasingly restrictive angling regulations were put into place. Cutthroat trout population numbers and the population age structure were restored. Whirling disease and illegally introduced lake trout in Yellowstone Lake now pose a significant threat to the cutthroat trout population. (See Chapter 9, "Aquatic Invaders.")

Westslope Cutthroat Trout

Oncorhynchus clarki lewisi

- Evolved independently of other cutthroat trout species, but share their food and habitat requirements (see above).
- Originally distributed throughout the Madison and Gallatin river drainages.
- Current distribution reduced to small headwater populations due to overfishing, competition, and interbreeding with non-native fish.
- Factors such as habitat loss and pollution appear negligible in the park.

Management

Park staff are searching for genetically pure populations of westslope cutthroat trout within the park. They conducted fish surveys in small headwater streams in the northwestern portion of the park, including Fan, Specimen, and Grayling creeks. DNA analysis identified one genetically pure population in North Fork Fan Creek, but that population is now hybridizing with rainbow trout. Information is being gathered to determine if this population is a viable source of fish for current and future restoration efforts within the park.

Cutthroat As Food

Cutthroat trout spawn in shallow water, where they become an important food resource for other Yellowstone wildlife, including the grizzly bear.

A Cutthroat Problem

Lake trout prey on native cutthroat trout. If left unchecked, they could easily decimate the cutthroat trout population in Yellowstone Lake, which would also impact predators that depend on cutthroat trout for food. See Chapter 9 for details.

Because the westslope cutthroat trout has interbred with rainbow trout and transplanted Yellowstone cutthroat trout, its genetics cannot be assumed pure, even in isolated populations.

The park's fishing regulations include illustrations of these fish and additional information about fishing in Yellowstone.

Whirling disease is a parasitic infection of fish caused by a microscopic protozoan that destroys the cartilage of juvenile trout. Seriously infected fish have a reduced ability to feed or escape from predators and mortality is high. See Chapter 9 for details.

Arctic Grayling *Thymallus arcticus*

- Used to share similar habitat with native cutthroat trout and whitefish (with which is is often confused).
- Displaced by non-native species.
- Now a rare and protected species in the park.
- Because of stocking in the 1920s, grayling live in some lakes within the park—particularly Grebe Lake.
- In these lakes, grayling spawn in June.

- Like trout, grayling eat insects and other fish.

Management

Current efforts on behalf of the grayling include sampling and tagging in Grebe and Wolf lakes and downstream in the Gibbon River. Park staff wants to determine if grayling captured in the Gibbon River are simply downstream migrants displaced from the lakes or a distinct subpopulation of the fluvial form. Genetic sampling of grayling handled during the Gibbon River surveys will also provide insight to this question.

Mountain Whitefish *Prosopium williamsoni*

- Slender silver fish, often confused with grayling.
- Lives in Yellowstone's rivers and streams.
- Requires deep pools, clear and clean water, and is very sensitive to pollution.
- Unlike other native fish, the whitefish

spawns in the fall.

- Generally feeds from the bottom, eating aquatic insect larvae.
- Does not seem to compete with trout for food.
- The whitefish has survived in its native waters for more than 100 years, unlike grayling.

NONGAME NATIVE FISH

Suckers: longnose, mountain, and Utah

- Bottom-dwelling fish that use ridges on their jaws to scrape aquatic flora and fauna from rocks.
- Eaten by birds, bears, otters, and brown trout.
- Habitat distinguishes species:

Mountain sucker *Castostomus platyrhynchus*: cold, fast, rocky streams and some lakes.

Longnose sucker *C. castostomusgriseus*: Yellowstone River drainage below the Grand Canyon; Yellowstone Lake and its surrounding waters (introduced). Equally at home in warm and cold waters, streams and lakes, clear and turbid waters.

Utah sucker *C. ardens*: Snake River drainage.

Mottled sculpin *Cottus bairdi*

- Resembles small catfish.
- Lives in shallow, cold water throughout Yellowstone.
- Eats small insects, some fish and plants.
- Eaten by trout.

Minnows

- Small fish living in a variety of habitats and eating a variety of foods.
- All four species eaten by trout.

Utah chub *Gila atraria*: Largest of the minnows (12 inches); native to Snake River drainage; seems to prefer slow, warm waters with abundant aquatic vegetation.

Longnose dace *Rhinichthys cataractae*: Most often found behind rocks and in eddies of cold, clear waters of the Yellowstone and Snake river drainages.

Redside shiner *Richardsonius balteatus hydrophlox*: Minnow of lakes; native to the Snake River drainage; has been introduced to Yellowstone Lake, where it might compete with native trout because its diet is similar to that of young trout. Large shiners will also eat young trout.

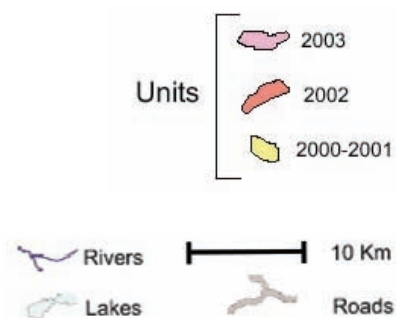
Speckled dace *Rhinichthys osculus*: Lives in the Snake River drainage.

Reptiles & Amphibians

Yellowstone is home for a small variety of reptiles and amphibians. Glacial activity and current cool and dry conditions are likely responsible for their relatively low species diversity. However, they can be abundant at breeding or wintering sites.

To inventory breeding populations of amphibians in the park, researchers randomly select watersheds to search (*see map below*). Many of these areas are remote from roads and have never been sampled for amphibians. Searches for reptiles concentrate in lower elevation and thermal areas where historical records or habitat suggest they are likely to be present. Baseline information from these inventories will be used to understand if amphibians and reptiles are declining and to test hypotheses about distribution and abundance.

Yellowstone provides a valuable study area; information about the status and trends of amphibians and reptiles here may shed light on declines documented in other high-elevation protected areas of the western U.S. Population declines may be caused by factors such as disease, drought, or climate change, chemical contamination, non-native species, and habitat loss and fragmentation. In addition, because many amphibians and reptiles congregate to breed or over winter, they can be adversely affected by disturbance or loss of key sites.



As of March 2006 . . .

Number in Yellowstone

- Reptiles—six species: prairie rattlesnake, bull snake, valley garter snake, wandering garter snake, rubber boa, sagebrush lizard.
- Amphibians—four species: boreal toad, chorus frog, spotted frog, tiger salamander.

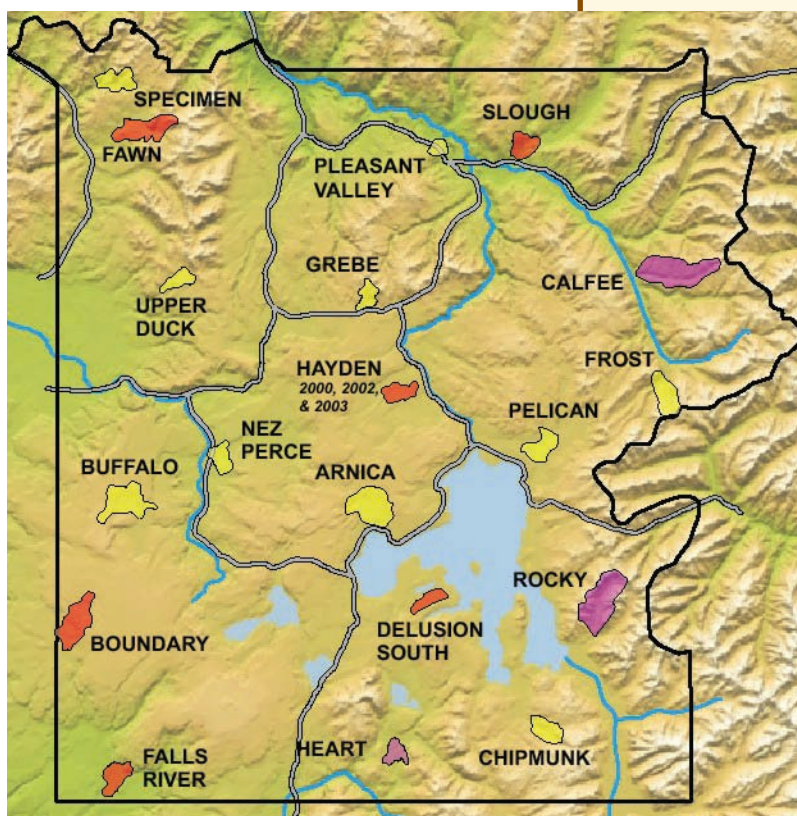
Current Research

1991: NPS staff and Idaho State University began sampling park habitats for reptiles and amphibians.
2000: Researchers began inventorying reptiles and amphibians.

Status

- Spotted and chorus frogs are widely distributed with many breeding sites in the park.
- A few species have been seen infrequently in the past and remain unconfirmed in Yellowstone.
- None of Yellowstone's reptile or amphibian species are listed as threatened or endangered.
- Scientists are concerned about the boreal toad, which has declined sharply in other parts of the West.

Inventory Sites



VALLEY GARTER SNAKE*Thamnophis sirtalis fitchi***Identification**

- Subspecies of the common garter snake.
- Medium sized snake up to 34 inches long.
- Nearly black background color with three bright longitudinal stripes running the length of the body, underside is pale yellow or bluish gray.
- Most distinguishing characteristics of this subspecies in our region are the irregular red spots along the sides.

Habitat

- Thought to be common in the past, now in decline for no apparent reason.
- Closely associated with permanent surface water.
- In Yellowstone observed only in the Falls River drainage in the Bechler region and three miles south of the south entrance along the Snake River.

Behavior

- Generally active during the day.
- In the Yellowstone area it eats mostly toads, chorus frogs, fish remains, and earthworms; can eat relatively poisonous species.
- Predators include fish, birds, and carnivorous mammals.

**WANDERING GARTER SNAKE***T. elegans vagrans***Identification**

- Most common reptile in the park.
- 6 to 30 inches long.
- Brown, brownish green, or gray with three light stripes—one running the length of the back and a stripe on each side.

Habitat

- Usually found near water in all areas of the park.
- Eats small rodents, fish, frogs, tadpoles, salamanders, earthworms, slugs, snails, and leeches.

Behavior

- May discharge musk from glands at the base of the tail when threatened.
- Gives birth to as many as 20 live young in late summer or fall.

BULLSNAKE *Pituophis catenifer sayi***Identification**

- A subspecies of the gopher snake, is Yellowstone's largest reptile, ranging from 50 to 72 inches long.
- Yellowish with a series of black, brown, or reddish-brown blotches down the back; the darkest, most contrasting colors are near the head and tail; blotches are shaped as rings around the tail.
- Head resembles a turtle's in shape, with a protruding scale at the tip of the snout and a dark band extending from the top of the head through the eye to the lower jaw.

Habitat

- In Yellowstone, found at lower elevations; drier, warmer climates; and open areas such as near Mammoth.

Behavior

- Lives in burrows and eats small rodents—behavior that gave the gopher snake its name.
- Often mistaken for a rattlesnake because of its appearance and its defensive behavior: when disturbed, it will coil up, hiss loudly, and vibrate its tail against the ground, producing a rattling sound.

Descriptive photos and illustrations exist in numerous books about these species; see "For More Information" on pages 130–132 for suggested titles.

RUBBER BOA *Charina bottae***Identification**

- Infrequently encountered in Yellowstone, perhaps due to its nocturnal and burrowing habits.
- One of two species of snakes in the United States related to tropical boa constrictors and pythons.
- Maximum length of 24 inches.
- Back is gray or greenish-brown, belly is lemon yellow; scales are small and smooth, making it almost velvety to the touch.

Habitat and Behavior

- Eats rodents.
- May spend great deal of time partially buried under leaves and soil, and in rodent burrows.
- Usually found in rocky areas near streams or rivers, with shrubs or trees nearby.
- Recent sightings have occurred in the Bechler region and Gibbon Meadows.

PRAIRIE RATTLESNAKE*Crotalis viridis viridis***Identification**

- More than 48 inches in length.
- Greenish gray to olive green, greenish brown, light brown, or yellowish with dark brown splotches down its back that are bordered in white.

Habitat

- Only dangerously venomous snake in the park.
- Lives in the lower Yellowstone River areas of the park, including Reese Creek, Stephens Creek, and Rattlesnake Butte, where the habitat is drier and warmer than elsewhere in the park.

Behavior

- Usually defensive rather than aggressive.
- Only two snake bites are known during the history of the park.

SAGEBRUSH LIZARD*Sceloporus graciosus graciosus***Identification**

- Only lizard in Yellowstone.
- Maximum size of five inches from snout to tip of the tail; males have longer tails and may grow slightly larger than females.
- Gray or light brown with darker brown stripes on the back set inside lighter stripes on the sides, running the length of the body; stripes not always prominent and may appear as a pattern of checks down the back; underside usually cream or white.
- Males have bright blue patches on the belly and on each side, with blue mottling on the throat.

Habitat

- Usually found below 6,000 feet but in Yellowstone lives up to 8,300 feet.
- Populations living in thermally influenced areas are possibly isolated from others.

- Most common along the lower portions of the Yellowstone River near Gardiner, Montana and upstream to the mouth of Bear Creek; also occurs in Norris Geyser Basin, Shoshone and Heart Lake geyser basins, and other hydrothermal areas.

Behavior

- Come out of hibernation about mid-May and active through mid-September.
- Diurnal, generally observed during warm, sunny weather in dry rocky habitats.
- During the breeding season males do push-ups on elevated perches to display their bright blue side patches to warn off other males.
- Feed on various insects and arthropods.
- Eaten by bull snakes, wandering garter snakes, rattlesnakes and some birds.
- May shed tail when threatened or grabbed.

Both reptiles and amphibians are ectothermic ("cold-blooded"), meaning they derive body heat from outside sources rather than generate it internally. Reptiles have scaly, dry skin. Some lay eggs; others bear live young. Amphibians have thin, moist glandular skin permeable to water and gases. The young must pass through a larval stage before changing into adults. Amphibious means "double life" and reflects the fact that salamanders, toads, and frogs live in water as larvae and on land for much of the rest of their lives.

7D

Reptiles & Amphibians

In the winter in Yellowstone, some amphibians go into water that does not freeze (spotted frogs), others enter underground burrows (salamanders and toads), and others (boreal chorus frog) actually tolerate freezing and go into a heart-stopped dormancy for the winter in leaf litter or under woody debris.

Toad or Frog?

Toads can easily be distinguished from frogs by their warty bodies, thick waists, and prominent glands behind their eyes.

BLOTCHED TIGER SALAMANDER

Ambystoma tigrinum melanostictum

Identification

- The only salamander in Yellowstone.
- Adults range up to about 9 inches, including the tail.
- Head is broad, with a wide mouth.
- Color ranges from light olive or brown to nearly black, often with yellow blotches or streaks on back and sides; belly is dull lemon yellow with irregular black spots.
- Larvae, which are aquatic, have a uniform color and large feathery gills behind the head; they can reach sizes comparable to adults but are considerably heavier.

Habitat

- Breeds in ponds and fishless lakes.
- Widespread in Yellowstone in a great variety of habitats, with sizable populations in the Lamar Valley.

Behavior

- Adult salamanders come out from hibernation in late April to June, depending on elevation, and migrate to breeding ponds where they lay their eggs.
- Mass migrations of salamanders crossing roads are sometimes encountered, particularly during or after rain.
- After migration, return to their moist homes under rocks and logs and in burrows.
- Feed on adult insects, insect nymphs and larvae, small aquatic invertebrates, frogs, tadpoles, and even small vertebrates.
- Preyed upon by a wide variety of animals, including mammals, fish, snakes, and birds such as sandhill cranes and great blue herons.

BOREAL TOAD *Bufo boreas boreas*

Identification

- Yellowstone's only toad.
- Adults range up to about 4 inches, juveniles just metamorphosed from tadpoles are only one inch long.
- Stocky body and blunt nose.
- Brown, gray, or olive green with irregular black spots, lots of "warts," and usually a white or cream colored stripe down the back.
- Tadpoles are usually black and often congregate in large groups.

Habitat

- Once common throughout the park, now appears to be much rarer than spotted frogs and chorus frogs; scientists fear this species has experienced a decline in the Greater Yellowstone Ecosystem.
- Adults can range far from wetlands because of their ability to soak up water from tiny puddles or moist areas.
- Lay eggs in shallow, sun-warmed water, such as ponds, lake edges, slow streams, and river backwaters.

Behavior

- Tadpoles eat aquatic plants; adults eat insects, especially ants and beetles, worms and other small invertebrates.
- Sometimes active at night.
- Defends itself against predators by secreting an irritating fluid from numerous glands on its back and behind the eyes.
- Eaten by snakes, mammals, ravens, and large wading birds.



COLUMBIA SPOTTED FROG*Rana luteiventris***Identification**

- Abundant and best known amphibian in Yellowstone.
- Maximum length is 3.2 inches, newly metamorphosed juveniles less than one inch long.
- Upper surface of the adult is gray-brown to dark olive or even green, with irregular black spots; skin is bumpy; underside is white splashed with brilliant orange on the thighs and arms on many but not all individuals.
- Tadpoles have long tails and may grow to 3 inches long.

Habitat

- Found all summer along or in rivers, streams, smaller lakes, marshes, ponds, and rain pools.
- Lay eggs in stagnant or quiet water, in globular masses surrounded by jelly.

Behavior

- Breeds in May or early June, depending on temperatures.
- Tadpoles mature and change into adults between July and September.
- Tadpoles eat aquatic plants, adults mostly eat insects but are highly opportunistic in their food habits (like many other adult amphibians).

BOREAL CHORUS FROG*Pseudacris maculata***Identification**

- Adults reach 1 to 1.5 inches in length, and females are usually larger than males; newly metamorphosed froglets are less than one inch long.
- Brown, olive, tan, or green (sometimes bi-colored) with a prominent black stripe on each side from the nostril through the eye and down the sides to the groin; three dark stripes down the back, often incomplete or broken into blotches.

Habitat

- Common, but seldom seen due to its small size and secretive habits.
- Live in moist meadows and forests near wetlands.
- Lays eggs in loose irregular clusters attached to submerged vegetation in quiet water.

Behavior

- Breeds in shallow temporary pools or ponds during the late spring.
- Calls are very conspicuous, resembles the sound of a thumb running along the teeth of a comb.
- Males call and respond, producing a loud and continuous chorus at good breeding sites, from April to early July, depending on elevation and weather.
- Usually call in late afternoon and evening.
- Tadpoles eat aquatic plants; adults mostly eat insects.
- Eaten by fish, predacious aquatic insect larvae, other amphibians, garter snakes, mammals, and birds.

MAMMALS

General

- Burt, W.H. 1964. *A Field Guide to the Mammals*. Boston: Houghton Mifflin.
- Clark, T.W. et al, editors. 1999. *Carnivores in Ecosystems*. New Haven: Yale University Press.
- Clark, T.W. and M.R. Stromberg. 1987. *Mammals in Wyoming*. Lawrence: University Press of Kansas.
- Consolo-Murphy, Sue and Kerry Murphy. 1999. *Wildlife @ Yellowstone*. Las Vegas: KC Publications.
- Curlee, A. P. et al, eds. 2000. *Greater Yellowstone Predators: Ecology and Conservation in a Changing Landscape. Proc., Third Biennial Conference on the Greater Yellowstone Ecosystem*. Jackson, WY: Northern Rockies Conservation Coop.
- Houston, D.B. 1982. *The Northern Yellowstone Elk: Ecology and Management*. New York: Macmillan Publishing Co.
- Reading, Richard and Brian Miller, eds. 2000. *Endangered Animals: A Reference Guide to Conflicting Issues*. Westport, CT: Greenwood Press.
- Ruth, Toni et al. 2003. Large carnivore response to recreational big-game hunting along the YNP and Absaroka-Beartooth Wilderness boundary. *Wildlife Society Bulletin*. 31(4):1–12.
- Schullery, Paul and Lee Whittlesey. 2001. Mountain goats in the Greater Yellowstone Ecosystem: a prehistoric and historical context. *Great Basin Naturalist*.
- Schullery, Paul and Lee Whittlesey. 1999. Early wildlife history of the GYE. Report, available in YNP Research Library.
- Schullery, Paul and Lee Whittlesey. 1995. Summary of the documentary record of wolves and other wildlife species in YNP prior to 1882. In *Ecology and Conservation of Wolves in a Changing World*. Canadian Circumpolar Institute, Occasional Publication 35.
- Streubel, Don. 1989. *Small Mammals of the Yellowstone Ecosystem*. Boulder: Roberts Rinehart.
- Yellowstone National Park. 1997. *Yellowstone's Northern Range: Complexity and Change in a Wildland Ecosystem*. Yellowstone National Park.

Bears

Staff reviewer: Kerry Gunther, Bear Management Biologist

- Blanchard, B.M. and R.R. Knight. 1991. Movements of Yellowstone grizzly bears, 1975–87. *Biol. Conserv.* 58:41–67.
- Craighead, John C., Jay S. Sumner, and John A. Mitchell. 1995. *The Grizzly Bears of Yellowstone, Their Ecology in the Yellowstone Ecosystem 1959–1992*. Washington: Island Press.
- French, S. P., M. G. French, and R. R. Knight. 1994. Grizzly bear use of army cutworm moths in the Yellowstone ecosystem. *Intl. Conf. Bear Res. and Manage.* 9: 389–399.
- Gunther, Kerry. Grizzly bears and cutthroat trout: Potential impact of the introduction of non-native trout to Yellowstone Lake. Bear Management Office Information Paper # BMO-9.
- Gunther, Kerry and Roy Renkin. 1990. Grizzly bear predation on elk calves and other fauna of Yellowstone National Park. *Intl. Conf. Bear Res. and Manage.* 8:329–334.
- Gunther, K.A. and D. W. Smith. 2004. Interactions between wolves and female grizzly bears with cubs in Yellowstone National Park. *Ursus* 15(2): 232–238.
- Gunther, K.A. et al. 2002. Probably grizzly bear predation on an American black bear in Yellowstone National Park. *Ursus* 12: 372–374.

- Haroldson, M.A. et al. 2002. Grizzly bear denning chronology and movements in the Greater Yellowstone Ecosystem. *Ursus* 13: 29–37.
- Mattson, D. J., and D. P. Reinhart. 1997. Excavation of red squirrel middens by Yellowstone grizzly bears in the whitebark pine zone. *J. Applied Ecol.* 34: 926–940.
- Peacock, Doug. 1990. *Grizzly Years*. New York: Holt.
- Schullery, Paul. 1992. *The Bears of Yellowstone*. Worland: High Plains Publishing Co.
- Schullery, Paul. 1991. *Yellowstone Bear Tales*. Boulder: Roberts Rinehart.
- Schullery, Paul. 1989. Yellowstone grizzlies: The new breed. *National Parks*. November/December.
- Schwartz, C.C. et al. 2003. Grizzly bear in *Wild Mammals of North America: Biology, Management, and Conservation*. 2nd edition. Baltimore: Johns Hopkins University Press.
- Varley, N. and K.A. Gunther. 2002. Grizzly bear predation on a bison calf in Yellowstone National Park. *Ursus* 13: 377–381.
- Wyman, T. 2002. Grizzly bear predation on a bull bison in Yellowstone National Park. 13: 375–377.

Beaver

Staff reviewer: Douglas W. Smith, Wolf Project Leader

- Murphy, S.L. Consolo and D.D. Hanson. 1991. Current distribution of beaver in Yellowstone National Park. *Wolves for Yellowstone. A Report to the United States Congress*. Washington: National Park Service.
- Murphy, S.L. Consolo and Robb B. Tatum. 1994. Distribution of beaver in Yellowstone National Park.
- Rue, Leonard Lee. 1964. *The World of the Beaver*. New York: Lippincott.
- Smith, D.W. 2001. Beaver Survey in Yellowstone National Park. Yellowstone Center for Resources.
- Smith, D.W. 1997. Beaver survey in Yellowstone National Park 1998. Mammoth, WY. YCR-NR-93-3.
- Smith, D.W. et al. 1997. Beaver survey in Yellowstone National Park 1996. Mammoth, WY. YCR-NR-97-1.

Bighorn Sheep

Staff reviewer: P.J. White, Wildlife Biologist

- Ostovar, K. 1998. Impacts of human activity on bighorn sheep in Yellowstone National Park. Master's thesis, Montana State Univ., Bozeman.

Bison

Staff reviewer: Rick Wallen, Bison Ecology & Management

- Dary, David. 1974. *The Buffalo Book: The Full Saga of an American Animal*. Chicago: Sage Books.
- Dawes, S. R. and L. R. Irby. 2000. Bison forage utilization in the upper Madison drainage, Yellowstone National Park. *Intermountain Journal of Science* 6(1):18–32.
- Franke, Mary Ann. 2005. *To Save the Wild Bison*. [need publisher]
- Geist, Valerius. 1996. *Buffalo Nation: History and Legend of the North American Bison*. Voyageur Press.
- Irby, L. and J. Knight, eds. 1998. *International Symposium on Bison Ecology and Management in North America*. Bozeman: Montana State Univ.
- Meagher, Mary. 1973. The bison of Yellowstone National Park. National Park Service, Scientific Monograph Series No. 1.
- Price, David and Paul Schullery. 1993. The bison of Yellowstone and the challenge of conservation. *Bison World*, November/December.

Rudner, Ruth. 2000. *A Chorus of Buffalo*. Burford Books.

Cougar

Staff reviewer: Kerry Murphy, Wildlife Biologist

Hansen, K. 1992. *Cougar: The American Lion*. Flagstaff: Northland Publishing Co.

Murphy, Kerry. 1998. The ecology of the cougar (Puma concolor) in the northern Yellowstone ecosystem: interactions with prey, bears, and humans. Ph.D. dissertation. Univ. of Idaho, Moscow.

Murphy, Kerry et al. 1998. Encounter competition between bears and cougars: some ecological implications. *Ursus* 10:55–60.

Ruth, Toni. 2004. Ghost of the Rockies. *Yellowstone Science* 12:1, Winter: 13–27.

Ruth, T.K. et al. 2003. Large carnivore response to recreational big game hunting along the Yellowstone National Park and Absaroka–Beartooth Wilderness boundary. *Wildlife Society Bulletin* 31(4):1150–1161.

Ruth, T. K. et al. 1999. Cougar–wolf interactions in Yellowstone National Park: competition, demographics, and spatial relationships. Annual technical report, Hornocker Wildlife Institute, Yellowstone cougars, Phase II.

Coyote

Staff reviewer: Douglas W. Smith, Wolf Project Leader

Gese, E. M. 1999. Threat of predation: do ungulates behave aggressively towards different members of a coyote pack? *Can. J. Zool.* 77:499–503.

Gese, E. M. 1998. Response of neighboring coyotes to social disruption in an adjacent pack. *Can. J. Zool.* 76:1960–1963.

Gese, E. M., and S. Grothe. 1995. Analysis of coyote predation on deer and elk during winter in Yellowstone National Park, Wyoming. *Am. Midl. Nat.* 133: 36–43.

Gese, E. M. and R. L. Ruff. 1998. Howling by coyotes: variation among social classes, seasons, and pack sizes. *Can. J. Zool.* 76: 1037–1043.

Gese, E. M. and R. L. Ruff. 1997. Scent-marking by coyotes: the influence of social and ecological factors. *Anim. Behav.* 54:1155–1166.

Gese, E. M. et al. 1996. Foraging ecology of coyotes: the influence of extrinsic factors and a dominance hierarchy. *Can. J. Zool.* 74:769–783.

Gese, E. M. et al. 1996. Intrinsic and extrinsic factors influencing coyote predation of small mammals in Yellowstone National Park. *Can. J. Zool.* 74:784–797.

Gese, E. M. et al. 1996. Social and nutritional factors influencing the dispersal of resident coyotes. *Anim. Behav.* 52:1025–1043.

Gese, E. M. et al. 1996. Interactions between coyotes and red foxes in Yellowstone National Park. Wyoming. *J. of Mamm.* 77(2):377–382.

Elk

Staff reviewer: P.J. White, Wildlife Biologist

Barmore, W.J. Jr. 2003. *Ecology of ungulates and their winter range in Northern Yellowstone National Park, Research and Synthesis 1962–1970*. Yellowstone Center for Resources.

Coughenour, M.B. and F. J. Singer. 1996. Elk population processes in YNP under the policy of natural regulation. *Ecological Applications*. 6: 573–593.

Evanoff, R. and F.J. Singer, eds. 1996. Effects of grazing by wild ungulates in Yellowstone National Park. Denver: National Park Service, Natural Resource Program Center.

Garrott, R.A. et al. 2003. Climate-induced variation in vital rates

of an unharvested large herbivore population. *Can. J. Zool.* 81:33–45.

Garrott, R.A. et al. 2002. A geochemical trophic cascade in Yellowstone's geothermal environments. *Ecosystems*. 5: 659–666.

Houston, D.B. 1982. *The Northern Yellowstone Elk: Ecology and Management*. New York: Macmillan Publishing Co.

Mao, J. 2003. Habitat selection by elk before and after wolf reintroduction in YNP. Unpublished M.S. thesis. University of Alberta, Edmonton, Alberta.

Murie, Olaus J. 1957. *The Elk of North America*. Harrisburg, PA: Stackpole Co.

Singer, F.J. et al. 1997. Density dependence, compensation, and environmental effects on elk calf mortality in YNP. *J Wildlife Management*. 61: 12–25.

Taper, M.L. and P.J.P. Gogan. 2002. The northern Yellowstone elk: density dependence and climatic conditions. *J Wildlife Management*. 66: 106–122.

Thomas, Jack Ward, and Dale E. Toweill, eds. 1982. *Elk of North America*. Harrisburg, PA: Stackpole Co.

White, P.J. et al. 2003. Evaluating the consequences of wolf recovery on northern Yellowstone elk. Yellowstone Center for Resources.

Moose

Staff reviewer: P.J. White, Wildlife Biologist

Houston, Douglas B. Aspects of the social organizations of moose. National Park Service Paper No. 37.

Houston, Douglas B. 1968. The Shiras moose in Jackson Hole, Wyoming. Technical Bulletin No. 1. Moose, WY: Grand Teton Natural History Association.

Tyers, Dan. 2003. Winter ecology of moose on the Northern Yellowstone Winter Range. Doctoral dissertation. Montana State University.

Pronghorn

Staff reviewer: P.J. White, Wildlife Biologist

Boccardi, S.J. 2002. Effects of winter range on a pronghorn population in YNP. MS thesis. Montana State University, Bozeman.

Byers, J.A. 2002. Fecundity and fawn mortality of northern Yellowstone pronghorn. Yellowstone Center for Resources.

Caslick, J., and E. Caslick. 1999. Pronghorn distribution in winter 1998–1999. Mammoth, WY: National Park Service. YCR–NR–99-2.

Goodman, D. 1996. Viability analysis of the antelope population wintering near Gardiner, Mont. Final report to the National Park Service.

Houston, D.B. 1973. Letter to Superintendent regarding status of pronghorn in YNP. January 24. Park archives box 119, Yellowstone National Park, WY.

Keating, K. 2002. History of pronghorn population monitoring, research, and management in Yellowstone National Park. Report to the NPS by USGS Northern Rocky Mountain Science Center, Bozeman, MT.

Wolf

Staff reviewer: Douglas W. Smith, Wolf Project Leader

Ferguson, Gary. 1996. *The Yellowstone Wolves: The First Year*. Helena, MT: Falcon Press.

Fischer, Hank. 1995. *Wolf Wars*. Helena, MT: Falcon Press.

Halfpenny, James C. 2003. *Yellowstone Wolves: In the Wild*. Helena, MT: Riverbend Press.

Lopez, Barry. 1978. *Of Wolves and Men*. New York: Scribners.

McIntyre, Rick, ed. 1995. *War against the Wolf: America's*

Campaign to Exterminate the Wolf. Stillwater, MN: Voyageur Press.

McIntyre, Rick. 1993. *A Society of Wolves: National Parks and the Battle over the Wolf*. Stillwater, MN: Voyageur Press.

McNamee, Thomas. 1997. *The Return of the Wolf to Yellowstone*. New York: Henry Holt.

Mech, L. David. 1981. *The Wolf: The Ecology and Behavior of an Endangered Species*. Minneapolis: U. of Minnesota Press.

Mech, L. David and L. Boitani. 1981. *Wolves: Behavior, Ecology, & Conservation*. [need publisher]

Peterson, Rolf et al. 2002. Leadership behavior in relation to dominance and reproductive status in gray wolves. *Can. J. Zool.* 80: 1405–1412.

Phillips, Michael K. and Douglas W. Smith. 1996. *The Wolves of Yellowstone*. Stillwater, MN: Voyageur Press.

Schullery, Paul, ed. 1996. *The Yellowstone Wolf: A Guide and Sourcebook*. Worland: High Plains Publishing Co.

Smith, D.W. 2005. Ten years of Yellowstone Wolves. *Yellowstone Science*, 13(1):7–33.

Smith, D.W. and Gary Ferguson. 2005. *Decade of the Wolf: Returning the Wild to Yellowstone*. Guilford, CT: Lyons

Smith, Douglas et al. 2000. Wolf–bison interactions in Yellowstone National Park. *J Mammalogy*, 81(4):1128–1135.

Stahler, D. R. 2000. Interspecific interactions between the common raven and the gray wolf in Yellowstone National Park, Wyoming: investigations of a predator and scavenger relationship. Master's thesis. Univ. of Vermont.

BIRDS

Staff reviewer: Terry McEneaney, Ornithologist

Follett, Dick. 1986. *Birds of Yellowstone and Grand Teton National Parks*. Boulder: Roberts Rinehart.

Hansen, Skylar. 1984. *The Trumpeter Swan—A White Perfection*. Flagstaff: Northland Press.

Harmata, Al. 1994. Yellowstone's bald eagles. *Yellowstone Science*. 2(3)

McEneaney, Terry et al. 1998. Greater Yellowstone peregrine falcons: their trials, tribulations, and triumphs. *Yellowstone Science*. 6(2)

McEneaney, Terry. *Yellowstone Bird Report*. Yellowstone National Park. Annual.

McEneaney, Terry. 1988. *Birds of Yellowstone: A Practical Habitat Guide to the Birds of Yellowstone National Park, and Where to Find Them*. Boulder: Roberts Rinehart Publishers.

McEneaney, Terry. 1997. Harlequin ducks: noble ducks of turbulent waters. *Yellowstone Science* 5(2): 2–7.

McEneaney, Terry. 2000. The common raven: Field notes on an important Yellowstone predator in Greater Yellowstone Predators: Ecology and Conservation in a Changing Landscape. Proc., third biennial conference on the Greater Yellowstone Ecosystem. Jackson, WY: Northern Rockies Conservation Cooperative.

Peterson, Roger Tory. 1990. *A Field Guide to Western Birds*. Boston: Houghton Mifflin.

Sibley, David. 2000. *The Sibley Guide to Birds*. New York: Alfred A. Knopf.

Skinner, M.P. 1925. *The Birds of Yellowstone National Park*. Roosevelt Wildlife Bulletin. 3(1).

FISH

Staff reviewer: Todd M. Koel, Supervisory Fisheries Biologist

Koel, Todd et al. Annual. *Yellowstone Fisheries and Aquatic Sciences Report*. National Park Service: Yellowstone.

Lilly, Bud and Paul Schullery. 2000. *Bud Lilly's Guide to Fly Fishing the New West*. Portland, OR: Frank Amato Publications.

Mathews, Craig and Clayton Molinero. 1970. *The Yellowstone Fly Fishing Guide*. New York: Lyons.

Parks, Richard. 1998. *Fishing Yellowstone National Park*. Helena, MT: Falcon.

Varley, John and Paul Schullery. 1998. *Yellowstone Fishes*. Harrisburg, PA: Stackpole.

Yellowstone National Park. *Fishing Regulations*. Annual.

REPTILES AND AMPHIBIANS

Koch, Edward D. and Charles R. Peterson. 1995. *Amphibians and Reptiles of Yellowstone and Grand Teton National Parks*. Salt Lake City: U. of Utah Press.

Patla, D.A. 2000. Amphibians in native fish restoration areas, Yellowstone National Park. Part II, Greater Yellowstone Amphibian Monitoring and Survey Project. Mammoth Hot Springs, WY. Herpetology Laboratory, Dept. of Biological Sciences, Idaho State Univ., Pocatello.

Patla, D. A. 1997. Changes in a population of spotted frogs in Yellowstone National Park between 1935 and 1995: the effects of habitat modification. Master's thesis. Idaho State Univ., Pocatello.

Patla, D.A. and Charles R. Peterson. 2004. Amphibian and reptile inventorying and monitoring: Grand Teton and Yellowstone National Parks 2000–2003. Report.

Additional Information from Yellowstone National Park

Yellowstone National Park website, www.nps.gov/yell, includes an array of park information about resources, science, recreation, and issues.

Yellowstone Science, published quarterly, reports on research and includes articles on natural and cultural resources. Free; available from the Yellowstone Center for Resources, in the Yellowstone Research Library, or online at www.nps.gov/yell.

Yellowstone Today, published seasonally and distributed at entrance gates and visitor centers, includes features on park resources such as hydrothermal features.

Area trail guides detail geology of major areas of the park.

Available for a modest donation at Canyon, Fountain Paint Pot, Mammoth, Norris, Old Faithful, and West Thumb areas.

Site Bulletins, published as needed, provide more detailed information on park topics such as bison management, lake trout, grizzly bears, and wolves. Free; available upon request from visitor centers.

Cultural resources are material evidence of past human activities. In the National Park Service, specialists in this field:

- Identify, evaluate, document, establish basic information about, and in some cases register, cultural resources
- Identify people associated with a park for two or more generations whose interests in the park's resources began prior to the park's establishment
- Plan to ensure that management decisions and priorities integrate cultural resources needs and provide for consultation and collaboration with outside entities
- Preserve and protect cultural resources, and make those resources available for public understanding and enjoyment.

The types of cultural resources are related to disciplines such as archeology, curation, ethnography, history, and historical architecture. Although each type is closely associated with a particular discipline, an interdisciplinary approach is often used to document and evaluate cultural resources.

Archeology: Resources in the Ground

From the discarded points of 10,000 years ago to the trash heaps of hotels, humans leave behind evidence of their presence. These pieces of evidence and the sites where they are found comprise the archeological resources of Yellowstone.

Archeologists have identified more than 1,100 prehistoric sites in Yellowstone—many more may exist. About two percent of the park has been surveyed for archeological sites, mostly along road corridors prior to construction or along the shores of Yellowstone Lake where erosion is uncovering and destroying sites.

The oldest known site is a shoreline site at risk from erosion. Rather than stopping that natural process, archeologists excavated the site in 2000 and 2002. They found evidence

YELLOWSTONE'S CULTURAL RESOURCES

- More than 230 ethnographic resources (animals, plants, sites); many provided by the more than two dozen associated tribes
- Approximately 1,100 prehistoric and historic Native American archeological sites and historic European American archeological sites
- 6 National Historic Landmarks
- 1 National Historic Landmark District
- 5 National Historic Districts and 5 listed sites
- Museum collection of more than 379,000 cultural objects and natural science specimens available to researchers
- Archives containing thousands of irreplaceable historic documents
- Thousands of books and periodicals available to the public; plus manuscripts and rare books available to historians and other researchers
- 90,000 historic photographs for use by staff, scholars, authors, and filmmakers



of early North American people considered typical of lower, more open lands. They probably used this Yellowstone site in the summer while hunting bear, deer, bighorn, and rabbits, and perhaps making tools and clothes. Archeologists speculate these people may have also made rafts to visit islands in Yellowstone Lake.

Also in summer 2000, archeologists excavated an old trash pit at the Lake Hotel. They found a large variety of materials from the early 20th century, including a key chain, old bricks, a jar of petroleum jelly with a top made after 1908, and many beverage bottles. No one story reveals itself in these artifacts; instead, a more general picture emerges of life at that time.

This photo, from 1933, conveys a wealth of historic information. It shows Max Big Man and his daughter, Myrtle, of the Crow Tribe. Max made presentations about how the Crow lived at the time of fur trappers. The tribe ceded part of its territory to the park in 1868. The photo also shows how interpretive signs once looked, and provides a visual record of Giant Geyser's appearance at the time.

Cultural Resources

Cultural Landscapes

A cultural landscape is a geographic area associated with a historic event, activity, or person or it exhibits other cultural or esthetic values. It is defined both by physical materials, such as roads, buildings, walls, and vegetation, and by use reflecting cultural values and traditions.

Yellowstone National Park contains landscapes reflecting the park's history, development patterns, and the relationship between people and the park. They include areas significant to European American culture, such as Fort Yellowstone, which are described on pages 136–139. They also include areas significant to Native American cultures, such as sacred sites that are considered ethnographic landscapes (see next section).

Yellowstone's cultural landscape program is building a baseline inventory of properties, beginning with Old Faithful Historic District, Artist Point Overlook, some backcountry cabin sites, the historic game ranch at Stephens Creek, and developed areas at Canyon, West Entrance, and South Entrance. These inventories inform on-going projects of ways in which new undertakings can be made compatible with the cultural landscape, and

identify landscapes eligible for the National Register.

Ethnography: Resources of the People

Ethnographic resources are natural and cultural features of a park significant to people traditionally associated with the park. These places are closely linked with the development and maintenance of their identity as a community. For example, tribal oral history may identify a site where the tribe began. Ethnographic resources may also be sites for ceremonial activities, hunting, or gathering, or are associated with migration routes and histories. Preservation of these resources is mandated by laws and executive orders, some of which are described on page 139.

Associated Tribes

In Yellowstone, more than two dozen Native American tribes are traditionally associated with the park (*see below*). Their ancestral presence is shown through archeological documentation, ethnohistoric documentation, interviews with tribal elders, and ongoing consultations (*see Chapter 1*). Some tribes lived here through a few seasons at least, if not year-round. Others came for ceremonial



Note: Map shows each tribe's reservation; it does not show their historic territory.

reasons, and almost all have hunted and gathered, traded and raided here. Certain places and resources remain important to these tribes' sense of themselves and in maintaining their traditional practices.

Yellowstone National Park has more than 230 ethnographic resources identified by tribal peoples. These include animals such as bison, plants, hydrothermal areas, mineral paints from hydrothermal areas, Yellowstone Lake, vision questing sites, obsidian, rendezvous sites, and hunting sites.

Tribes and Yellowstone National Park have a mutual interest in cultural preservation. Tribes want traditions to survive and the National Park Service wants to assist such preservation as part of its commitment to protecting cultural resources. In addition, tribes are sovereign nations whose leaders have a legal relationship with the federal government that is not shared by the general public. Consequently, representatives of Yellowstone's associated tribes participate in periodic consultation meetings with park managers. They bring tribal perspectives to current issues such as bison management. (Bison in Yellowstone are a precious resource to all associated tribes.) Tribes also comment on park projects that could affect their ethnographic resources.

By Word of Mouth

Oral histories provide information to help with resource management, interpretation, and documentation. They also can provide evidence of human use where scant archeological evidence and little or no written information exists.

Native American tribes relate their histories through the oral tradition, and in recent years some of Yellowstone's associated tribes have been willing to be interviewed about their history. For example:

- The Kiowa of Oklahoma spoke of their presence in Yellowstone from the 1400s to the 1700s. They also told the heroic story of their creator giving Yellowstone to the Kiowa as their homeland. The site where this is said to have occurred is Dragon's Mouth in the Mud Volcano area.
- Elders of the Nez Perce have also visited sites in Yellowstone associated with their people's flight through the park in 1877 (see page 26). They spoke emotionally about this trek, adding a different and

valuable dimension to our understanding of this historic event.

Together with archeology and history, oral tradition enriches our understanding about Yellowstone's complex history. This knowledge also assists with the management of Yellowstone's heritage resources in ways that strengthen the ability of indigenous peoples to perpetuate their culture and to enrich parks with a deeper sense of place.

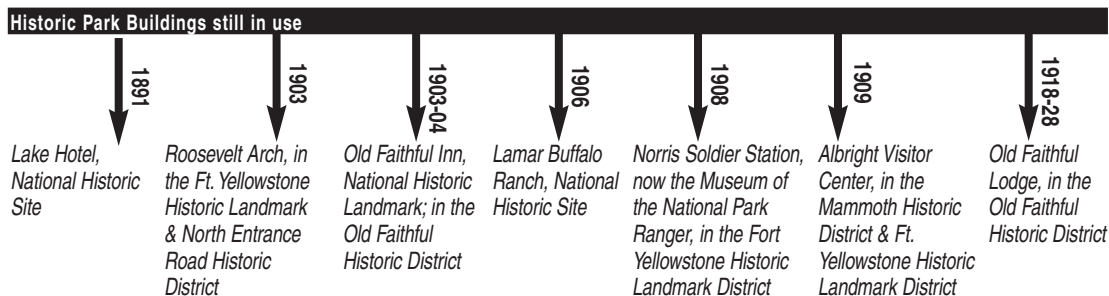


Above: Nez Perce tribal representatives sit at Nez Perce Ford and relate the story of their people's flight through Yellowstone (see page 26).

Right: The late historian Aubrey Haines documented Yellowstone history through careful research and conversations with "old timers."

The history of park management is documented through oral histories of former and current employees. For example, dozens of former employees were interviewed about elk management in the 1950s and 60s. They contributed stories of what it was like to round up elk, how they felt about participating in this operation, and how the public reacted. Other projects include an oral history of the Civilian Conservation Corps, in which surviving workers have been interviewed, and an on-going oral history of scientists and rangers involved in bear management over the years.

These interviews now reside on CDs, in written transcripts, and—in some cases—as videos in the park's archives.



Historic Structures & Districts

Historic buildings are preserved because of their role in the Yellowstone's history and/or as examples of architectural styles. At some sites, visitors can learn about the park's history through exhibits, publications, and tours led by park and concession interpreters.

Mammoth Hot Springs/Fort Yellowstone

In March 2002, Mammoth Hot Springs Historic District was listed in the National Register of Historic Places. It includes Fort Yellowstone, where 35 structures remain from the 1890s and early 1900s when the U.S. Army administered the park (*see pages 26–27*). Significant developments occurred here in national conservation policies that led

to the origin of the National Park Service. In July 2003, Fort Yellowstone was listed as a National Historic Landmark District—the highest historic designation possible.

Lake Hotel

The Lake Hotel is the oldest operating hotel in the park. At the time it was opened, in 1891, the building resembled any other railroad hotel financed by the Northern Pacific Railroad. In 1903, the architect of the Old Faithful Inn, Robert Reamer, masterminded a renovation, designing the ionic columns, extending the roof in three places, and adding the 15 false balconies, which prompted it to be known for many years as the “Lake Colonial Hotel.” By 1929, a number of additional changes—dining room, porte-cochere (portico), sunroom, plus the refurbishing of the interior—created the landmark we see today. The hotel was placed on the National Register of Historic Places in 1991.

Roosevelt Arch

Visitors entering at the North Entrance pass through the Roosevelt Arch in the North Entrance Road Historic District and part of the Fort Yellowstone Historic Landmark. This soaring stone structure was conceived by U.S. Engineer Hiram Chittenden; Robert Reamer may have contributed to the design, and architect N.J. Ness also worked on it.

President Theodore Roosevelt placed the cornerstone for the arch. The top of the arch is inscribed with a line from the Yellowstone National Park Act of 1872: “For the benefit and enjoyment of the people.”

Roosevelt Area

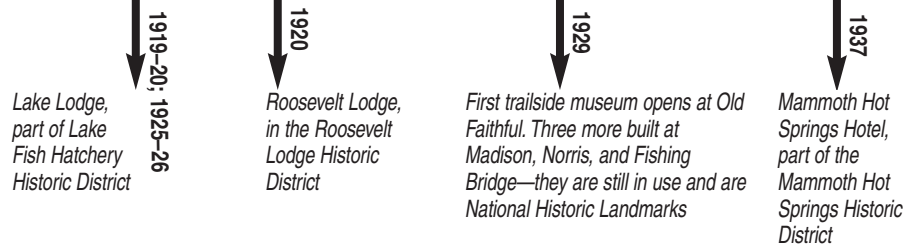
Diners at Roosevelt Lodge (Roosevelt had camped nearby) view much the same



Above: Albright Visitor Center, above, in the Mammoth Hot Springs Historic District and Ft. Yellowstone Historic Landmark District, housed the first “information office” (visitor center). Right: Lake Hotel, a National Historic Site



Historic Park Buildings still in use



landscape seen by visitors when the lodge first opened in 1920. The area surrounding and including the lodge is registered as the Roosevelt Lodge Historic District.

The Buffalo Ranch

The Lamar Buffalo Ranch Historic District overlooks Lamar Valley. The ranch, which operated from 1906 until the 1950s, was the focal point of an effort to increase the herd size of the few remaining bison in Yellowstone. Remnants of irrigation ditches, fencing, and water troughs can still be found, and four buildings from the original ranch compound remain (*photo above*)—two residences, the bunkhouse, and the barn. New cabins, which blend with the historic buildings, house students at the Yellowstone Association Institute or the National Park Service’s residential education program.

Old Faithful Inn & Historic District

Most people who step into the Old Faithful Inn (*photo right*) for the first time stop as their eyes follow thick rustic logs up to the soaring peak of the ceiling. Robert Reamer designed this National Historic Landmark, which opened in 1904. It is the centerpiece of the Old Faithful Historic District.

The Old Faithful Lodge, part of the historic district, is a result of numerous changes dating back to the early days of tent camps. In 1918, a laundry was built on the site and construction continued until 1928 when the lodge reached its present configuration.

Trailside Museums

Four trailside museums were built in Yellowstone as part of a national idea that a national park is itself a museum and an interpretive structure should blend in with its surroundings and its exhibits explain but not



Left: Ranger residences in the Lamar Buffalo Ranch Historic District.
Below: Old Faithful Inn, which opened in May 1904 and is now undergoing renovation.



substitute for the park experience. The museums here are well-known examples of the architectural style, National Park Rustic (also called “parkitecture”).

The Old Faithful Museum was the first trailside museum in Yellowstone. It opened in 1929 to acclaim for its quality materials and construction, and for the way it blended into its surroundings. It was replaced by a visitor center in 1972, which is now closed. A new visitor center is under construction.

The Norris Museum, built in 1930 and still in use, is a gateway to the Norris Geyser Basin. Visitors first glimpse the area’s hydrothermal

Cultural Resources

1 National Historic Landmark District:

Fort Yellowstone

6 National Historic Landmarks:

Fishing Bridge
Trailside Museum
Madison Junction
Trailside Museum

Norris Geyser
Basin Trailside
Museum

Northeast
Entrance Station
Obsidian Cliff
Old Faithful Inn

5 National Register Historic Districts:

Lake Fish
Hatchery
Grand Loop Road*
Mammoth Hot
Springs
North Entrance
Road
Old Faithful Area
Roosevelt Lodge

5 National Historic Sites:

Lake Hotel
Lamar Buffalo
Ranch
Obsidian Cliff
Kiosk
Queen's Laundry
Bath House
Post Office at
Mammoth Hot
Springs

features from a breezeway; they learn about the features from exhibits in the wings.

The Madison Museum (*photo right*), overlooking the junction of the Gibbon and Firehole rivers, features many elements associated with National Park Rustic: stone and wood-shingled walls, and rafters of peeled logs. Built in 1930, it now serves as an information station and bookstore.

The Fishing Bridge Museum, built in 1932, retains many of its original exhibits as an example of early National Park Service displays. On the lake side of the museum, visitors can cross a flagstone terrace overlooking the lake and descend steps to the shore.

Canyon Village

The Canyon Village development is eligible for listing in the National Register of Historic Places because of its place in Mission 66 history (*see page 28*). However, the visitor center shown below no longer meets the needs of visitors and has been closed for extensive renovation to solve these problems. When it reopens later this year, it will reflect a combination of the building's original architectural style—"National Park Service Modern"—and that of the last Canyon Hotel (no longer standing), which was Arts and Crafts style.



The Madison Trailside Museum, now an information station

Lodging No Longer Standing

Marshall's Hotel, which stood near the present-day intersection of Fountain Flats Drive and Grand Loop Road, was built in 1880 and was the second hotel in the park. Later renamed the Firehole Hotel, it was torn down between 1892 and 1895.

Fountain Hotel opened in 1891 north of Fountain Paint Pot. This was one of the first

National Register of Historic Places

The National Register of Historic Places is the Nation's official list of cultural resources worthy of preservation. Authorized under the National Historic Preservation Act of 1966, the National Register is part of a national program to coordinate and support public and private efforts to identify, evaluate, and protect our historic and archeological resources. Properties listed in the Register include districts, sites, buildings, structures, and objects that are significant in American history, architecture, archaeology, engineering, and culture. The National Register is administered by the National Park Service. Currently 73,000 listings have been nominated by governments, organizations, and individuals because they are important to a community, a state, or the nation.

National Historic Landmarks

National Historic Landmarks are nationally significant historic places designated by the Secretary of the Interior because they possess exceptional value or quality in illustrating or interpreting the heritage of the United States. Today, fewer than 3,500 historic places bear this national designation. Working with citizens throughout the nation, the National Historic Landmarks program draws upon the expertise of National Park Service staff who evaluate potential landmarks and provide assistance to existing landmarks.

Cultural Resources

Yellowstone hotels where bears were fed for the entertainment of guests. The hotel closed after 1916 and was torn down in 1927.

Four lodging facilities were built at Norris. Three were built between 1886 and 1892, and all three burned their first year. The last hotel at Norris, which overlooked Porcelain Basin, served the public from 1901 through 1916.

Three hotels were built in succession at Canyon, the last being the largest hotel in the park. Sited where the horse stables are now, the Canyon Hotel was closed in 1959 due to financial and/or maintenance problems and burned in 1960.

These and other sites of former park facilities are historic archeologic sites. They are studied and documented for what they reveal about the history of visitor use in the park.

More Than a Century of Collecting

The park maintains a unique and valuable collection of prehistoric and historic artifacts, documents, and specimens reflecting the unique resources and history of Yellowstone. It includes paintings and pencil sketches by Thomas Moran; photographs by William H. Jackson; historic hotel furnishings; historic vehicles; park souvenirs; archeological objects; and fossil and plant specimens.

Historic photographs document European American explorations of the region and the

history of the park. Historians consult these photos for visual information; the park's landscape architects consult them to plan historically accurate renovations. Documentary filmmakers request photos of people and the park to visually tell the story of Yellowstone.

The park maintains archives through an agreement with the National Archives and Records Administration.

Irreplaceable documents include manuscripts and diaries by N.P. Langford and Thomas Moran, logs from park patrols and management, and field notes from researchers who have studied Yellowstone's cultural and natural resources.

A new collection facility—the Heritage and Research Center—opened in 2005 in Gardiner, Montana near the North Entrance. It houses the Yellowstone Research Library, archives, and most of the museum collection.



The Heritage and Research Center opened in 2005

Construction Dates for Other YNP Buildings

Tower General Store	1932, 36
Lake General Store	1920
Lake Ranger Station	1922–23
Mammoth Chapel	1912–13
Mammoth Gas Station	1920
Old Faithful Gas Station (Lower)	1920, 1925
Old Faithful Lower General Store	1897, 1921 addition
Old Faithful Upper General Store	1930
South Entrance Ranger Station Duplex	1928
West Thumb Ranger Station	1925; now an information station

Cultural Resource Laws

These laws guide the management of historic and cultural resources in national parks:

The Antiquities Act (1906) provides for the protection of historic, prehistoric, and scientific features on and artifacts from federal lands.

The Historic Sites Act (1935) sets a national policy to “preserve for future public use historic sites, buildings, and objects.”

The National Historic Preservation Act (1966) authorizes the creation of the National Register of Historic Places and gives extra protection to national historic landmarks and properties in the national register. National parks established for their historic value automatically are registered; others, such as Yellowstone, must nominate landmarks and properties to the register.

The Archeological and Historic Preservation Act (1974) provides for the preservation of significant scientific, historic, and archeological material and data that might be lost or destroyed by federally sponsored projects. For example, federal highway projects in Yellowstone include archeological surveys.

The Archeological Resources Protection Act (1979) provides for the preservation and custody of excavated materials, records, and data.

The Native American Graves Protection and Repatriation Act (1990) assigns ownership or control of Native American human remains, funerary objects, and sacred objects of cultural patrimony to culturally affiliated Native American groups.

American Indian Religious Freedom Act (AIRFA) protects and preserves American Indian access to sites, use and possession of sacred objects, and the freedom to worship through ceremonials and traditional rites.

Executive Order 13007 guarantees access to and ceremonial use of Indian sacred sites by Indian religious practitioners and that these sites not be adversely affected.

For More Information

Staff reviewers: Herb Dawson, Architectural Historian; Ann Johnson, Archeologist; Zehra Osman, Landscape Architect; Rosemary Sucec, Cultural Anthropologist; Lee Whittlesey, Park Historian

Culpin, Mary S. 2003. *For the Benefit and Enjoyment of the people: A History of Concession Development in Yellowstone National Park, 1872–1966*. YCR-CR-2003-01. NPS, Mammoth, WY

Davis, L. B. et al. 1995. The Obsidian Cliff plateau prehistoric lithic source, Yellowstone National Park, Wyoming. U. S. Dept. of the Interior, NPS Rocky Mtn. Region, Div. of Cultural Resources, Selections Series. No. 6, Denver, CO.

Everhart, William. 1983. *The National Park Service*. Boulder: Westview Press.

Frison, George. 1978. *Prehistoric Hunters of the High Plains*. New York: Academic Press.

Haines, Aubrey. 1996. *The Yellowstone Story: A History of Our First National Park*. 2 vols. Niwot: U. Press of Colorado.

Haines, Aubrey. 1974. *Yellowstone National Park: Its Exploration and Establishment*. National Park Service.

Janetski, Joel C. 2002. *Indians of Yellowstone Park*. Revised edition. Salt Lake City: University of Utah Press.

Keller, Robert and Michael Turek. 1998. *American Indians and National Parks*. Tucson: University of Arizona Press.

Langford, Nathaniel P. 1972. *The Discovery of Yellowstone Park*. Lincoln: University of Nebraska Press.

Merrill, M. *Yellowstone and the Great West: Journals, Letters, and Images from the 1871 Hayden Expedition*. 1999. University of Nebraska Press, Lincoln.

Nabokov, Peter and Larry Loendorf. 2004. *Restoring a Presence: American Indians in Yellowstone National Park*. Norman/UOklahoma

National Park Service. Cultural Resource Management in *Management Policies 2001*. NPS D1416; www.nps.gov/refdesk

National Park Service. Director's Order 28: Cultural Resource Management. (1998; being revised) www.nps.gov/refdesk

National Park System Advisory Board. 2001. *Rethinking the National Parks for the 21st Century*. www.nps.gov/policy

Quinn, Ruth. 2004. *Weaver of Dreams: The Life and Architecture of Robert C. Reamer*. Bozeman, MT: Ruth & Leslie Quinn.

Reinhart, Karen and Jeff Henry. 2004. *Old Faithful Inn: Crown Jewel of National Park Lodges*. Emigrant, MT: Roche Jaune Pictures, Inc.

Santucci, Vincent. 1998. Paleontological resources of Yellowstone National Park. Mammoth, WY. YCR-NR-98-1. www2.nature.nps.gov/grd/geology/paleo/yell_survey/index.htm

Whittlesey, Lee H. 1998. *Yellowstone Place Names*. Helena:

Montana Historical Society.

Whittlesey, Lee H. and National Park Service Staff. *A Yellowstone Album*. Boulder: Roberts Rinehart.

Whittlesey, Lee H. and Paul Schullery. 2003. *Myth and History in the Creation of Yellowstone National Park*. Lincoln/University of Nebraska

Additional Information from Yellowstone National Park

Yellowstone National Park website, www.nps.gov/yell, includes an array of park information about resources, science, recreation, and issues.

Yellowstone Science, published quarterly, reports on research and includes articles on natural and cultural resources. Free; available from the Yellowstone Center for Resources, in the Yellowstone Research Library, or online at www.nps.gov/yell.

Yellowstone Today, published seasonally and distributed at entrance gates and visitor centers, includes features on park resources such as hydrothermal features.

Site Bulletins, published as needed, provide more detailed information on park topics such as trailside museums. Free; available upon request from visitor centers.

During the late 1880s when the Army administered Yellowstone National Park, the U.S. Fish Commission (a predecessor of today's U.S. Fish and Wildlife Service) was invited to stock non-native fish in some park waters. These stockings comprise the first known, deliberate introductions of non-native fish to Yellowstone. Four trout species were introduced—brook, brown, lake, and rainbow. They have hybridized with native trout and caused a loss of genetic diversity.

The other invasive aquatic species—New Zealand mud snail and the microorganism causing whirling disease—probably arrived via unaware boaters and anglers carrying the organisms from other fishing locations around the country.

Angler and boater introduction of aquatic invasive species remain a serious threat to Yellowstone's aquatic ecosystem. Presently, invasive exotic aquatic species occur in streams, rivers, and lakes (both near the coasts and inland) all across the United States. We may never know exactly how whirling disease or mud snails were introduced to the park's waters, but anglers can help prevent other species from arriving.

For this reason, Yellowstone is publicizing this issue through a brochure and other information available to anglers and boaters who pursue their recreation in the park. The park's efforts join those of other agencies in the region and the nation working to protect the nation's aquatic ecosystems.

Mud Snails

The New Zealand mud snail has invaded park waters. About one-quarter inch long (*photo at right*), the New Zealand mud snail forms dense colonies on aquatic vegetation and rocks along streambeds. The snails crowd out native aquatic insect communities, which are a primary food source for fish. They also consume a majority of algae growth in park streams, another primary food source for fish and other native species. Strategies for dealing with this invader are being developed.

The Issue

Aquatic invaders can irreversibly damage the park's naturally functioning ecosystems.

Current Status

- In the U.S. currently, more than 250 exotic (from another continent) aquatic species and more than 450 non-native (moved outside their natural range) aquatic species exist.
- At least 3 invasive aquatic species exist in Yellowstone's waters:
 - 1 mollusk
 - 1 fish
 - 1 exotic disease-causing microorganism
- Park staff continues to educate visitors about preventing the spread of aquatic invasive species.

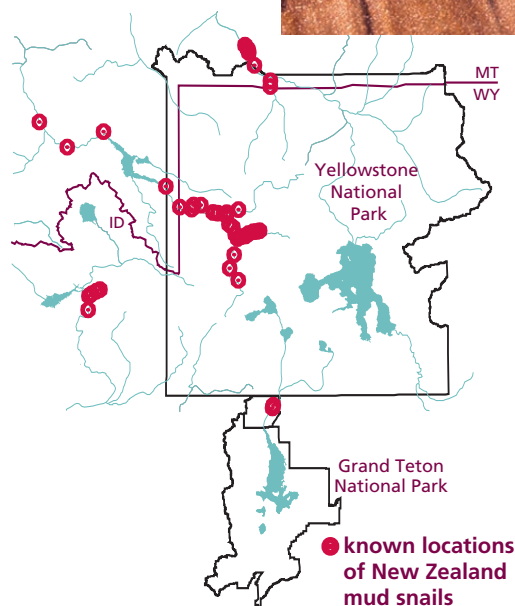
Recommendations for the Public *Clean Your Boat! Clean Your Gear!*

- Remove all plants, animals, mud, sand, and other debris from your boat and equipment.
- Rinse your boat, trailer, and equipment with high-pressure hot water.
- Drain lake and river water from your boat bilge area, livewell, and other hidden compartments, away from park waters.
- Dispose of all bait before entering the park. Otherwise, seal bait in plastic bags and place in park trash containers.
- Dry all equipment in the sun for up to 5 days or treat equipment with a 10 percent bleach solution.

Repeat all of the above before you leave Yellowstone National Park.



New Zealand mud snails



Aquatic Invaders: Lake Trout

Lake Trout

Non-native lake trout have been found in Yellowstone Lake and threaten the survival of native Yellowstone cutthroat trout and other species that depend on the native trout.

History/Background

- During the time that the park stocked fish, lake trout were introduced to Lewis and Shoshone lakes.
- In 1994, an angler caught the first verified lake trout in Yellowstone Lake.
- No one knows how lake trout were introduced into Yellowstone Lake, but it probably occurred several decades ago.
- One lake trout can consume approximately 41 cutthroat trout per year.
- If no action is taken, cutthroat trout in Yellowstone Lake could decline 50–90% in 20 years.
- Many wildlife species, including the

grizzly bear and bald eagle, may depend on the cutthroat trout for a portion of their diet.

- Most predators can't catch lake trout because they live at greater depths than cutthroat trout, spawn in the lake instead of shallow tributaries, and are too large for many predators.

Current Status

- The fisheries staff is removing lake trout by gill-netting: more than 130,000 lake trout have been removed this way since the mid-1990s.
- Regulations encourage anglers to catch lake trout; approximately 5,000 per year are caught.
- Biologists are researching the abundance and distribution of lake trout in Yellowstone Lake.
- With continued aggressive control efforts, lake trout numbers can be reduced and the impacts to cutthroat trout lessened.

The lake trout is a large and aggressive predatory fish that has decimated cutthroat trout in other western waters. If its population is not controlled in Yellowstone Lake, the impacts will reach far beyond the cutthroat trout population. It has the potential to be an ecological disaster.

Tracking Lake Trout

Lake trout gill-netting begins after ice is gone from the lake, and continues into October. Since lake trout control operations began in the mid-1990s, more than 130,000 lake trout have been caught. Gill net operations also provide valuable population data—numbers, age structure, maturity, and potential new spawning areas—leading to more effective control of this species. For example, during 1996, a lake trout spawning area was discovered in the West Thumb region of Yellowstone Lake at Carrington Island. Since then, scientists found spawning areas in West Thumb between Breeze Point and the mouth of Solution Creek, and off the geyser basin.



Hydroacoustic work (using sonar-based fish finders) in 1997 confirmed lake trout were concentrated in the western portion of Yellowstone Lake. These surveys also revealed medium-sized (12–16 inches) lake trout tended to reside in deeper water (greater than 130 feet) than Yellowstone cutthroat. Now scientists can more easily target lake trout without harming cutthroat trout. Hydroacoustic data also provides minimum abundance estimates of both cutthroat and lake trout, which is invaluable information for long-term evaluation of our efforts.

Anglers are an important component in the lake trout management program. They have had the most success in catching lake trout between 15 and 24 inches long. These fish are found in shallow, near-shore waters in June and early July. Anglers have taken approximately 4–5 percent of the lake trout removed from Yellowstone Lake. Fishing regulations require anglers to kill all lake trout caught in Yellowstone Lake and its tributaries. In 2001, regulations further restricted all cutthroat trout fishing to catch-and-release.

About 80 percent of a mature lake trout's diet consists of cutthroat trout. Based on lake trout predation studies in Yellowstone Lake, fisheries biologists estimate that approximately 41 cutthroat trout are saved each year for every lake trout caught.

Lake trout probably can't be eliminated from Yellowstone Lake. However, ongoing management of the problem can control lake trout population growth, maintain the cutthroat trout population, which are a critical ecological link between Yellowstone Lake and its surrounding landscape.

Aquatic Invaders: Whirling Disease

The Madison River in western Montana has long been considered a stable, world-class trout fishery. However, beginning in 1991, studies in a section of the river outside Yellowstone National Park indicated this was changing. The population of rainbow trout in the study section was declining dramatically. Testing completed in late 1994 confirmed the presence of whirling disease, which scientists believe is one of the factors in the decline.

Whirling disease is caused by a microscopic parasite that can infect trout and salmon; it does not infect humans. The parasite attacks the developing cartilage of fish between 1–6 months old and causes deformities of the bony structures. An infected fish may have a deformed head and tail, blackened areas of the tail, and whirling swimming behavior. It may be unable to feed normally and is vulnerable to predation.

Whirling Disease

Whirling disease is caused by a parasite attacking the developing cartilage of young fish, resulting in skeletal deformities and sometimes whirling behavior. Affected fish cannot feed normally and are vulnerable to predation.

History/Background

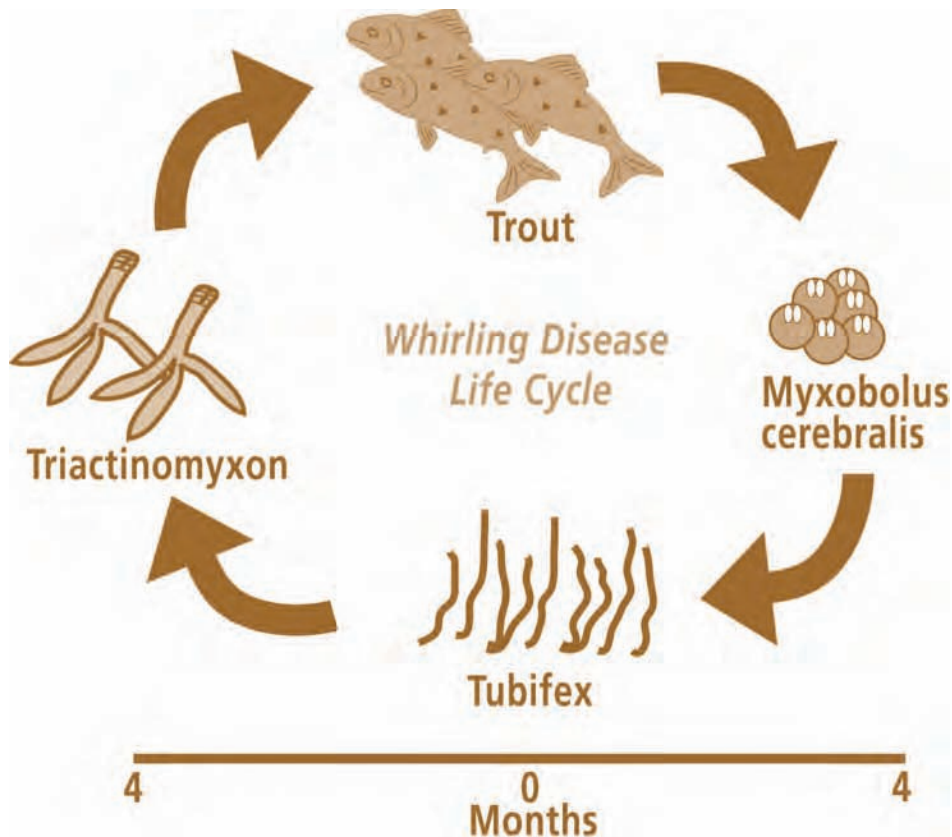
- The disease was first described in Europe more than 100 years ago. It was detected in the U.S. in the mid-1950s.
- It most likely came to the U.S. in frozen fish products.
- Whirling disease has been confirmed in 20 states and appears to be

rapidly spreading throughout the western United States.

- Rainbow trout populations appear to be most susceptible to the disease; recent laboratory tests suggest cutthroat trout are also highly susceptible. Lake trout and grayling appear immune to the disease, and brown trout are resistant, but can be infected and can carry the parasite.
- There is no treatment for the disease.

Current Status

- Testing for whirling disease continues throughout the park.
- Pelican Creek's population of migratory cutthroat trout is probably gone.



Aquatic Invaders

Little information exists on how the parasite moves from one drainage to another in the wild. In Montana, it is in the Madison, Gallatin, and Yellowstone rivers. In Yellowstone National Park, severe infections exist in the Yellowstone River and Pelican Creek; light infections exist in Clear Creek and the Firehole River. It has decimated the cutthroat trout population in Pelican Creek.

In a June 1996 report, the Whirling Disease Task Force (Montana) stated that whirling disease is “the most significant threat to wild, native and nonnative naturally reproducing trout populations in Montana,” and “the relevant question appears no longer to be if

whirling disease will spread, but how long it will take.”

No effective treatment exists for wild trout infected with this disease or for the waters containing infected fish. Therefore, anyone participating in water-related activities—including anglers, boaters, or swimmers—are encouraged to take steps to help prevent the spread of the disease. This includes thoroughly cleaning mud and aquatic vegetation from all equipment and inspecting footwear before moving to another drainage. Anglers should not transport fish between drainages and should clean fish in the body of water where they were caught.



Round goby



Bighead carp



The zebra mussel clogs water intakes, crowds out bottom invertebrates, and reduces lake productivity.

Not shown: three species of zooplankton, which can displace native zooplankton species that are important food for Yellowstone's native cutthroat trout. Furthermore, the three species of exotic zooplankton have long spines, which make them difficult for young fish to eat.

More Invaders on Their Way

Several exotic aquatic species are spreading through the United States, among them the species shown here. Fisheries biologists believe they are moving toward Yellowstone rapidly, and may appear in park waters very soon. Their arrival might be delayed if anglers remember:

- It is illegal to use any fish as bait in Yellowstone National Park.
- It is illegal to transport fish among any waters in the Yellowstone region.
- It is illegal to introduce fish species of any kind to Yellowstone waters.



Eurasian water-milfoil

Eurasian water-milfoil has spread throughout 45 of the 48 contiguous United States. Montana, Wyoming, and Maine are the three states still free of this aquatic invader.

This exotic aquatic plant lives in calm waters such as lakes, ponds, and calm areas of rivers and streams. It grows especially well in water that experiences sewage spills or abundant motorboat use, such as Bridge Bay.

Eurasian water-milfoil colonizes via stem fragments carried on boating equipment, which is another reason why boats should be thoroughly cleaned, rinsed, and inspected before entering Yellowstone National Park.

Yellowstone's hydrothermal microbes (called thermophiles) have been the subject of scientific research and discovery for more than 100 years. One of these discoveries—of the uses for *Thermus aquaticus*—has led to scientific and economic benefits far beyond what anyone could have imagined. Today, several dozen scientific research projects—sponsored by universities, NASA, and corporations—are underway in the park to investigate thermophiles. (See Chapter 4 for more information on these life forms.) Some of their discoveries have been used for commercial purposes, which is the heart of the benefits-sharing issue.

History

Careful scientific study of these curious life forms began in earnest in 1966, when Dr. Thomas Brock discovered a way to grow one of the microorganisms living in the extraordinarily hot waters (more than 158°F/70°C) of Mushroom Pool in the Lower Geyser Basin. This bacterium, *T. aquaticus*, proved essential to one of the most exciting discoveries in the 20th century.

Two decades ago, our ability to study DNA was limited. Things we take for granted today such as DNA fingerprinting to identify criminals, DNA medical diagnoses, DNA-based studies of nature, and genetic engineering were unimaginable. But in 1985, the polymerase chain reaction (PCR) was invented. PCR is an artificial way to do something that living things do every day—replicate DNA. PCR is the rocket ship of replication, because it allows scientists to make billions of copies of a piece of DNA in a few hours. Without PCR, scientists could not make enough copies of DNA quickly enough to perform their analyses. An enzyme discovered in *T. aquaticus*—called Taq polymerase—made PCR practical. Because it came from a thermophile, Taq polymerase can withstand the heat

The Issue

Should researchers who study material obtained under a Yellowstone National Park research permit be required to enter into benefits-sharing agreements with the National Park Service before using their research results for any commercial purpose?

Definitions

Bioprospecting is the search for useful scientific information from genetic or biochemical resources. It does not require large-scale resource consumption typical of extractive industries associated with the term “prospecting” such as logging and mining.

Benefits-sharing is an agreement between researchers, their institutions, and the National Park Service that returns benefits to the parks when results of research have potential for commercial development.

History

1966: The microorganism *Thermus aquaticus* was discovered in a Yellowstone hot spring.

1985: An enzyme from *T. aquaticus*, which is synthetically reproduced, contributed to the DNA fingerprinting process that has earned hundreds of millions of dollars for the patent holder.

1997: The park signed a benefits-

sharing agreement with Diversa Corporation, ensuring a portion of their future profits from research in Yellowstone National Park will go toward park resource preservation. 1999: A legal challenge put on hold implementation of this agreement until an environmental analysis (EA or EIS) is completed.

Current Status

- NPS is conducting an environmental impact statement (EIS) to decide whether benefits-sharing should be a part of NPS policy for parks nationwide. It will examine the potential impacts of implementing and not implementing benefits-sharing agreements.
- Each year, approximately 40 research permits are granted to scientists to study microbes in Yellowstone. Research permits are only granted for projects that meet stringent park protection standards.
- Research microbiologists continue to find microorganisms in Yellowstone that provide insights into evolution, aid in the search for life on other planets, and reveal how elements are cycled through ecosystems.

See Chapter 4, “Thermophiles.”

of the PCR process without breaking down like ordinary polymerase enzymes. A laboratory version of this enzyme is now used and has allowed DNA studies to be practical and affordable.

Many other species of microbes have been found in Yellowstone since 1966. Each of these thermophiles produces thousands of



Dr. Thomas Brock

uncommon, heat-stable proteins, some useful to scientists. Researchers estimate more than 99 percent of the species actually present in Yellowstone's hydrothermal features have yet to be identified.

Science

Because much of modern biotechnology is based on the use of enzymes in biochemical reactions—including genetic engineering, fermentation, and bioproduction of antibiotics—heat-stable catalytic proteins that allow reactions to occur faster are increasingly important in the advancement of science, medicine, and industry. In addition, genetic studies using knowledge developed from the study of microbes is increasingly important to medical and agricultural research. Yellowstone's geology provides a wide variety of high-temperature physical and chemical habitats that support one of the planet's greatest concentrations of thermophilic biodiversity. Research on these thermophiles can contribute to further advances.

Ongoing Research

Approximately 40 research studies are being conducted in Yellowstone on the ecological roles and community dynamics of microorganisms, and how to search for traces of similar life forms in the inhospitable environments of other planets. Research on park microbes also has proved useful in producing ethanol, treating agricultural food waste, bioremediating chlorinated hydrocarbons,

recovering oil, biobleaching paper pulp, improving animal feed, increasing juice yield from fruits, improving detergents, and a host of other processes.

Controversy

Along with this exciting new dimension in understanding park resources through research, questions have been raised about whether or not bioprospecting should be allowed. Bioprospecting is biological research associated with the development of commercial products. Bioprospecting does not require the sort of grand-scale resource consumption required by the kinds of extractive industries typically associated with the term "prospecting," such as timber harvesting and mining. In this case, the "prospecting" is for new knowledge. As required by law, research is encouraged in Yellowstone if it does not adversely impact park resources and visitor use and enjoyment. Importantly, only research results, i.e. information and insight gained during research on park specimens, may be commercialized—*not the specimens themselves*. Nonetheless, some people question the appropriateness of allowing scientists to perform research in a national park if they are bioprospectors.

The most famous commercial application for Yellowstone-related research was the invention of the polymerase chain reaction (PCR), discussed above. PCR generated significant profits for Cetus Corporation, which had patented the processes. In 1991, Hoffman-La

Roche, a Swiss pharmaceutical company, purchased the U.S. patents for a reported \$300 million. Since then, annual sales of Taq polymerase have been approximately \$100 million. Yellowstone National Park and the United States public have received no direct benefits even though this commercial product was developed from the study of a Yellowstone microbe. Hoffman-La Roche and the researchers acted lawfully throughout the development and sales of Taq polymerase. At issue is whether or not the National Park Service (NPS) should require researchers who study material obtained under a research permit to enter into benefits-sharing agreements with NPS before using their research results for any commercial purpose.

Benefits-Sharing

Federal legislation authorizes the National Park Service to negotiate benefits-sharing agreements that provide parks a reasonable share of profits when park-based research yields something of commercial value. Similar agreements are used by other countries to allow the host nation to benefit from commercial discoveries that depended on its natural heritage. In 1997, Yellowstone National Park became the first U.S. national park to enter into a benefits-sharing agreement with a commercial research firm. The Yellowstone-Diversa Cooperative Research and Development Agreement (CRADA) provided that Diversa Corp. would pay Yellowstone \$100,000 over five years (even if research resulted in no commercially valuable discoveries) and included provisions of no-cost scientific analyses and laboratory equipment, plus a royalty based on any sales revenues related to results from research in the park. *The CRADA did not authorize Diversa to collect specimens or conduct research in the park.* Permission to conduct research can only be acquired by applying for a research permit. In Yellowstone, an interdisciplinary team requires research permit applicants to abide by strict resource protection standards. Diversa, which has research sites around the world, was collecting DNA samples directly from nature and screening the genes for the ability to produce useful compounds. In its labs, scientists splice the most useful genes into microbial “livestock,” and these microbes then produce the compound or enzyme. As

with all NPS research specimens, the Yellowstone microbes and DNA collected in the park remain in federal ownership and are never sold.

Into Court

Shortly after the Yellowstone-Diversa CRADA was signed, opponents sued NPS in federal court arguing that the policy put into play a new commercial activity and was illegal and inappropriate in parks. In 1999, the judge ordered NPS to prepare an environmental analysis of the potential impacts of benefits-sharing agreements and suspended the CRADA pending completion of the analysis. In 2000, the court dismissed the remainder of the case, ruling the CRADA: 1) was consistent with the NPS mission of resource conservation; 2) that bioprospecting did not constitute a consumptive use; 3) that bioprospecting did not represent a “sale or commercial use” of park resources; and 4) Yellowstone fell within the definition of a federal laboratory and appropriately implemented the CRADA.

NPS is conducting an environmental impact statement (EIS) to decide whether benefits-sharing should be a part of NPS policy for parks nationwide. Through a public process, the EIS will examine the potential impacts of implementing and not implementing benefits-sharing agreements.

The study of natural resources has long been a source of knowledge that benefits humanity. For example, more than half of the pharmaceuticals used in the United States contain at least one major active compound derived from or patterned after natural compounds. As global biodiversity declines, national parks and other preserves become increasingly important as sources of genetic diversity for scientific study to discover knowledge to develop new solutions to the problems faced by humanity.



Thermus aquaticus,
magnified

For more detailed information, including the 2000 court decision, go to www.nature.nps.gov/benefitssharing

Section revised
& updated

The Issue

About half of Yellowstone's

bison test positive for exposure to brucellosis, a disease that can cause bison and domestic cattle to abort their first calf. Because Yellowstone bison migrate into Montana, their exposure to brucellosis concerns the state's cattle industry.

History/Background

(See also timeline on pages 150–151)

- Bison probably contracted brucellosis from domestic cattle raised in the park to provide milk and meat for park visitors in the early 1900s.
- Brucellosis has little impact on the growth of the bison population.
- The disease may be contracted by contact with infected tissue and birth fluids of infectious cattle or bison that are shed at the end of pregnancy.
- The human form of the disease, called undulant fever, was once a public health threat in the U.S., but is no longer.
- A vaccine used in cattle, RB51, is being used for bison.
- Bison have not been shown to transmit brucellosis to cattle under natural conditions although such transmis-

sion has occurred in captivity.

- The state of Montana, like other states, has spent much time, effort, and money attempting to eradicate brucellosis in cattle.
- Elk in the greater Yellowstone area also carry brucellosis.

Current Status

- A bison management plan has been in effect since December 2000.
- The plan allows for adaptive management, systematically increasing the winter range outside the park as partner agencies increase efforts to lower the disease prevalence in the population.
- As of March 2006, the plan is still in the initial phase, which does not yet provide additional winter range north of the Reese Creek area.

Agencies Involved

National Park Service (NPS)
Animal Plant Health Inspection Service (APHIS)
U.S. Forest Service (USFS)
Montana Department of Livestock (DOL)
Montana Department of Fish, Wildlife & Parks (FWP)

About Brucellosis

Brucellosis, caused by the bacterium *Brucella abortus*, can cause pregnant cattle to abort their calves. The disease is transmitted primarily when uninfected, susceptible animals come into direct contact with infected birth material. No cure exists for brucellosis in wild animals. All cattle that use overlapping ranges with bison are vaccinated for brucellosis, as are bison released after capture.

Although rare in the United States, humans can contract brucellosis through unpasteurized, infected milk products or contact with infected birth tissue. (*Brucellosis cannot be contracted by eating meat from an infected animal.*) In humans, the disease is called undulant fever. With milk pasteurization, which is required by U.S. law, people in the United States have virtually no risk of contracting the disease. And if they do, they can be treated with antibiotics.

Brucellosis was discovered in Yellowstone bison in 1917. They probably contracted the disease from domestic cattle raised in the park to provide milk and meat for visitors staying at hotels. Now about 50 percent of the park's bison test positive for exposure to the brucella organism. However, testing positive for exposure (seropositive) does not mean the animal is infectious and capable of transmitting brucellosis. (For example, people who received smallpox immunization during their childhood will test positive for smallpox antibodies even though they are not infected with the disease and cannot transmit it.) Research indicates less than half of seropositive female bison are infectious at the time of testing. Male bison do not transmit the disease to other bison. (Transmission between males and females during reproduction is unlikely because of the female's protective chemistry.) Bison have a very low probability of transmitting brucellosis to cattle under natural conditions, in part because management strategies prevent bison from commingling with cattle.



Bison outside the North Entrance in Gardiner, MT



So far, research shows that bison calves pose no risk to cattle. The risk of brucellosis transmission in the wild occurs only during the time afterbirth and its residue remain on the ground. Bison typically consume these materials.

in a cattle herd becomes infected with brucellosis, the entire herd is quarantined and may be slaughtered. Federal and state indemnity funds partially compensate the livestock producer for this loss.

Park managers face numerous uncertainties about how to best manage and preserve bison while addressing the issue of brucellosis-infected wildlife in Yellowstone National Park. In the absence of data to describe bison-*brucella* interactions, assumptions are based on the best available information. Studies conducted on cattle and *brucella* offer clues to how the disease may function in bison. Current information shows both species exhibit very similar clinical signs of brucellosis infection and very similar methods for transmitting the disease to other individuals. However, a scientific review of published and unpublished data indicates bison differ from cattle in their response to vaccines and possibly to standard testing for the disease. Elk in the Greater Yellowstone Ecosystem are also infected with brucellosis, and this reservoir for the disease may be a brucellosis transmission risk to bison. Studies are being conducted on wild bison to better understand the bison-*brucella* relationship, and to study these other questions.

Cattle–Bison Conflicts

Federal and state agencies and the livestock industry have spent much time and money to eradicate brucellosis from cattle. States accomplishing this task receive “brucellosis class-free” status and can export livestock without restrictions and costly disease testing. Montana attained this status in 1985.

Brucellosis infections in two Montana cattle herds would downgrade the state’s status and affect the finances of ranchers. When one cow

Because of concern over losing brucellosis class-free status, livestock regulatory agencies recommend an aggressive strategy to achieve the goal of brucellosis eradication. A National Academy of Sciences review panel suggested that brucellosis eradication is not possible in wildlife with the current technology. The panel recommended managing bison and livestock to minimize transmission risks.

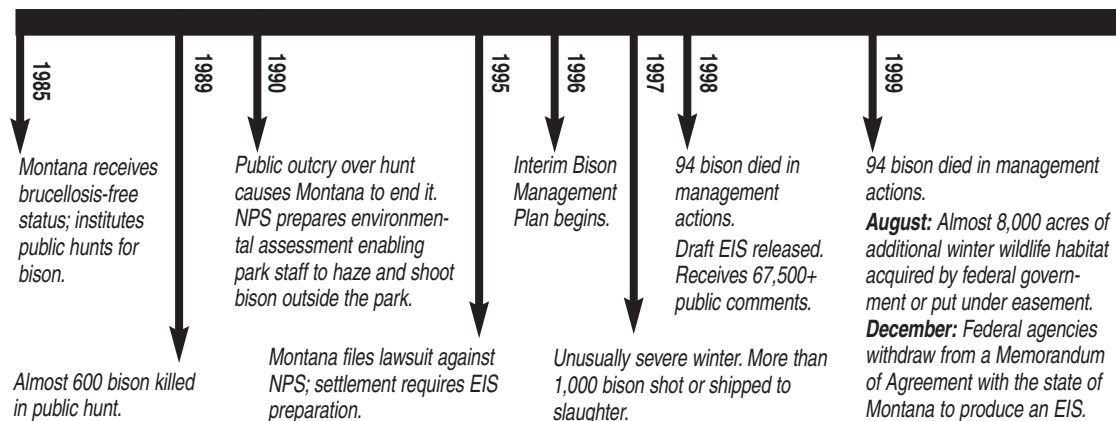
Keeping bison and livestock separated is one part of the current interagency management plan (*described on pages 150–152*).

Vaccinating cattle and bison is another. RB51 is a brucellosis vaccine safe for bison calves, yearlings, and adult males. Unlike with other vaccines, animals vaccinated with RB51 will not test positive for brucellosis with the standard battery of diagnostic tests. Vaccination of Yellowstone bison began in spring 2004.

Recent History

In 1985, Montana initiated a public bison hunt along the north boundary near Reese Creek and areas along the west boundary near West Yellowstone. During the severe winter following the fires of 1988, 569 bison were killed. The resultant nationwide public controversy caused the Montana Legislature to rescind authorization for the hunt.

Beginning in 1990, while Montana and the federal agencies were preparing a long-term plan, Montana needed an interim management plan to protect private property, provide for human safety, and protect the state’s brucellosis class-free status. NPS complied with an environmental assessment (EA) that



provided for limited NPS management of bison through hazing, monitoring, and shooting outside of park boundaries at the request and under the authority of the Montana Department of Fish, Wildlife and Parks. In 1992, the state of Montana entered into an agreement with NPS, the U.S. Department of Agriculture (USDA) Forest Service (USFS) and the USDA Animal Protection Health Inspection Service (APHIS) to develop a long-term management plan and environmental impact statement (EIS) for managing bison migrating from Yellowstone into Montana.

Lawsuit Filed

In January 1995, the state of Montana filed a lawsuit against NPS and APHIS because it believed the federal agencies were asking the state to implement conflicting management actions. NPS wanted more tolerance for bison on winter range outside the park; APHIS said if bison from an infected population ranged free in Montana, the state could lose its brucellosis class-free status. In the settlement, APHIS agreed to not downgrade Montana's status if bison migrated from Yellowstone into Montana as long as certain actions were taken, including completing a long-term bison management plan.

The Interim Management Plan

The 1996 interim plan called for NPS to build a bison capture facility inside Yellowstone National Park at Stephens Creek, near the northern boundary. All captured bison would be tested for brucellosis; seropositive animals would be shipped to slaughter. Any bison migrating north of the park into the Eagle Creek/Bear Creek area (east of the Yellowstone River) would be monitored and not captured. The Montana Department of Livestock (which, in 1995, had been given authority to manage bison in Montana) was to capture all bison migrating out of the park at

West Yellowstone and test them for brucellosis. All seropositive bison and seronegative pregnant females would be sent to slaughter. Other seronegative bison were to be released on public land. At their discretion, Montana could shoot any untested bison in the West Yellowstone area that they could not capture.

This plan began during the winter of 1996–97, the most severe winter since the 1940s. Large numbers of bison migrated across the north and west boundaries. By the end of the winter, 1,084 bison had been shot or sent to slaughter. Public outcry was much stronger than in 1989.

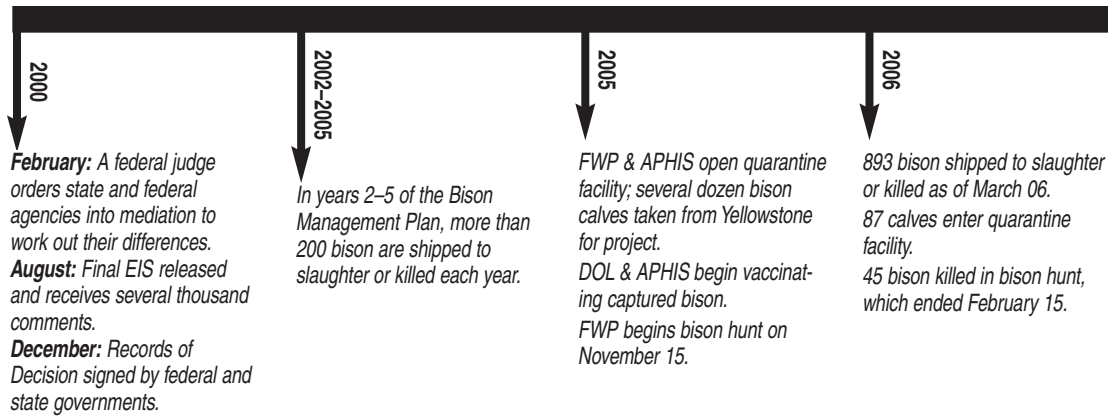
Draft EIS Released

A draft long-term bison management plan and EIS was released in 1998. The alternatives ranged from capturing all bison leaving the park and sending those that test positive to slaughter, to the use of public hunting to control bison in Montana, to establishing tolerance zones for bison outside park boundaries.

The plan received more than 67,500 public comments, the majority favoring an alternative plan that emphasized protection of bison.

The Final EIS & Management Plan

During development of the final EIS, the lead agencies reached an impasse and in December 1999, the federal agencies withdrew from a Memorandum of Agreement with the state of Montana to jointly produce a long-term management plan. The state challenged this action and a federal judge upheld the federal agencies' withdrawal in February 2000. However, before formal dismissal of the lawsuit, the state and federal agencies agreed to work out their differences using a court-appointed mediator to help find common ground in managing the bison population. The agencies developed a modified preferred alternative that minimized the risk of brucellosis



transmission from bison to cattle, systematically worked toward eradication of brucellosis in the bison herd, provided a mechanism to increase winter range for bison on public lands outside the park, and minimized the killing of bison that left the park.

In August 2000, the *Final Environmental Impact Statement for the Interagency Bison Management Plan for the State of Montana and Yellowstone National Park* was released. After a public comment period, the final management plan was refined in consultation with the state of Montana and is a slightly altered version of the federal agencies' modified preferred alternative presented in the FEIS. In December 2000, the federal government and the state of Montana released separate Records of Decision that describe the negotiated settlement.

The final management plan uses adaptive management and progressive steps to phase in greater tolerance for bison outside Yellowstone. Step One limits bison to the park and one management area outside the west boundary (for up to 100 seronegative bison). In the third phase of implementation, up to 100 untested bison would be tolerated in winter both outside the park boundary near Reese Creek and the west boundary. During all phases of the adaptive management strategy, one management area outside the north boundary—in the Eagle Creek/Bear Creek area—would allow unlimited number of bison. The Interagency Bison Management Plan allows managers to capture and remove all bison, regardless of disease status, outside the west boundary or near the north boundary if the late winter or early spring bison population estimate is above 3,000. Cattle will be vaccinated and monitored in specific areas near Yellowstone National Park. Methods for bison management may include additional monitoring of bison on public lands outside



the park, hazing onto appropriate public lands or back into the park in the spring, and control on public lands outside the park through capture and slaughter or agency shooting. The plan also includes provisions for continued research to address uncertainties identified during the planning process.

Recent Developments

Understanding bison movement

Observations of bison movement during the first five years of the management plan have revealed patterns. In the west management zone, groups of ten or less adult male bison use this area from late September until early June. Groups of adult females move into this area in late winter and remain well into the birthing season. Groups of adult females move into the north management zones earlier and stop prior to birthing period. Up to 200 bison use the Eagle Creek/Bear Creek area each winter.

Winter 2005–2006

During August of 2005, close to 5,000 bison lived in the park. In response to winter weather conditions, hundreds of bison migrated to winter range along and outside

The last public hearing on the draft EIS, in Minneapolis, MN, was preceded by a rally organized by area tribes.

Bison Management

NPS objectives in the Final EIS and Bison Management Plan:

- *Maintain genetic integrity of the bison population.*
- *Maintain a wild, free-ranging bison population.*
- *Maintain and preserve the ecological function that bison provide in the Yellowstone area, such as their role as grassland grazers and as a source of food for carnivores.*
- *Lower brucellosis prevalence because it is not a native organism.*
- *Reduce risk of brucellosis transmission from bison to cattle.*

the park's north boundary. More than 800 bison were captured and shipped to slaughter. Also, more than 80 calves were sent to quarantine (see below). The loss of this many bison, in addition to those that died from predation, accidents, and the harsh weather conditions, will not prevent the long term conservation of the bison population.

Vaccination

The bison management plan includes a bison vaccination program. State and federal agencies have developed such programs to be used at boundary capture facilities. The National Park Service is undergoing an environmental study to evaluate vaccinating bison throughout the park in the field, using remote delivery methods that do not require handling individual bison. Because scientists now know more about bison movement patterns, group dynamics, and habitat distribution, they better understand where and when field vaccination could succeed.

Bison hunt

The state of Montana authorized a bison hunt on public lands outside Yellowstone National Park, which runs November 15 to February 15. Fifty permits were issued. Through the

hunt, the state can manage bison on low elevation winter ranges within the state.

Quarantine

A bison quarantine feasibility study is being conducted outside the north boundary of Yellowstone National Park. A protocol is being tested to certify disease-free bison. If a successful protocol is developed, quarantine could provide a way for Yellowstone bison to be a part of bison conservation in other places.

Outlook

In September 2005, the partner agencies in the bison management plan completed a five-year review of management actions. The report noted success in keeping bison and cattle apart, which has protected both Yellowstone's bison population and Montana's brucellosis-free status. The agencies will continue to monitor bison abundance, distribution and movements, and brucellosis prevalence in the population. In addition, they will continue to advance the management program toward greater tolerance for bison on low elevation winter range outside Yellowstone. The federal Record of Decision is available at www.planning.nps.gov/document/yellbisonrod.pdf

Brucellosis Management in Greater Yellowstone

NPS participates in the Greater Yellowstone Interagency Brucellosis Committee (GYIBC), whose goal is to "protect and sustain the existing free-ranging elk and bison populations in the greater Yellowstone area and protect the public interests and economic viability of the livestock industry in Wyoming, Montana and Idaho." The mission of GYIBC is to develop and implement brucellosis management plans for elk and bison. Objectives include maintaining viable elk and bison populations; maintaining the brucellosis-free status of Wyoming, Montana, and Idaho; aggressively seeking public involvement in the decision making process; and planning for the elimination of *Brucella abortus* from the Yellowstone area by the year 2010.

*An NPS–Natural Resources Preservation Program project began research and collection of data on bison ecology and how *B. abortus* survives and functions in a wild environment. This project involved Grand Teton and Yellowstone national parks, and the information gathered from the research will help managers make sound defensible decisions for the future management of bison and elk in the two parks.*

NPS is also working with the Biological Resources Division of the U.S. Geological Survey in an ongoing research effort to examine the demographic characteristics from a previous study of bison in Yellowstone National Park. Preliminary results about bison movement in the park suggest that the animals do not travel on groomed roads as much as expected, but tend to follow rivers and other corridors.

Early visitors to Yellowstone National Park developed an interest in the area's wildlife—especially the bears. Dumps as bear-viewing sites quickly became a primary tourist attraction. At the height of the bear-feeding era, hundreds of people sat nightly in bleachers and watched as bears fed on garbage.

Despite the official prohibition in 1902 against hand-feeding bears, Yellowstone National Park became known as the place to see and interact with bears. Roadside bears, often receiving handouts from enthusiastic park visitors, caused “bear jams”—a traffic jam resulting from the presence of one or more photogenic black bears, often with a park ranger standing by to direct traffic, answer questions, and even pose for pictures.

In 1931, as park visitation and the number of bear-human conflicts began to increase, park managers began keeping detailed records of bear-caused human injuries, property damages, and subsequent nuisance bear control actions. Between 1931 and 1969 an average of 48 bear-inflicted human injuries and more than 100 incidents of property damage occurred annually in Yellowstone.

In 1959 and continuing through 1971, Drs. John and Frank Craighead, who were brothers, conducted a pioneering ecological study of grizzly bears in Yellowstone. Their research provided the first scientific data about grizzlies in this ecosystem, which enabled park staff to manage bears based on science and solve the underlying causes leading to bear-human conflicts.

In 1960, the park implemented a bear management program—directed primarily at black bears—designed to reduce the number of bear-caused human injuries and property damages that occurred in the park and to re-establish bears in a natural state. It included expanded efforts to educate visitors about bear behavior and the proper way to store food, garbage, and other bear attractants;

Bear Management

Feeding Bears

- 1889: Bears gathered at night to feed on garbage behind park hotels.
- 1910: First incidents of bears seeking human food along park roads.
- 1916: First confirmed bear-caused human fatality.

Early Management

- 1931: Park began keeping detailed records of bear-inflicted human injuries, property damage, and bear control actions.
- 1931–1969: average of 48 bear-inflicted human injuries and more than 100 incidents of property damage occurred annually in Yellowstone.

Changes in Management

- 1970: Yellowstone implemented a new bear management program to restore bears to subsistence on natural foods and to reduce human injuries and property damage.
- Strict enforcement of regulations prohibiting the feeding of bears, and requiring proper storage of human food and garbage.
- All garbage cans in the park

- converted to a bear-proof design.
- Garbage dumps closed within and adjacent to the park.

Current Status

- In 1975, the grizzly bear population in the Yellowstone ecosystem was listed as a threatened species under the Endangered Species Act.
- Decrease in human injuries from 45 injuries per year in the 1960s to 1 injury per year in the 2000s.
- Decrease in property damage claims from 219 per year in the 1960s to an average of 7 per year in the 1990s.
- Decrease in number of bears that must be killed or removed from the park from 33 black bears and 4 grizzlies per year in the 1960s to an average of 0.2 black bear and 0.3 grizzly bear per year in the 1990s.
- Decrease in bear relocations away from the front country from more than 100 black bears and 50 grizzlies per year in the 1960s to an average of 0.4 black bear and 0.9 grizzly bear per year in the 1990s.

prompt removal of garbage to reduce its availability to bears, and the development and use of bear-proof garbage cans; stricter enforcement of regulations prohibiting the feeding of bears; and removal of potentially hazardous bears, habituated bears, and bears that damaged property in search of food.

After 10 years of this bear management program, the number of bear-caused human injuries decreased only slightly, to an average of 45 each year. Consequently, in 1970, Yellowstone initiated a more intensive bear management program that included the controversial decision to eliminate the unsanitary open-pit garbage dumps inside the park. The long-term goal was to wean bears off human foods and garbage and back to a natural diet of plant and animal foods available throughout the ecosystem.

The Craigheads predicted bears would range more widely, resulting in more bear-human conflicts and subsequent bear mortalities. This indeed occurred in the short term. During the program's first three years, an average of 38 grizzly bears and 23 black bears were trapped each year and translocated from roadsides and developed areas to back-country areas. In addition, an average of 12 grizzly bears and 6 black bears were removed from the population each year. However, bear-caused human injuries decreased significantly to an average of 10 each year. After 1972, the number of bear-human conflicts and bear management control actions declined significantly.

In 1983, the park implemented a new grizzly bear management program. The 1983 program emphasized habitat protection in back-country areas. The park established "bear management areas" where recreational use was restricted in areas with seasonal concentrations of grizzly bears. The goals were to minimize bear-human interactions that might lead to habituation of bears to people, to prevent human-caused displacement of bears from prime food sources, and to decrease the risk of bear-caused human injury in areas with high levels of bear activity. This program continues today.

Listing As a Threatened Species

In 1975, the grizzly bear in the lower 48 states was listed as threatened under the Endangered Species Act, in part, because the species was reduced to only about two percent of its former range south of Canada. Five or six small populations were thought to remain, totaling 800 to 1,000 bears. The southernmost—and most isolated—of those populations was in greater Yellowstone, where 136 grizzly bears were thought to live in the mid-1970s.

The listing of the grizzly for protection under the Endangered Species Act resulted in cessation of grizzly bear hunting in the Greater Yellowstone Ecosystem, and the development of numerous plans and guidelines to protect the remaining bears and their habitat within an identified recovery area. The Yellowstone grizzly bear recovery area is approximately 9,500 square miles in size and includes all of Yellowstone National Park, the John D. Rockefeller, Jr. Memorial Parkway, significant portions of Grand Teton National Park and the Bridger-Teton, Shoshone, Gallatin,

Caribou-Targhee, Custer, and Beaverhead-Deer Lodge national forests. It also includes Bureau of Land Management lands and state and private lands in Idaho, Montana, and Wyoming.

Research and management of grizzlies in greater Yellowstone intensified after the 1975 establishment of the Interagency Grizzly Bear Study Team (IGBST). The team, in cooperation with state wildlife managers in Idaho, Montana, and Wyoming, have monitored bears, estimated the number and trend of the population, and enhanced our understanding of grizzly bear food habits and behavior in relation to humans and to other wildlife species.

In 1983, the Interagency Grizzly Bear Committee (IGBC) was created in order to increase the communication and cooperative efforts among managers of grizzly bears in all recovery areas. Twice each year, managers meet to discuss common challenges related to grizzly bear recovery. They supervise the implementation of public education programs, sanitation initiatives, and research studies to benefit the grizzly bear populations in Yellowstone and the other recovery areas.

Scientists and managers believe that, despite the continuing growth in human use of greater Yellowstone, the grizzly population has been stable to slightly increasing since 1986. The bears seem to be reproducing well and raising cubs in nearly all portions of the recovery area. More and more frequently, bears have been seen well outside Yellowstone National Park, south into Wyoming's Wind River Range, north throughout the Gallatin Range, and east of the Absarokas onto the plains. By radio tracking, trapping, and aerial observation, we know bears are dispersing into new habitat. In 2004, scientists estimated 588 grizzly bears lived in the Greater Yellowstone Ecosystem.



On July 28, 1975, under the authority of the Endangered Species Act (ESA), the U.S. Fish and Wildlife Service listed the grizzly bear as a threatened species. A primary goal of the ESA is to recover threatened or endangered species to self-sustaining, viable populations that no longer need protection. To achieve this goal, federal and state agencies have developed and are implementing a Grizzly Bear Recovery Plan and a Conservation Strategy

The Grizzly Bear Recovery Plan

Parameter 1: Females with Cubs

Adult female grizzly bears with cubs-of-the-year (COY) are the most reliable segment of the population to count. Using aerial and ground observations, a minimum number of unduplicated females with cubs is recorded each year. Females are identified by the number of cubs and pelage color combinations of different family groups; some also wear radio collars.

Recovery Goal: Average 15 adult females with COY on a 6-year running average both inside the recovery zone and within a 10-mile area immediately surrounding the recovery zone.

Rationale: To estimate an average minimum population size and to demonstrate that a known minimum number of adult females are alive so that reproduction is sufficient to sustain existing levels of human-caused bear mortality in the ecosystem. A running 6-year average accounts for two breeding cycles and will allow at least two years when each live adult female can be reported with cubs. The 6-year average number of unduplicated

The Issue

The grizzly bear is listed as a threatened species, which requires recovering the species to self-sustaining, viable population.

Background

1975: The grizzly bear is listed as a threatened species.

1993: A recovery plan is implemented with three specific recovery goals that have to be met for six straight years.

2000: A team of biologists and managers from the USFS, NPS, USFWS and the states of Idaho, Wyoming, and Montana complete the Draft Conservation Strategy for the Grizzly Bear in the Greater Yellowstone Ecosystem.

2000–2002: Public comment periods included meetings held in Montana, Wyoming, and Idaho; total number of comments: 16,794.

2002: The Conservation Strategy is approved.

2003: The recovery goals are met for the sixth year in a row.

2005: The USFWS proposes removing the grizzly bear from the list of threatened species.

Three Recovery Goals

1. Average 15 adult females with cubs of the year inside the recovery zone and within a 10-mile area surrounding the recovery zone.
2. Females with young occupy 16 of 18 recovery zones; no two adjacent areas shall be unoccupied.
3. Known human-caused mortality is below 4% of the population estimate based on the most recent three-year sum of females with cubs minus known, adult female deaths. In addition, no more than 30% of the known human-caused mortality shall be females. These mortality limits cannot be exceeded during any two consecutive years.

Conservation Strategy Highlights

1. Establishes population and habitat triggers that initiate a biological review of the species if the population or habitat fall below certain threshold levels.
2. Protect habitat.
3. Monitor changes in grizzly genetic diversity, major food sources, bear predation of livestock, private land development inside the recovery area, hunter-related bear deaths, and cub production, mortality, and distribution.

Current Status

The USFWS has proposed delisting the grizzly bear in the Greater Yellowstone Ecosystem. The public comment period ended in March 2006, but no decision has been announced as of March 2006.

females with cubs is intended to derive a minimum population estimate, not to determine precise population size or trend.

Current Status: Achieved: The annual average number of unduplicated females with COY (2000–2005, 6-year average) is 39.5.

Parameter 2: Distribution of Females with Cubs

Monitor grizzly bear population trends and analyze consequences of human activities and development on bears in 18 Bear Management Units (BMUs) within the recovery area. Most BMUs contain complete spring, summer, and fall habitat for grizzly bears.

Recovery Goal: To have 16 of 18 BMUs occupied by at least one female with young from a running 6-year sum of observations and no two adjacent BMUs unoccupied. Occupancy requires verified sightings or tracks of at least one female with young at least once in each of 16 BMUs during a 6-year period.

Rationale: Demonstrate an adequate distribution of reproductive females within the recovery zone. Adult female grizzlies have a strong affinity for their home range and their offspring, especially females, tend to occupy habitat within or near the home range of their mother after being weaned. This parameter assumes successful reproduction indicates sufficient habitat is available and is being managed adequately.

Current Status: Achieved: From 2000 through 2005 (6-year running sum), all 18 BMUs were occupied at least once with family groups.

Parameter 3: Mortality

The rate of human-caused grizzly bear mortality, especially of adult females, is a key factor in the potential recovery of the population in the Yellowstone ecosystem. Therefore, recovery cannot be achieved if mortality

limits are exceeded during any two consecutive years.

Recovery Goals:

1: Known human-caused mortality is no more than 4 percent of the population estimate.

2: Females comprise no more than 30 percent of the known human-caused mortality.

Rationale: Grizzly bear populations probably can sustain 6 percent human-caused mortality without population decline, which is why the first mortality goal is set at no more than 4 percent of the minimum population estimate. The most recent 3-year sum of unduplicated females with cubs is used to calculate a minimum population estimate, applying the proportion of adult females in a population to the minimum number of adult females known to be alive. Mortality limits are recalculated annually based on population monitoring.

Current Status: Achieved. From 2000 through 2005 (6-year running sum), the annual average of known, human-caused grizzly bear deaths was 13.7 bears (14.5 allowed). During the same period, the average of known human-caused female mortality was 6.2 female bears per year, above the allowed 4.3 bears (30 percent of the total allowable of 17).

Status of Grizzly Recovery Goals

	94	95	96	97	98	99	00	01	02	03	04	05
Goal 1 Average of 15 adult females with COY for 6 years in and around the recovery zone.	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Goal 2 16 Bear Management Units occupied by females with young for 6 years.	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Goal 3 4% or less human-caused mortality; female bears comprise 30% or less of mortalities.	✓				✓	✓	✓	✓	✓	✓		

The Grizzly Conservation Strategy

The conservation strategy is the primary long-term guide for managing and monitoring the grizzly bear population and assuring sufficient habitat to maintain recovery. It emphasizes continued coordination and cooperative working relationships among management agencies, landowners, and the public to ensure public support, continue application of best scientific principles, and maintain effective actions to benefit the coexistence of grizzlies and humans in the ecosystem. It incorporates existing laws, regulations, policies, and goals such as those of the Grizzly Bear Recovery Plan.

Flexibility in the Strategy

- Grizzly/human conflict management and bear habitat management are high priorities in the recovery zone, which is known as the Primary Conservation Area (PCA). Bears are favored when grizzly habitat and other land uses are incompatible; grizzly bears are actively discouraged and controlled in developed areas.
- State wildlife agencies have primary responsibility to manage grizzly bears outside of national parks, including bears on national forests; national parks manage bears and habitat within their jurisdictions.
- The goal to sustain a grizzly bear population at or above 500 bears includes the entire Greater Yellowstone Ecosystem.
- State and federal wildlife managers will continue to monitor the grizzly population and habitat conditions using the most feasible and accepted techniques, including the maintenance of a radio-collared sample of bears and scientific methods to assess habitat conditions and changes on a broad geographic scale.
- Removing nuisance bears will be conservative and consistent with mortality limits outlined above, and with minimal removal of females. Managers will emphasize removing the human cause of conflict rather than removal of a bear.
- Managers have more flexibility to manage nuisance grizzlies, particularly male bears. Bears may be relocated as many times as judged prudent by managers.
- Management areas, previously used to delineate differences in land-management

strategies, are eliminated. Decisions affecting grizzly bears and/or their habitat will be based on existing and future management plans incorporating input from biologists, other professional land managers, and affected publics.

- Outside the PCA, state management plans define where grizzly bear occupancy are



acceptable. These decisions will be made with input from affected groups and individuals.

- Managers will periodically share information, implement coordinated management actions, ensure data collection, and identify research and financial needs across state and federal jurisdictions.

What Is Next

Completion of a conservation strategy does not in itself propose or accomplish a change in status of the grizzly bear population. The conservation strategy is a commitment by the responsible agencies to long-term management of grizzly bears and their habitat in ways that are compatible with human occupation and enjoyment of greater Yellowstone.

In 2005, the U.S. Fish and Wildlife Service (FWS) proposed delisting the Yellowstone grizzly population. If delisting is approved, long-term recovery goals will continue to be monitored. When conditions deviate from these goals, a recommendation can be made for a formal status review by FWS to determine if the Yellowstone grizzly bear population needs to be relisted under the Endangered Species Act.

Issues: Northern Range

The Issue

Some people believe the park has more ungulates (hoofed mammals) than the northern range can sustain. Elk and bison are blamed for increased erosion and declines in willows, aspen, and beaver, ostensibly due to overgrazing. Other scientists have found no evidence that the park's grasslands are overgrazed.

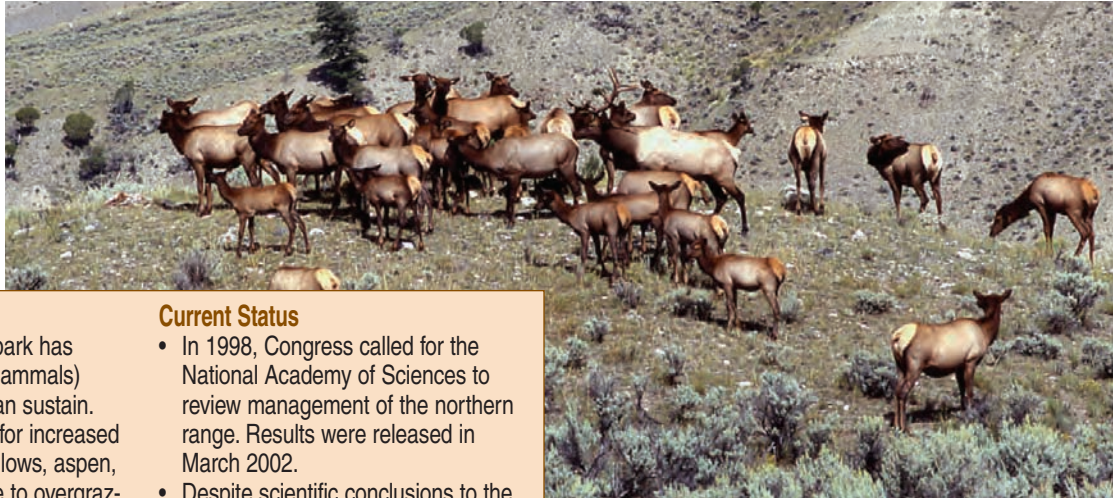
History/Background

- For decades, the park intensively managed elk, bison, and pronghorn.
- The park discontinued wildlife reductions in 1968 to restore natural dynamics and minimize human intervention.
- In the 1970s and early 1980s, scientific and public concerns grew about the increasing population of ungulates on the northern range.
- In 1986, Congress mandated a major research initiative to answer these concerns. Results found that the northern range was healthy and that elk did not adversely affect the overall diversity of native animals and plants.

Current Status

- In 1998, Congress called for the National Academy of Sciences to review management of the northern range. Results were released in March 2002.
- Despite scientific conclusions to the contrary, some people continue to claim the northern range is overgrazed.
- In response to new controversy about the impact of wolves on the elk herds of the northern range, numerous researchers have been studying this elk population and the impact of wolf restoration.
- Some people are now concerned because elk counts have declined approximately 50% since 1994.

The northern range refers to the broad grassland that borders the Yellowstone and Lamar rivers in the northern quarter of the park (*map next page*). This area sustains one of the largest and most diverse populations of free-roaming large animals seen anywhere on Earth. Many of the park's ungulates spend the winter here. Elevations are lower and the area receives less snow than elsewhere in the park. Often the ridge tops and south-facing hillsides here are clear of snow, a result of wind as well as snowmelt during the many sunny winter days. Animals take advantage of this lack of snow, finding easy access to forage.



History

The northern range has been the focus of one of the most productive, if sometimes bitter, dialogues on the management of a wildland ecosystem. For more than 80 years this debate focused on whether there were too many elk on the northern range. Although early censuses of the elk in the park, especially on the northern range, are highly questionable, scientists and managers in the early 1930s believed that grazing and drought in the early part of the century had reduced the range's carrying capacity and that twice as many elk were on the range in 1932 as in 1914. Due to these concerns about overgrazing and overbrowsing, park managers removed ungulates—including elk, bison, and pronghorn—from the northern range by shooting or trapping from 1935 to 1968. More than 26,000 elk were culled or shipped out of the park to control their numbers and to repopulate areas where over-harvesting or poaching had eliminated elk. Hunting outside the park removed another 45,000 elk during this period. These removals reduced the elk counts from approximately 12,000 to 4,000 animals.

As the result of public pressure and changing NPS conservation philosophy, YNP instituted a moratorium on elk removals in 1969 and has since let a combination of weather, predators, range conditions, and outside-the-park hunting and land uses influence elk abundance. Without any direct controls inside YNP, elk counts increased to approximately 12,000 elk by the mid-1970s, 16,000 elk by 1982, and 19,000 elk by 1988. This rapid population increase accentuated the debate

regarding elk grazing and its effects on the northern range.

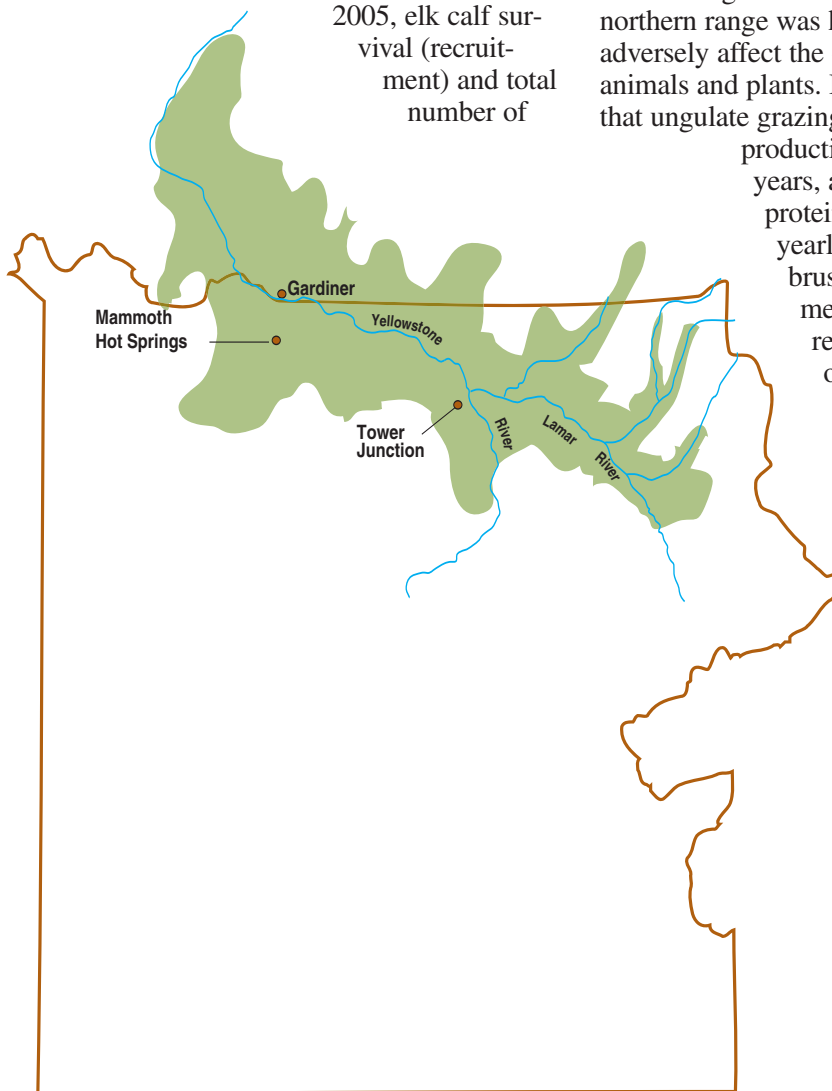
The restoration of wolves into Yellowstone and their rapid increase changed the debate from concerns about “too many” elk to speculation about “too few” elk in the future because of wolf predation. Elk are the most abundant ungulates on the northern range and comprised more than 89 percent of documented wolf kills during winters from 1997 to 2005. These data cause some people to think wolves are killing off elk, despite the fact that elk continue to populate the northern range at relatively high density compared to areas outside the park.

Another set of statistics also alarm hunters, outfitters, and state legislators: From 2002 to 2005, elk calf survival (recruitment) and total number of

the northern elk herd declined. Many factors (e.g. predators, drought, winterkill, hunting) contributed to the low recruitment and decreased elk numbers.

Research Results

Studies of the northern range began in the 1960s and have continued to the present. These studies reveal some overbrowsing of riparian plants, but no clear evidence of overgrazing. In 1986, continuing concern over the condition of the northern range prompted Congress to mandate more studies. This research initiative, one of the largest in the history of NPS, encompassed more than 40 projects by NPS biologists, university researchers, and scientists from other federal and state agencies. Results found that the northern range was healthy and elk did not adversely affect the overall diversity of native animals and plants. It was also determined that ungulate grazing actually enhances grass production in all but drought years, and grazing also enhances protein content of grasses, yearly growth of big sagebrush, and seedling establishment of sagebrush. No reductions in root biomass or increase in dead bunchgrass clumps were observed. However, studies on aspen and willows and their relationship to ungulates on the northern range are not so clear-cut and are continuing. Despite these results, the belief that elk grazing is damaging northern range vegetation and that grazing accelerates erosion persists among many people, including some scientists.



Yellowstone's northern range



Some sections of the northern range are fenced, as shown above, to study the long-term effects of grazing by fencing out large herbivores. The results were complex: Animals prune shrubs outside the fence but shrubs stay healthy. Apparently the herds are not destroying the unprotected vegetation.

Continuing Controversy

In 1998, Congress again intervened in the controversy, calling for the National Academy of Sciences to review management of the northern range. The results, published in *Ecological Dynamics on Yellowstone's Northern Range* (2002), concluded that “the best available scientific evidence does not

indicate ungulate populations are irreversibly damaging the northern range.” Studies investigating the responses of elk populations to wolf restoration continue.

In part, the controversy is likely due to the personal or scientific back-

ground of each person. Many urban dwellers live among intensively managed surroundings (community parks and personal gardens and lawns) and are not used to viewing wild, natural ecosystems. Livestock managers and range scientists tend to view the landscape in terms of maximizing the number of animals that a unit of land can sustain. Range science has developed techniques that allow intensive human manipulation of the landscape for this goal, which is often economically based.

Many ecologists and wilderness managers, on the other hand, have come to believe that the ecological carrying capacity of a landscape is different from the concept of range or economic carrying capacity. They believe variability and change are the only constants in a naturally functioning wilderness ecosystem. What may look bad, in fact, may not be.

Change on the Northern Range

During the 1990s, the ecological carrying capacity of the northern range increased as elk colonized new winter ranges north of the park that had been set aside for this purpose. Summers were also wet while winters were generally mild. The fires of 1988 also had opened many forest canopies, allowing more grasses to grow.

Many scientists believe that winter is the major factor influencing elk populations. Mild winters allow many more elk to survive until spring, but severe winters result in significant levels of winter kill for many animals, not just elk. In severe winters (like the winter of 1988–89 or 1996–97), up to 25 percent of the herd can die. The northern Yellowstone elk herd demonstrates the ecological principle of density-dependence: over-winter mortality of calves, older females, and adult bulls all increase with higher elk population densities.

Elk are subject to predation by other species in the ecosystem, including bears, wolves, coyotes, and mountain lions. Also, the northern Yellowstone elk population is subject to four hunts each year. Elk that migrate out of the park may be legally hunted during an archery season, early season backcountry hunt, general autumn hunt, and the Gardiner late hunt, all of which are managed by the Montana Department of Fish, Wildlife and Parks. The primary objective of the Gardiner late hunt is to regulate the northern Yellowstone elk population that migrates outside the park during winter and limit depredation of crops on private lands. During 1996–2002, approximately 5–19 percent (mean ~11 percent) of the adult female portion of this population was harvested each year during the late hunt. However, antlerless harvest quotas have been reduced ninety-six percent in recent years due to decreased elk numbers.

The complex interdependence of these relationships results in fluctuations in the elk population—when there are lots of elk, predator numbers increase, which, in part, helps reduce elk numbers and recruitment.

National Park Service policies protect native species and the ecological processes that occur naturally across the landscape.

Whenever possible, human intervention is discouraged. While controversy continues about the northern range and NPS management practices, many research projects continue in an effort to more accurately describe what is happening on Yellowstone's northern range.

In 1997, when Yellowstone National Park celebrated its 125th anniversary, one of the questions asked was what can we do to preserve and protect this national treasure for the next 125 years? The result was “The Greening of Yellowstone.” Some “green” projects had already begun, such as demonstrating the cleanliness and efficiency of biodiesel fuel. Since that time the park and various partners have addressed a wide variety of pollution prevention, waste reduction, alternative fuels, and recycling projects. Together they have increased effective environmental conservation in the park and surrounding communities.

Greening of Yellowstone Workshop and Symposium

Yellowstone National Park partnered with the states of Montana and Wyoming, the U.S. Department of Energy (DOE), and private groups to host three-day symposia in October of 1996 and May of 1998. Participants developed a shared vision for sustainability of the park’s values and providing ways to improve environmental quality. They considered a wide range of strategies such as developing a regional composting facility, operating alternatively fueled vehicles, replacing toxic solvents, using more environmentally-sound products, and modifying the energy infrastructure to make it more environmentally friendly. Participants ended the meetings with a commitment to work as partners in protecting and enhancing the region’s unique environment.

Walking on Sustainability

Yellowstone has more than 15 miles of wood boardwalk, most of which are at least 20 years old. The wood for these boardwalks was pressure treated with chemicals for preservation. As the walkways deteriorate, toxic chemicals from the wood leach into the ground and water. As recycled plastic lumber replaces the pressure-treated wood, increasingly smaller quantities of toxic chemicals will be released in the park.

The Issue

Yellowstone is a leader in demonstrating and promoting sound environmental stewardship through regional and national partnerships.

History:

- 1995: Biodiesel truck donated to park to test alternative fuel.
- 1997: Park celebrates 125th anniversary and “greening” efforts increase.
- 1998: Old Faithful wood viewing platform replaced with recycled plastic lumber; employee Ride-Share Program begins.
- 1999: Yellowstone National Park begins using nontoxic cleaning & janitorial supplies; ethanol blended fuel offered to visitors.
- 2002: The Park’s entire diesel fleet converts to biodiesel; the Greater Yellowstone/Teton Clean Cities Coalition receives federal designation.

2003: Regional composting facility opens; the park demonstrates the first fuel cell in a national park; the park begins testing prototype alternatively fueled multi-season vehicles.

2004: Park employees begin using four donated hybrid vehicles; Xanterra employee housing receives LEED designation.

Statistics

Annual recycling in the park:
newspapers, magazines, office paper:
207 tons
aluminum/steel: 102 tons
glass: 97 tons
plastic containers: 2 tons
cardboard: 150 tons

In addition, annually in Yellowstone:

- 300 vehicles use more than 167,000 gallons of biodiesel fuel
- 350 vehicles use more than 212,000 gallons of ethanol blended fuel

In 1998, Lever Brothers Company donated plastic lumber made from recycled plastic containers to replace the viewing platform around Old Faithful geyser. The equivalent of three million plastic milk jugs were used in this lumber. Now visitors receive an educational message about recycling while waiting for the world’s most famous geyser eruption.

Driving Sustainability

Yellowstone National Park offers a unique opportunity to demonstrate alternative fuels in an environmentally sensitive and extremely cold area. To do so, the National Park Service partnered with the Montana Department of Environmental Quality (DEQ), DOE, and the University of Idaho to test a biodiesel fuel made from canola oil and ethanol from potato waste. In February 1995, Dodge Truck Inc. donated a new three-quarter ton 4x4 pickup to the project. The truck has been driven more than 180,000 miles on 100 percent biodiesel. It averages about 17 miles per gallon, the same as with petroleum-based diesel fuel.

Emissions tests showed reductions in smoke, hydrocarbons, nitrogen oxides, and carbon monoxide. Tests also showed bears were not attracted by the sweet odor of biodiesel exhaust, which had been a concern. In September 1998, the truck's engine was analyzed, revealing very little wear and no carbon build-up. Since that time, the park has begun using other alternative fuels and vegetable-based lube and hydraulic oils in many of its vehicles.

All diesel-powered vehicles used by park employees plus many used by concession operations use a 20 percent blend of canola oil and diesel. Gasoline-powered vehicles in the park use an ethanol blend (E-10). This fuel is also available to park visitors at service stations in the park—the first time this option has been available in any national park.

In 2004, the park began using hybrid vehicles, which operate with electricity generated by the gasoline engine and its braking system. These vehicles conserve gas, reduce emissions, and run quietly when using electricity. Toyota USA donated four Prius models, which help educate visitors about the environmental advantages of hybrid vehicles.

Building Sustainability

Yellowstone's buildings—many historic—present opportunities for incorporating sustainable building materials and techniques as they are maintained, remodeled, or replaced. To make the best use of these opportunities, the park and its partners have:

- drafted an architectural and landscape design standard based on national green building standards and Yellowstone Design Guidelines
- planned the new Old Faithful Visitor Education Center to meet LEED certification requirements (LEED—Leadership in Energy and Environmental Design—requires buildings to meet sustainable building standards. See above.)
- retrofitted several maintenance facilities with sustainable heating systems, insulation, and high-efficiency lighting
- encouraged concessioners to retrofit facilities and ask guests to conserve energy and water in the hotels and lodges

LEED Certification

The U.S. Green Building Council (USGBC), a building industry group, developed national standards for environmentally-sound buildings. Called LEED (Leadership in Energy and Environmental Design) Green Building Rating System®, these standards have been met in the Yellowstone Park area for an employee housing project completed in 2004. The National Park Service partnered with concessioner Xanterra Parks & Resorts to build two houses following LEED certification standards. The project earned LEED certification—the first in Montana, and the first single-family residence in the country. The features include:

- Energy efficient design standards
- Passive solar gain
- State of the art heating/cooling systems list
- Landscaping with Yellowstone-produced compost

“Green” Cleaning Products

In August 1998, the U.S. Environmental Protection Agency partnered with Yellowstone National Park to assess the park's cleaning products. They found existing products included some with slightly toxic ingredients and others with potentially significant health hazards. As a result, the park switched from more than 130 products with health or environmental risks to less than 10 products that are safe for the environment and employees. The assessment expanded to include park concessioners, who also switched to safer products. This switch to safer and more environmentally sound cleaning products has expanded into many other national parks.

Renewable Energy

Yellowstone managers have identified several facilities where alternative renewable energy sources are economical and efficient. One of the easiest to see is the solar electric array installed at the Lamar Buffalo Ranch. It provides more than 80% percent of the complex's energy needs. The Lewis Lake Contact Station and Ranger residence also use solar energy, reducing the use of a polluting propane generator

Even more efficient renewable electricity may come from fuel cells, which convert hydrogen into power and don't rely on sunny weather or battery storage. In 2002, park managers demonstrated this new technology will work in Yellowstone's extreme climate by using a fuel cell to provide electricity to the West Entrance Station.

Greening the new Old Faithful Visitor Education Center

The proposed Old Faithful Visitor Education Center (seen above in a computer-generated model) has been planned to showcase the park's commitment to environmental practices and sustainability. It will be built following standards set by the U.S. Green Building Council. The goal is to meet "Silver LEED Certification" (see previous page)—the first visitor center in the National Park System to do so.

Features include:

- *a design that reduces heated space in winter*
- *water-conserving fixtures*
- *public education of sustainable practices in the visitor center displays and programs*
- *unobtrusive, down-directed exterior lighting*

Recycling and Composting

In 1994, a study was done in Yellowstone National Park showing 60–75 percent of solid waste (the waste stream) could be composted. Large-scale composting becomes even more economical when compared to hauling the park's solid waste more than 150 miles to landfills.

The Southwest Montana Composting Project—a partnership among area counties, municipalities, and the National Park Service—built an industrial-grade composting facility near West Yellowstone. It began operating in July 2003 and will eventually transform 60 percent of park's solid waste into valuable soil conditioner.

Another regional partnership, The Headwaters Cooperative Recycling Project, which includes Yellowstone National Park, is expanding opportunities for recycling in the park and surrounding communities. For example, it has placed recycling bins for glass, plastic, paper, aluminum, and cardboard in the park's campgrounds and other visitor areas.

In 2005, Yellowstone became the first national park to recycle small propane cylinders, such as those used for lanterns and some camp stoves. In six months, the park collected more than 3,000 cylinders, which were crushed and redeemed as steel.

Employee Ride-Share Program

In January 1998, Yellowstone National Park initiated a Ride-Share Program at the suggestion of park employees living north of the park—many of whom live more than 50 miles away. They were willing to help finance the program. Benefits of the program include:

- reducing fuel consumption and air pollution
- improving safety by decreasing traffic
- easing parking constraints in the park
- saving employees money
- improving employee morale, recruitment, and retention

Approximately 45 employees participate in the Ride-Share Program, a significant demonstration of the National Park Service commitment to public transportation.

Clean Cities Coalition

The Clean Cities program is a DOE grass-roots effort to address energy security and increase the use of alternative, cleaner fuels. The Greater Yellowstone/Teton Clean Cities Coalition comprises public and private stakeholders in Yellowstone and Grand Teton national parks and surrounding gateway communities in Idaho, Montana, and Wyoming.

To receive Clean Cities designation, the coalition had to agree on common goals and an action plan for reaching those goals. Although the national Clean Cities program focuses on

alternative fuels in vehicles, the coalition expanded its scope to include alternative fuel use in buildings and other operations. Their goals include:

- substantially reducing particulate matter entering the atmosphere
- educating and promoting the advancement of renewable fuels
- reducing dependency on fossil fuels
- setting the example for environmental stewardship

Upon receiving Clean Cities designation in 2002, the coalition became eligible for federal assistance to implement the various plans. Projects underway include:

- expanding the use of renewable fuels
- developing partnerships to foster sustainable efforts
- converting all stationary applications (heating boilers, generators, etc) to renewable fuels
- creating a tour district to promote a shuttle service within the Yellowstone region

Greening of Concessions

Yellowstone National Park's major concessioners contribute to environmental sustainability beyond the partnerships with the National Park Service described above. They also made a corporate commitment to an environmental management system (EMS) that meets international business standards for sustainability.

GreenPath and Delaware North

Delaware North, which operates the park's general stores, calls its EMS "GreenPath." Its goal is to reduce waste, increase recycling, and "make a positive environmental contribution to communities." Practices include:

- using nontoxic cleaning products
- stocking merchandise with recycled content, biodegradability, and minimal packaging

Employee "GreenTeams" at each location implement these practices and develop new ones.

Ecologix and Xanterra Parks & Resorts

Xanterra, which provides lodging in the park, calls its EMS "Ecologix." It includes

employee participation to develop and implement sustainable practices such as the following:

- replaced more than 22,000 incandescent bulbs with efficient compact fluorescent lighting
- replaced two-stroke outboard engines for rental boats with cleaner burning and more efficient four-stroke engines
- recycle all used automotive batteries, antifreeze, and paint solvents
- purchase bleach-free paper products containing 100 percent post consumer content
- serve organic fair-trade coffee (pesticide-free, grown and harvested in a manner supporting wildlife and bird habitats, purchased from local farmers at a fair price)
- serve sustainable beef and pork (pigs and free-range cattle raised without hormones or antibiotics in humane facilities)

Even the menus and other printed items are produced sustainably. At Xanterra's print shop in Yellowstone, more than 4.1 million documents are printed annually. The ink is 100 percent soy-base and the paper contains post-consumer waste. To clean the presses, the employees use a solvent far less toxic than previous materials.

Outlook

Yellowstone National Park continues to develop partnerships in sustainable resources. For example, Yellowstone managers and their peers from concession companies, the Yellowstone Association, and regional partners have formed a working group to coordinate the waste management and resource development efforts. Partnerships such as this ensure Yellowstone and its partners remain leaders in testing and implementing sustainable environmental practices.

A wilderness, in contrast with those areas where man and his own works dominate the landscape, is . . . an area where the earth and its community of life are untrammelled by man, where man himself is a visitor who does not remain . . . an area of undeveloped federal land retaining its primeval character and influence, without permanent improvements or human habitation, which is protected and managed so as to preserve its natural condition. . . .

The Wilderness Act of 1964

Yellowstone National Park has always managed its backcountry to protect natural and cultural resources and to provide park visitors the opportunity to enjoy a pristine environment within a setting of solitude. Yet none of the park is designated as federal wilderness under the Wilderness Act of 1964.

In 1972, in accordance with that law, Yellowstone National Park recommended 2,016,181 acres of Yellowstone's backcountry be designated as wilderness. Although Congress has not acted on this recommendation, these lands are managed so as not to preclude wilderness designation in the future. The last Yellowstone wilderness recommendation sent to Congress was for 2,032,721 acres.

Wilderness in the National Park System

Congress specifically included the National Park Service in the Wilderness Act and directed NPS to evaluate all its lands for suitability as wilderness. Lands evaluated and categorized as "designated," "recommended," "proposed," "suitable," or "study area" in the Wilderness Preservation System must be managed in such a way as 1) to not diminish their suitability as wilderness, and 2) apply the concepts of "minimum requirements" to all management decisions affecting those lands, regardless of the wilderness category.

Director's Order 41

Director's Order 41, issued in 1999, provides accountability, consistency, and continuity to the National Park Service's wilderness management program, and guides NPS efforts to meet the letter and spirit of the 1964 Wilderness Act. Instructions include:

- "... all categories of wilderness (designated, recommended, proposed, etc.) must be administered by NPS to protect wilderness resources and values, i.e., all areas must be managed as wilderness."
- "Park superintendents with wilderness resources will prepare and implement a wilderness management plan or equivalent

The Issue

In 1972, 90% of Yellowstone National Park was recommended for federal wilderness designation. Congress has not acted on this recommendation.

History

1964: Wilderness Act becomes law.

1972: National Park Service recommends 2,016,181 acres in Yellowstone as wilderness

1994: YNP writes a draft Backcountry Management Plan (BCMP) and environmental assessment, which is never signed. The BCMP begins to provide management guidance even though not official document.

1999: Director's Order 41 (DO 41) issued to guide NPS efforts to meet the letter and spirit of the 1964 Wilderness Act. It states that recommended wilderness must be administered to protect wilderness resources and values.

2003: NPS Intermountain Region implements a Minimum Requirement Policy to evaluate proposed management actions within proposed wilderness areas.

Backcountry Statistics

- Approximately 1,000 miles of trail.
- 72 trailheads within the park; 20 trailheads on the boundary.
- 301 designated backcountry campsites.
- Approximately 18% of backcountry users travel with boats and 7% travel with stock.
- During 2005: 16,970 overnight backcountry visitors spent an average of 2.3 nights in the wilderness.

Areas of Concern for Park Wilderness

- Accommodating established amount of visitor use.
- Protecting natural and cultural resources.
- Managing administrative and scientific use.
- Monitoring & implementing Limits of Acceptable Change [LAC].
- Educating users in Leave No Trace practices.

Current Status

Yellowstone's natural resource staff is preparing a wilderness plan to manage wilderness within the park.

integrated into an appropriate planning document. An environmental compliance document, in keeping with NEPA requirements, which provides the public with the opportunity to review and comment on the park's wilderness management program, will accompany the plan."

Minimum Requirement Analysis

The Intermountain Regional Director said "all management decisions affecting wilderness must be consistent with the minimum requirement concept." This concept allows managers to assess:

- if the proposed management action is appropriate or necessary for administering the area as wilderness and does not impact wilderness significantly

90% of the park is recommended for federally designated wilderness. Areas near roads, around major visitor areas, around backcountry ranger cabins, and in previously disturbed areas are not included.

- what techniques and type of equipment are needed to minimize wilderness impact.

Superintendents apply the minimum requirement concept to all administrative practices, proposed special uses, scientific activities, and equipment use in wilderness. They must consider potential disruption of wilderness character and resources before, and given significantly more weight than, economic efficiency and convenience. If wilderness resources or character impact is unavoidable, the only acceptable actions are those preserving wilderness character and/or having localized, short-term adverse impacts.

Wilderness Designation and Current Practices in Yellowstone

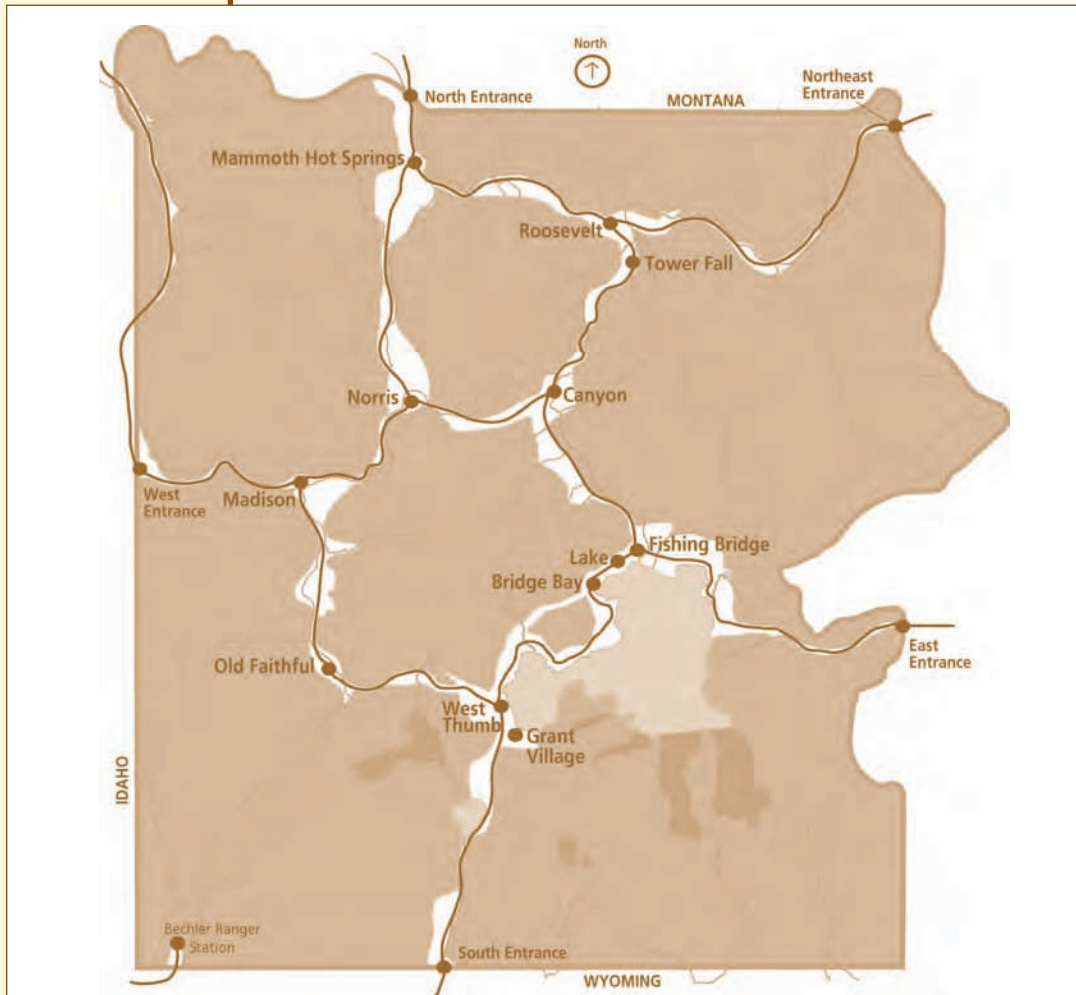
As managers develop a wilderness plan for Yellowstone, they must determine how current practices in the park will be handled within the proposed wilderness areas:

- Protecting natural and cultural resources while also maintaining the wilderness character of the park's backcountry.
- Managing administrative and scientific use to provide the greatest contribution with the minimum amount of intrusion in the wilderness.
- Monitoring Limits of Acceptable Change (LAC) to develop and enact long-range management strategies to better protect wilderness resources and enhance visitor experiences.
- Minimizing visitor wilderness recreation impact by educating users in Leave No Trace outdoor skills and ethics that promotes responsible outdoor recreation.

Outlook

Yellowstone will continue to manage its backcountry to protect park resources and provide a wilderness experience to park

visitors. Park managers are developing a wilderness plan to best manage and preserve the wilderness character that Yellowstone's backcountry has to offer. Yellowstone will then wait for the time when Congress will act upon the recommendation to officially designate Yellowstone's wilderness.





Background

Winter use in Yellowstone has been the subject of debate for more than 75 years. At least twelve times since 1930, the National Park Service (NPS) and its interested observers and park users have formally debated what Yellowstone should look and be like in winter; undoubtedly, some form of debate continued between those 12 times.

Beginning in the early 1930s, communities around the park began asking NPS to plow Yellowstone's roads year-round so tourist travel and associated spending in their communities would be stimulated. Each time, NPS resisted, citing non-winterized buildings, harsh weather conditions, and roads too narrow for snow storage. Meanwhile, snow-bound entrepreneurs in West Yellowstone began to experiment with motorized vehicles capable of traveling over snow-covered roads. In 1949, they drove the first motorized winter visitors into Yellowstone in snowplanes, which consisted of passenger cabs set on skis and blown about (without becoming airborne) with a rear-mounted airplane propeller and engine. In 1955, they began touring the park on Bombardier snowcoaches (then called snowmobiles), enclosed oversnow vehicles capable of carrying about ten people. Finally, in 1963 the first visitors on modern snowmobiles entered Yellowstone; not long after, snowmobiling became the predominant mode of touring the park in winter.

Still, pressure to plow park roads persisted, and Yellowstone authorities knew that they could not accommodate both snowmobiles

The Issue

We have debated what forms of use are appropriate in Yellowstone in winter for 75 years.

History: See also timeline

- 1949: First motorized oversnow visitors enter Yellowstone by snowplane.
- 1955: First use of snowcoaches (Bombardiers) in Yellowstone.
- 1963: First snowmobiles (six, total) entered the park.
- 1967: Congressional hearing held on plowing Yellowstone's roads year-round.
- 1968: Yellowstone managers decided, instead of plowing, to formalize their over-snow program.
- 1971: Managers begin grooming roads and Yellowstone Park Co. opened Old Faithful Snowlodge for first time.
- 1990: NPS issued *Winter Use Plan Environmental Assessment* for Yellowstone and Grand Teton National Parks.
- 1997: 1,084 bison killed upon leaving the park amid concerns about transmitting brucellosis to Montana cattle. Fund for Animals filed lawsuit; NPS signed agreement requiring development of a new winter use plan and environmental impact statement (EIS).
- 1999: Draft EIS released, received more than 48,000 public comments.
- 2000: The final EIS released, received about 11,000 public comments; record of decision (ROD) signed.
- 2000: December: The International Snowmobile Manufacturers Association (ISMA), et al. files suit challenging the proposed ban.
- 2001: January: The final rule published in the Federal Register; would ban snowmobiles from Yellowstone and Grand Teton in the winter of 2003–04.
- 2001: June: Settlement agreement reached with ISMA; NPS agrees to

prepare a supplemental environmental impact statement (SEIS).

- 2002: spring: draft SEIS released; more than 350,000 comments received.
- 2003: Final SEIS and ROD signed, and on December 11, final rule published in *Federal Register*; allowed 950 Best Available Technology, guided snowmobiles daily.
- 2003: December 16: Judge Sullivan remands 2003 (SEIS) decision and directs NPS to begin phasing out recreational snowmobile use in Yellowstone.
- 2004: February 10: Judge Brimmer issues preliminary injunction against 2001 Final Rule (first EIS) banning snowmobiles. In October, he invalidated that rule.
- 2004: NPS completed EA for Temporary Winter Use Plans for Yellowstone & Grand Teton national parks; 95,000 comments received.
- 2005: NPS began preparation of third EIS on winter use; 33,000 scoping comments received.

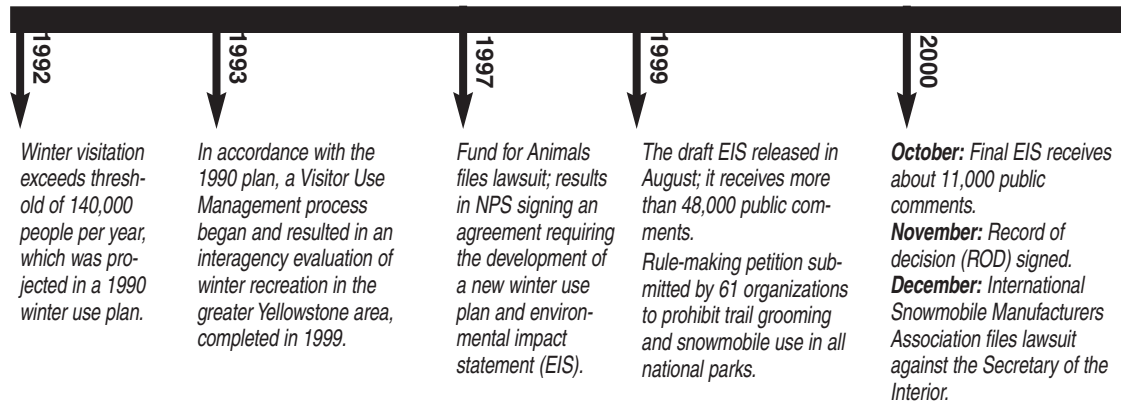
Current Status: See also p. 173

Under a three-year plan in effect through 2006-2007, limited numbers of snowmobiles with professional guides can enter Yellowstone during the winter season.

Winter Use Goals

- Provide a high quality, safe and educational winter experience for visitors.
- Provide for visitor and employee health and safety.
- Preserve pristine air quality.
- Preserve natural soundscapes.
- Mitigate impacts to wildlife.
- Minimize adverse economic impacts to gateway communities.

Updates: <http://www.nps.gov/yell/plan-visit/winteruse/index.htm>



and automobiles. The matter culminated in a congressional hearing in Jackson, Wyoming, in 1967. By this time, Yellowstone's managers realized that if they plowed, the look and feel of the park's winter wilderness would be dramatically altered. Snowmobiles offered them a way to accommodate visitor use while preserving a park-like atmosphere. Consequently, managers chose to formalize their oversnow vehicle program, believing it would preserve park resources better than plowing. In 1971, they began grooming snowmobile routes to provide smoother, more comfortable touring, and also opened Old Faithful Snowlodge, so that visitors could stay overnight at the famous geyser.

Throughout the 1970s, 80s, and early 90s, visitation by snowmobile grew consistently (some visitors continued to take snowcoaches into the park, but not until recently did snowcoach use substantially grow). This growth brought unanticipated problems, especially air and noise pollution, conflicts with other users, and wildlife harassment.

In 1990, recognizing that in solving one problem, others were developing, park managers completed the *Winter Use Plan Environmental Assessment* for Yellowstone and Grand Teton national parks and the John D. Rockefeller, Jr. Memorial Parkway. This plan formalized the park's existing winter use program and included a commitment to examine the issue further if winter visitation exceeded certain thresholds.

In the winter of 1992–1993, winter use exceeded the projection for the year 2000 (143,000 visitors), and shortly thereafter the Continental Divide Snowmobile Trail opened through Grand Teton National Park. According to the 1990 plan, then, NPS began a Visitor Use Management analysis, which included all types of winter recreation on all NPS and U.S. Forest Service (USFS) lands in the greater Yellowstone area. Park and forest staff utilized scientific studies, visitor surveys, and public comments to analyze the issues or

problems with winter use. The final report, *Winter Use Management: A Multi-Agency Assessment*, published in 1999, made many recommendations to park and forest managers and summarized the state of knowledge regarding winter use at that time.

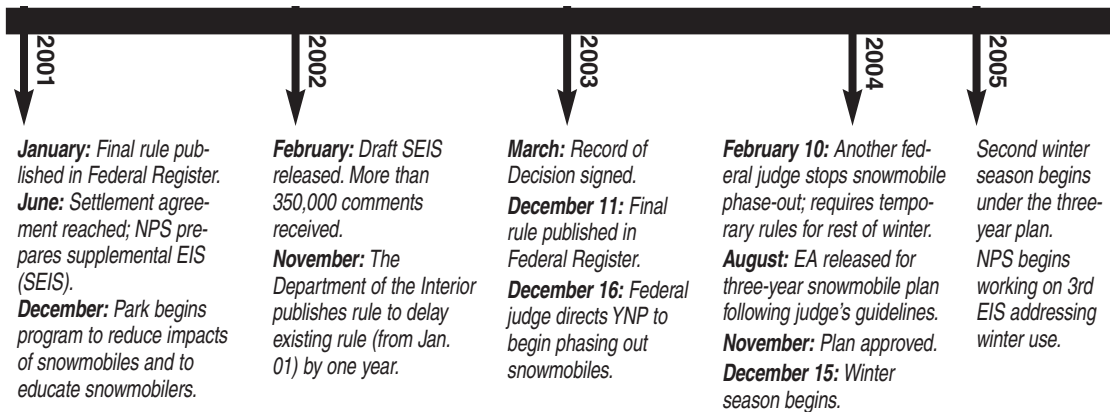
A Lawsuit and the First Environmental Impact Statement

During the severe winter of 1996–97, more than 1,000 bison left the park and were shot or shipped to slaughter amid concerns they could transmit brucellosis to cattle in Montana. Concerned that groomed roads increased the number of bison leaving the park and being killed, the Fund for Animals and other stakeholders filed suit in Washington, D.C. Federal District Court against NPS in May 1997. The lawsuit listed three primary complaints:

- NPS had failed to prepare an environmental impact statement concerning winter use in Yellowstone and Grand Teton national parks and the Rockefeller Parkway.
- NPS had failed to consult with the U.S. Fish and Wildlife Service on the effects of winter use on threatened and endangered species.
- NPS had failed to evaluate the effects of road grooming in the parks on wildlife and other park resources.

In October 1997, all parties signed an agreement to settle the lawsuit; mainly, NPS would prepare a new winter use plan and corresponding environmental impact statement (EIS), and would consult with the U.S. Fish and Wildlife Service on the effects of winter use on threatened and endangered species.

Park planners began preparing the EIS and associated winter use plan in early 1998. Besides addressing the concerns of the lawsuit, the plan had several overarching goals, which have remained the same throughout all subsequent winter planning efforts and are listed in the sidebar on page 169.



In August 1999, NPS released a draft EIS for public comment. The alternatives addressed the issues of visitor access, sound, emissions, wildlife concerns, and affordability. The preferred alternative called for, among other things, plowing the road from West Yellowstone to Old Faithful and allowing snowmobiles on other park roads (because the plowed road would not connect with other roads, plowing would not have altered park character substantially). The agency received more than 48,000 public comments that were fairly evenly split between those favoring snowcoach-only access and those desiring continued snowmobile use. Relatively few people favored plowing.

Separately, in January 1999, the Bluewater Network (a national conservation group) and 60 other associated organizations petitioned the Department of the Interior (DOI) to prohibit snowmobile trail grooming and use in all national park units. DOI did not formally respond to Bluewater Network, although in April 2000, DOI and NPS announced an intention to better implement the general snowmobile regulations and better comply with the laws and executive orders on off-road vehicle use on federal lands. The Network's

petition helped to transform the winter use issue from a regional controversy into a national one.

In February 2004, at the direction of Judge Emmet Sullivan in Washington (see "A Winter of Critical Judicial Decisions," page 171), DOI responded to the Bluewater Network's petition, stating a complete ban on snowmobiles throughout the park system was unnecessary. The memo said, "We continue to believe that each park presents a unique set of environmental conditions and uses and, as such, would be better served through individual analysis and rulemaking as to snowmobile management."

Returning to its EIS effort, NPS invited nine regional governmental agencies to be "cooperating agencies," which provide technical input to the EIS writers. The nine were the three local states (Idaho, Montana, and Wyoming), the five local counties (Gallatin and Park in Montana; Park and Teton in Wyoming; and Fremont County, Idaho), and the U.S. Forest Service. At a meeting with them in March 2000, NPS announced a new direction for the preferred alternative: using snowcoaches as the only mechanized access to the interior of Yellowstone. In part, NPS



Concerns Raised at Public Meetings

overcrowding
 visitor impacts on natural resources
 noise & air pollution
 availability of facilities and services
 use restrictions
 user group conflicts
 importance of winter visitation to the local and regional economy
 wildlife use of groomed surfaces
 wildlife displacement
 health & human safety

made this decision because the Environmental Protection Agency (EPA) designated it as the “environmentally preferred alternative” based on impacts to human health, air quality, water quality, and visibility; as well, NPS was responding to public opinion.

NPS released the final EIS proposing to ban snowmobiles and convert to snowcoach-only travel in October 2000. Attempting to fully engage the public, NPS accepted another 11,000 public comments, even though the Council on Environmental Quality (which oversees EIS development) does not require public review of a final EIS. The record of decision (ROD) was signed on November 22. These two steps (a final EIS and a ROD) are generally the first of three steps required for a federal agency to implement a major new policy. The third, publication of final regulations in the *Federal Register* (the publication used to advise Americans of new rules and decisions), occurred on January 22, 2001 (with another 5,200 public comments received). The new rules banned snowmobiles in the 2003–04 winter season, allowed for oversnow motorized recreational access by NPS-managed snowcoaches, and phased in these rules with reduced snowmobile numbers in the winter of 2002–03.

Significantly, the Record of Decision determined that past snowmobile use in the parks impaired the wildlife, air, soundscape, and

certain recreational resources of the three parks. As such, snowmobile use violated the National Park Service Organic Act of 1916.

A Second Lawsuit and a Supplemental EIS

On December 6, 2000, the International Snowmobile Manufacturers Association (ISMA, an industry trade group) and the State of Wyoming filed lawsuits in the U.S. District Court for the District of Wyoming against NPS challenging the validity of the decision to phase out snowmobiles. Meanwhile, NPS began implementing the winter use plan (from the recently-completed EIS), allowing existing snowcoach and snowmobile outfitters to add snowcoaches to their fleet, and allowing 11 new outfitters to provide snowcoach tours. NPS also partnered with the U.S. Department of Energy’s Idaho National Engineering and Environmental Laboratory (INEEL) to develop a snowcoach addressing the deficiencies of snowcoaches (unreliability, slow speeds, and cramped traveler conditions). The new vehicle would be multi-season, multi-passenger, multi-fueled, and fully accessible, and a prototype premiered in 2003 as the “New Yellow Bus.” Also, Yellowstone National Park began working with its partners to develop a marketing strategy for visiting Yellowstone by snowcoach.

In June 2001, the parties to the suit reached a settlement agreement, requiring NPS to prepare a Supplemental EIS (SEIS). The purpose of the SEIS was to consider new snowmobile technologies and solicit additional public involvement. Cooperating agencies involved in the EIS again participated in the development of the SEIS, with the addition of the EPA. The SEIS looked at a wide range of ideas for managing winter use in the parks and reviewed new data, including emissions information from industry and from NPS and state-sponsored studies. This work did not contradict the findings of impairment of park resources and values from past snowmobile use as found in the 2000 Record of Decision. Rather, it pointed NPS toward new solutions to those problems. NPS received nearly 360,000 public comments (many of them form letters). Although approximately 80% of these comments were opposed to continued snowmobile use in the parks, federal managers addressed the common concerns about snowmobile effects on wildlife, soundscapes, air quality, and visitor experience.





Park concessioners and NPS are testing new multi-season vehicles, such as this bus tested in 2004.

Park planners soon found they needed more time to analyze the voluminous public comment. Consequently, NPS published a rule (the “Delay Rule”) on November 18, 2002, which delayed the phase-out of snowmobiles by one year, to the winter of 2003–04. This detail would become more important than it might seem on the surface.

NPS released the final SEIS in February 2003, and the ROD was signed in March (the final rule on this decision would wait until December 2003). The SEIS goals remained the same as those in the original EIS. The Preferred Alternative was a package with several interrelated components, which were:

- To reduce air and noise pollution, all snowmobiles entering Yellowstone would be Best Available Technology (BAT), which used four-stroke engines to reduce hydrocarbon emissions 90 percent and carbon monoxide emissions 70 percent, compared to a standard two-stroke snowmobile. The same technologies reduced sound emissions to 73 decibels or below, when measured at full throttle.
- To address concerns about wildlife and safety, all snowmobilers in Yellowstone would be accompanied by an NPS-approved guide. Eighty percent of those would be commercial guides; 20 percent would be non-commercial group leaders who had attended a detailed training and orientation program).
- No more than 950 snowmobiles per day would be allowed into Yellowstone, with an additional 140 in Grand Teton National Park (such numerical restrictions would also help address noise and air pollution and wildlife concerns).
- NPS would implement a comprehensive monitoring and adaptive management program to assess the short- and long-term effects of management actions on park resources and values. Adjustments would be made in the management of the parks as a result of the monitoring.

- NPS would continue to develop a new generation of snowcoaches as a key to winter transportation, and 15 miles of side roads were designated snowcoach only.

A Winter of Critical Judicial Decisions

Upset over the proposed return to snowmobiling, the Fund for Animals and the Greater Yellowstone Coalition (GYC) both quickly filed suits contesting the SEIS and its new direction for winter use. The Fund for Animals lawsuit argued road grooming in Yellowstone had adversely affected bison distribution, abundance, and ecology, and called for an end to all road grooming, with the exception of the road from the South Entrance to Old Faithful, where few bison are located. GYC alleged (among other things) the change in snowmobile policy was unnecessary and snowmobile impacts were inconsistent with the mission of Yellowstone. Because the lawsuits had points in common, they were considered jointly by Judge Sullivan of the U.S. District Court in Washington, D.C. (the same court where the 1997 suit was filed).

While these lawsuits were under consideration, NPS proceeded with implementing the winter use plan. For example, the agency worked with Xanterra (Yellowstone’s primary concessioner) to establish a new entrance reservation system for non-commercial snowmobiles to ensure that the 950 daily limit would not be exceeded.

On December 11, 2003, NPS published the final rule implementing the SEIS in the Federal Register. Five days later—just 13 hours before the park was to open under the newly approved rule—the D.C. District Court discarded that rule. Judge Sullivan ruled in favor of GYC, writing that the March 2003 decision allowing snowmobiling to continue was “arbitrary and capricious,” a violation of the Administrative Procedures Act (APA) because it was a reversal of policy that needed extra justification; that the SEIS violated the National Environmental Policy Act (NEPA)

During the 2003–2004 winter season, two different judges struck down two different NPS decisions, because both violated the same two laws.

by not including a full range of alternatives (specifically one permitting no road grooming); and that NPS did not adequately explain why grooming did or did not affect bison populations. Because his decision was rendered when the delay rule was to take effect, Judge Sullivan directed Yellowstone National Park to begin the snowmobile phase-out as stipulated in the delay rule. Consequently, park authorities began the winter allowing only commercially-guided snowmobiles in the park with 11 or fewer machines, and no more than 493 snowmobiles per day could enter Yellowstone. Also, the new reservation system was abandoned.

Anticipating an unfavorable ruling from Judge Sullivan, ISMA and the State of Wyoming moved in December 2003 to

reopen their original (2000) lawsuit in Wyoming District Court, again contesting the snowmobile phase-out. On February 10, 2004, Judge Clarence Brimmer of the Wyoming court ruled in favor of ISMA and Wyoming, issuing a preliminary injunction barring NPS from implementing the snowmobile phase-out. That October, he finalized his decision, writing that NPS violated the same two laws that Judge Sullivan said NPS had violated: the APA and NEPA. He said NPS had failed to fully analyze the snowcoach-only alternative (violating NEPA); failed to adequately involve the public (violating NEPA); and did not provide adequate justification for a reversal of several decades of snowmobile access (violating the APA).

Because Brimmer's February injunction came

Legal Framework for Snowmobiles in National Parks

National Park Service Organic Act of 1916:

To conserve the scenery and the natural and historic objects and the wildlife therein and to provide for the enjoyment of the same and by such means as will leave them unimpaired for the enjoyment of future generations.

NPS Management Policies—2001: Impairment is an impact that, in the professional judgement of the responsible NPS manager, would harm the integrity of the park resources or values, including the opportunities that would otherwise be present for the enjoyment of those resources and values.

General Authorities Act—1978: The authorization of activities shall be construed and the protection, management, and administration of these areas shall be conducted in light of the high public value and integrity of the National Park System and shall not be exercised in derogation of the values and purposes for which these various areas have been established, except as may have been or shall be directly and specifically provided for by Congress.

National Parks and Recreation Act—1978: Directs that management plans be prepared for all units of the National Park System that include, but are not limited to: (3) identification of and implementation commitments for visitor carrying capacities for all areas of the unit.

Clean Air Act: Section 160 states one of the purposes of the act is "to preserve, protect, and enhance the air quality in national parks, national wilderness areas, national monuments, national seashores, and other areas of special national or regional natural, recreational, scenic, or historic value."

Section 162 mandates the designation of national park areas greater than 6,000 acres and wilderness areas greater than 5,000 acres as Class I.

Yellowstone and Grand Teton national parks are mandatory Class I areas.

Section 169(A) states that "Congress hereby declares as a national goal the prevention of any future, and the remedying of any existing impairment of visibility in mandatory Class I Federal areas which impairment results from any manmade air pollution."

E.O. 11644—2/8/72 (President Nixon) "Use of Off-Road Vehicles on the Public Lands": Areas and trails shall be located in areas of the National Park System only if the respective agency head determines that off-road vehicle use in such locations will not adversely affect their natural, esthetic or scenic values.

E.O. 11989—5/24/77 (President Carter): The respective agency head shall, whenever he determines that the use of off-road vehicles will cause or is causing considerable adverse effects on the soil, vegetation, wildlife, wildlife habitat or cultural or historic resources of the particular areas or trails of the public lands, immediately close such areas or trails to the type of off-road vehicle causing such effects, until such time as he determines that such adverse effects have been eliminated and that measures have been implemented to prevent future recurrences.

Departmental Implementation of Executive Order 11644, as amended by E.O. 11989, pertaining to use of off-road vehicles on the public lands (DOI prepared EIS, 1976): Clearly defines use of snowmobiles on roads as off-road vehicles.

36 CFR 2.18: The use of snowmobiles is prohibited, except where designated and only when their use is consistent with the park's natural, cultural, scenic, and esthetic values, safety considerations, park management objectives, and will not disturb wildlife and damage park resources.

in the middle of Yellowstone's winter season, he further ordered NPS to issue temporary regulations for the rest of the 2003–2004 season that were “fair and equitable to all parties.” Consequently, Yellowstone and Grand Teton authorities scrambled again to come up with winter rules. This time, they used the authority in 36 CFR 1.5 (known as the “superintendent’s compendium”) to allow continued, managed snowmobile use in the parks. These temporary rules allowed 780 snowmobiles per day in Yellowstone and 140 per day in Grand Teton for the remainder of that season. All additional snowmobiles beyond the 493 already permitted daily would have to be BAT machines and commercially guided.

By the end of that winter, then, two different judges had struck down two different NPS decisions, because both violated the same two laws. In both cases, the winning plaintiffs were interested stakeholders feeling disenfranchised from decisions they arguably viewed as extreme, and all chose courts they believed would be sympathetic to their cause.

The Temporary Plan

Because it had no clear rules under which to operate Yellowstone for the 2004–05 winter season, NPS wrote the *Temporary Winter Use Plans Environmental Assessment* in 2004. The EA reflected the experience gained between 1998 and 2004. For example, requiring all visitors to use approved, commercial guides best protected park resources while offering visitors a quality winter experience. As evidence, law enforcement incidents were well below historic numbers for the winter of 2003–04, even after accounting for reduced visitation.

The temporary plan was approved in November 2004 with a “Finding of No Significant Impact” (FONSI) and a Final Rule published in the *Federal Register*, and implemented with the 2004–2005 winter season (EAs have fewer decision-making steps, not requiring RODs). Its provisions include:

- 720 snowmobiles are allowed to enter the park each day.
- All snowmobiles must be commercially guided.
- All recreational snowmobiles entering Yellowstone must meet BAT standards for reducing noise and air pollution.

This temporary winter use management plan

is a balanced approach ensuring park resources are protected, providing visitors access to the parks, and giving visitors, employees, and residents of the park’s gateway communities the information they need to plan for the next few years. The plan is in effect through the 2006–07 winter season. If a new plan is not approved, both snowmobile and snowcoach use will phase out.

Outlook

Various lawsuits were filed contesting the EA decision and some are still being considered. In October 2005, Judge Brimmer ruled on the most visible such lawsuit, from the State of Wyoming and the Wyoming Lodging and Restaurant Association against NPS contesting the temporary winter use plan. Brimmer ruled in favor of NPS, but retained jurisdiction over future NPS winter use decisions. Other court proceedings will continue and their result is unpredictable.

Separately, the U.S. Congress passed appropriations bills including language requiring the temporary winter use rules be followed in both fiscal years 2005 and 2006. Such laws superseded legal actions and provided certainty to all interested stakeholders regarding the upcoming winters.

Meanwhile, the park’s scientists continue to monitor winter use. This information will be used to develop a new EIS that will result in new regulations for winter use for Yellowstone and Grand Teton national parks and the John D. Rockefeller, Jr. Memorial Parkway. In drafting the EIS, the park is continuing to work with its neighbors and partners—including concessioners, snowmobile and snowcoach guides and outfitters, chambers of commerce, businesses, the conservation community, and state tourism organizations. Park planners expect that regulations will be issued prior to the start of the 2007–08 winter season.

A historic turnabout in winter use has occurred in Yellowstone National Park. Rather than the essentially unmanaged situation of 40 years, the last two winters have seen the implementation of a well-managed, enjoyable winter use program. Yellowstone and Grand Teton national parks and the John D. Rockefeller, Jr. Memorial Parkway remain open for winter visitation, and are great places to visit.

Issues: Wolf Restoration

The Issue

The wolf is a major predator that had been missing from the Greater Yellowstone Ecosystem for decades until its restoration in 1995.

History

Late 1800s–early 1900s: predators, including wolves, were routinely killed in Yellowstone.

1926: The last wolf pack in Yellowstone was killed, although reports of single wolves continued.

1974: The gray wolf was listed as endangered; recovery is mandated under the Endangered Species Act.

1975: The long process leading to wolf restoration in Yellowstone began.

1991: Congress appropriated money for an EIS for wolf recovery.

1994: EIS completed for wolf reintroduction in Yellowstone and central Idaho. More than 160,000 public comments were received—the largest number of public comments on any federal proposal.

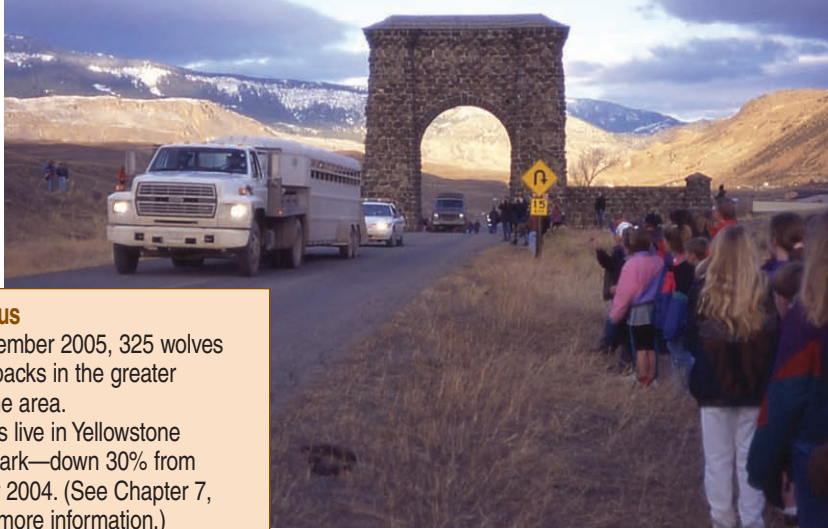
1995 and 1996: 31 gray wolves from western Canada were relocated to Yellowstone.

1997: U.S. District Court judge ordered the removal of the reintroduced wolves in Yellowstone, but stayed his order, pending appeal.

2000: January, the decision was reversed.

Current Status

- As of December 2005, 325 wolves live in 45 packs in the greater Yellowstone area.
- 118 wolves live in Yellowstone National Park—down 30% from December 2004. (See Chapter 7, “Wolf,” for more information.)
- 140 documented wolf deaths have occurred since the beginning of reintroduction. More than half the mortalities are human caused with the rest being natural. The leading natural cause of mortality is wolves killing other wolves.
- Livestock predation was expected to be 40–50 sheep and 10–12 cows per year, but has been much lower: 256 sheep, 41 cattle during 1995–2003.
- A private non-profit group, Defenders of Wildlife, compensates livestock owners for the value livestock proven to have been killed by wolves.
- Research is underway to determine impact of wolf restoration on cougars, coyotes, and elk.
- Delisting of the wolf from the endangered species list will be considered after the U.S. Fish and Wildlife Service approves management plans from the states of Wyoming, Montana, and Idaho. Wyoming's plan has not been approved; Montana's and Idaho's plans have been.
- In February 2005, wolf management authority transferred from the federal government to the states in Idaho and Montana.



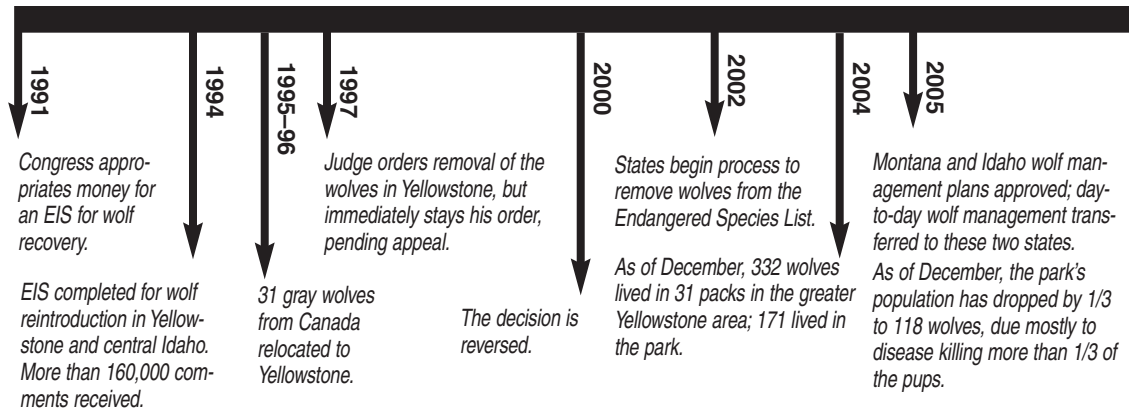
Welcoming the wolves on January 12, 1995

The gray wolf (*Canis lupus*) was present in Yellowstone when the park was established in 1872. Predator control, including poisoning, was practiced here in the late 1800s and early 1900s. Between 1914 and 1926, at least 136 wolves were killed in the park; by the 1940s, wolf packs were rarely reported. An intensive survey in 1978 found no evidence of a wolf population in Yellowstone, although an occasional wolf probably wandered into the area. A wolf-like canid was filmed in Hayden Valley in August 1992, and a wolf was shot just outside the park's southern boundary in September 1992. However, no verifiable evidence of a breeding pair of wolves existed. During the 1980s, wolves began to reestablish breeding packs in northwestern Montana; 50–60 wolves inhabited Montana in 1994.

Restoration Proposed

NPS policy calls for restoring native species when: a) sufficient habitat exists to support a self-perpetuating population, b) management can prevent serious threats to outside interests, c) the restored subspecies most nearly resembles the extirpated subspecies, and d) extirpation resulted from human activities.

The U.S. Fish & Wildlife Service (USFWS) 1987 Northern Rocky Mountain Wolf Recovery Plan proposed reintroduction of an “experimental population” of wolves into Yellowstone. (An experimental population, under section 10(j) of the Endangered Species Act, is considered nonessential and allows more management flexibility.) Most scientists



believed that wolves would not greatly reduce populations of mule deer, pronghorns, bighorn sheep, white-tailed deer, or bison; they might have minor effects on grizzly bears and cougars; and their presence might cause the decline of coyotes and increase of red foxes.

In 1991, Congress provided funds to the USFWS to prepare, in consultation with NPS and the U.S. Forest Service, an environmental impact statement (EIS) on restoration of wolves. In June 1994, after several years and a near-record number of public comments, the Secretary of the Interior signed the Record of Decision for the final EIS for reintroduction of gray wolves to Yellowstone National Park and central Idaho.

Staff from Yellowstone, the USFWS, and participating states prepared for wolf restoration to the park and central Idaho. The USFWS prepared special regulations outlining how wolves would be managed as an experimental population.

Park staff completed site planning and archeological and sensitive plant surveys for the release sites. Each site was approximately one acre enclosed with 9-gauge chain-link fence in 10 x 10 foot panels. The fences had a two-foot overhang and a four-foot skirt at the bottom to discourage climbing over or digging under the enclosure. Each pen had a small holding area attached to allow a wolf to be separated from the group if necessary (i.e., for medical treatment). Plywood boxes provided shelter if the wolves desired isolation from each other.

Relocation & Release

In late 1994/early 1995, and again in 1996, USFWS and Canadian wildlife biologists captured wolves in Canada and relocated and released them in both Yellowstone and central Idaho. In mid-January 1995, 14 wolves were temporarily penned in Yellowstone; the first 8 wolves on January 12 and the second 6 on



Released from the cage into the pen

January 19, 1995. Wolves from one social group were together in each release pen. On January 23, 1996, 11 more wolves were brought to Yellowstone for the second year of wolf restoration. Four days later they were joined by another 6 wolves. The wolves ranged from 72 to 130 pounds in size and from approximately nine months to five years in age. They included wolves known to have fed on bison. Groups included breeding adults and younger wolves one to two years old.

Each wolf was radio-collared as it was captured in Canada. While temporarily penned, the wolves experienced minimal human contact. Approximately twice a week, they were fed elk, deer, moose, or bison that had died in and around the park. They were guarded by law enforcement rangers who minimized the amount of visual contact between wolves and humans. The pen sites and surrounding areas were closed to visitation and marked to prevent unauthorized entry. Biologists checked on the welfare of wolves twice each week, using telemetry or visual observation while placing food in the pens. Although five years of reintroductions were predicted, no transplants occurred after

See Chapter 2 for more information on changes to the ecosystem.

See Chapter 7, "Wolf," for updates on wolf populations, including the decline due to disease.

1996 because of the early success of the reintroductions.

Some people expressed concern about wolves becoming habituated to humans while in captivity. However, wolves typically avoid human contact, and they seldom develop habituated behaviors such as scavenging in garbage. Captivity was also a negative experience for them and reinforced their dislike of humans.

Lawsuits

Several lawsuits were filed to stop the restoration on a variety of grounds. These suits were consolidated, and in December 1997, the judge found that the wolf reintroduction program in Yellowstone and central Idaho violated the intent of section 10(j) of the Endangered Species Act because there was a lack of geographic separation between fully protected wolves already existing in Montana and the reintroduction areas in which special rules for wolf management apply. The judge wrote that he had reached his decision "with utmost reluctance." He ordered the removal (and specifically not the killing) of reintroduced wolves and their offspring from the Yellowstone and central Idaho experimental population areas, but immediately stayed his order pending appeal. The Justice Department appealed the case, and in January 2000 the decision was reversed.

Results of the Restoration

Preliminary data from studies indicate that wolf recovery will likely lead to greater biodiversity throughout the Greater Yellowstone Ecosystem (GYE). Wolves have preyed primarily on elk and these carcasses have provided food to a wide variety of other animals, especially scavenging species. They are increasingly preying on bison, especially in late winter. Grizzly bears have usurped wolf kills almost at will, contrary to predictions and observations from other areas where the two species occur. Wolf kills, then, provide an important resource for bears in low food years. Aggression toward coyotes has decreased the number of coyotes inside wolf territories, which may benefit other smaller predators, rodents, and birds of prey.

So far, data suggests wolves are contributing to decreased numbers of calves surviving to

adulthood and decreased survival of adult elk in the Yellowstone elk herds. Wolves may also be affecting where and how elk use the habitat. Some of these effects were predictable, but were based on research in relatively simple systems of one to two predator and prey species. Such is not the case in Yellowstone, where four other large predators (black and grizzly bears, coyotes, cougars) prey on elk—and people hunt the elk outside the park. Thus, interactions of wolves with elk and other ungulates has created a new degree of complexity that makes it difficult to project long-term population trends.

The effect of wolf recovery on the dynamics of northern Yellowstone elk cannot be generalized to other elk populations in the GYE. The effects will be depend on a complex of factors including elk densities, abundance of other predators, presence of alternative ungulate prey, winter severity, and—outside the park—land ownership, human harvest, livestock depredations, and human-caused wolf deaths. A coalition of natural resource professionals and scientists representing federal and state agencies, conservation organizations and foundations, academia, and land owners are collaborating on a comparative research program involving three additional wolf-ungulate systems in the western portion of the GYE. These ongoing studies began 3–5 years ago; results to date indicate the effects of wolf predation on elk population dynamics range from substantial to quite modest.

Delisting

The biological requirement for removing the wolf from the endangered species list has been achieved: Three years of 30 breeding pairs across the three recovery areas. However, the states of Idaho, Montana, and Wyoming must have management plans that are acceptable to the U.S. Fish and Wildlife Service (USFWS). As of March 2006, Montana and Idaho have met this requirement, Wyoming has not. As a result, day-to-day wolf management has been transferred to the states of Montana and Idaho. (This does not mean wolves have been delisted.) Wolves in Wyoming are still managed by the USFWS. This change does not affect wolf management in Yellowstone.

Aquatic Invaders

**Staff reviewer: Todd M. Koel,
Supervisory Fisheries Biologist**

www.100thmeridian.org
nas.er.usgs.gov
www.sgnis.org

Benhke, R.J. 1992. Native Trout of Western North America. Monograph 6. Bethesda, MD: American Fisheries Society.

Elle, Steven. 1997. Comparative infection rates of cutthroat and rainbow trout exposed to *Myxobolus cerebralis* in Big Lost River, Idaho during June, July, and August. Whirling Disease Symposium, Logan, UT.

Gunther, Kerry. Grizzly bears and cutthroat trout: Potential impact of the introduction of non-native trout to Yellowstone Lake. Bear Management Office Information Paper. Number BMO-9.

Koel, Todd et al. Yellowstone Fisheries & Aquatic Sciences. Yellowstone National Park. Annual.

MacConnell, E. et al. 1997. Susceptibility of grayling, rainbow, and cutthroat trout to whirling disease by natural exposure to *Myxobolus cerebralis*. Whirling Disease Symposium, Logan, UT.

Mahony, D.L. and C.J. Hudson. 2000. Distribution of *Myxobolus cerebralis* in Yellowstone cutthroat trout *Oncorhynchus clarki bouvieri* in Yellowstone Lake and its tributaries. Whirling Disease Symposium, Coeur d'Alene, Idaho.

Mattson, D.J., and D.P. Reinhart. 1995. Influences of cutthroat trout on behavior and reproduction of Yellowstone grizzly bears 1975–1989. *Can. J. Zool.* 73:2072–2079.

Nickum, D. 1999. *Whirling disease in the United States: a summary of progress in research and management*. Arlington, VA: Trout Unlimited.

Reinhart, D.P. and D.J. Mattson. 1990. Bear use of cutthroat trout spawning streams in YNP. *Int. Conf. Bear Res. and Manage.* 8:343–350.

Varley, J. D. and P. Schullery. 1996. Yellowstone Lake and its cutthroat trout in *Science and Ecosystem Management in the National Parks*. Halvorson, W. L., and G. E. Davis, eds. Tucson: U. of Arizona Press.

Varley, J. D., and P. Schullery, eds. 1995. The Yellowstone Lake crisis: confronting a lake trout invasion. A report to the director of the NPS. Mammoth, WY: NPS.

Vincent, E.R. 1996. Whirling disease and wild trout: the Montana experience. *Fisheries* 21(6): 32–33.

Bioprospecting

Staff reviewers: Ann Deutch, Sue Mills, Environmental Protection Specialist

www.nature.nps.gov/benefitssharing

Doremus, H. 1999. Nature, knowledge, and profit: the Yellowstone bioprospecting controversy and the core purposes of America's national parks. *Ecol. Law Quarterly* 26:401–488.

Doremus, Holly. 2004. Contracts for bioprospecting: The Yellowstone National Park Experience. In *Microbial Diversity and Bioprospecting*, Alan T. Bull, ed. Washington: American Society for Microbiology Press.

Bison Management & Brucellosis

Staff reviewer: Rick Wallen, Bison Ecology & Management

www.nps.gov/gyibc
www.nps.gov/yell

Cheville, N.F. et al. 1998. *Brucellosis in the Greater Yellowstone Area*. Washington, DC/National Academy Press.

Irby, L. and J. Knight, eds. 1998. *International Symposium on Bison Ecology and Management in North America*. Mont. State Univ., Bozeman.

Meagher, M. and M. E. Meyer. 1995. Brucellosis in captive bison. *J. Wildl. Dis.* 31(1):106–110.

Meagher, M. and M. E. Meyer. 1994. On the origin of brucellosis in bison of Yellowstone National Park: A review. *Conserv. Biol.* 8(3):645–653.

Meyer, M. E. and M. Meagher. 1995. Brucellosis in free-ranging bison (*Bison bison*) in Yellowstone, Grand Teton, and Wood Buffalo National Parks: A Review. Letter to the Editor in *J. Wildl. Dis.* 32(4):579–598.

Grizzly & Black Bear Management

Staff reviewer: Kerry Gunther, Bear Management Biologist

Anderson, C. et al. 2005. Reassessing methods to estimate population size and sustainable mortality limits for the Yellowstone grizzly bear. Report. Interagency Grizzly Bear Study Team. Bozeman, MT: Montana State University.

Blanchard, B.M. and R.R. Knight. 1995. Biological consequences of relocating grizzly bears in the Yellowstone ecosystem. *J. Wildl. Manage.* 59:560–565.

Cole, G. F. 1974. Management involving grizzly bears and humans in Yellowstone National Park, 1970–1973. *BioScience* 24:6.

Felicetti, L.A. et al. 2003. Use of sulfur and nitrogen stable isotopes to determine the importance of whitebark pine nuts to Yellowstone grizzly bears. *Can. J. Zoology* 81:763–770.

Felicetti, L.A. et al. 2004. Use of naturally occurring mercury to determine the importance of cutthroat trout to Yellowstone grizzly bears. *Can. J. Zoology* 82(3):493–501.

Gunther, K.A. et al. 2004. Grizzly bear–human conflicts in the GYE, 1992–2000. *Ursus* 15(1): 10–22.

Gunther, K.A., and D.L. Smith. 2004. Interactions between wolves and female grizzly bears with cubs in YNP. *Ursus* 15(2):232–238.

Gunther, K.A. et al. 2004. Management of habituated grizzly bears in North America in: J. Rahm ed., *Transactions of the 69th North American Wildlife and Natural Resources Conference*. Washington: Wildlife Management Institute.

Gunther, K.A. et al. 2002. Probable grizzly bear predation on an American black bear in Yellowstone National Park. *Ursus* 13:372–374.

Haroldson, M.A. et al. 2005. Changing numbers of spawning cutthroat trout in tributary streams of Yellowstone Lake and estimates of grizzly bears visiting streams from DNA. *Ursus* 16(2):167–180.

Haroldson, M.A. et al. 2002. Grizzly bear denning chronology and movements in the GYE. *Ursus* 13:29–37.

Herrero, S. et al. 2005. Brown bear habituation to people—safety, risks, and benefits. *Wildlife Society Bulletin* 33(1):362–373.

Kieter, Robert B. 1991. Observations on the future debate over 'delisting' the grizzly bear in the GYE. *The Environmental Professional* 13.

Mattson, D.J. et al. 1996. Designing and managing protected areas for grizzly bears: how much is enough? In R. G. Wright, ed. *National Parks and Protected Areas: Their Role in Environmental Protection*. Cambridge: Blackwell Science.

Podrzensky, S.R. et al. 2002. Grizzly bear denning and potential conflict areas in the GYE. *Ursus* 13: 19–28.

Schwartz, C.C. et al. 2002. Distribution of grizzly bears in the GYE, 1990–2000. *Ursus* 13: 203–212.

Servheen, C., M. et al. 2004. Yellowstone mortality and conflicts reduction. Report. Missoula, MT: U.S. Fish and Wildlife Service.

Varley, N., and K.A. Gunther. 2002. Grizzly bear predation on a bison calf in YNP. *Ursus* 13:377–381.

Wyman, T. 2002. Grizzly bear predation on a bull bison in YNP. *Ursus* 13:375-377.

Northern Range

Staff reviewer: P.J. White, Wildlife Biologist

Houston, D.B. 1982. *The Northern Yellowstone Elk: Ecology and Management*. New York: Macmillan Publishing Co.

Huff, D. E. and J.D. Varley. 1999. Natural regulation in Yellowstone National Park's Northern Range. *Ecol. Appl.* 9(1):17-29.

Krauseman, P. R. 1998. Conflicting views of ungulate management in North America's western national parks. *Wildlife Soc. Bull.* 26(3): 369-371.

National Research Council. 2002. *Ecological Dynamics on Yellowstone's Northern Range*. National Academy Press: Washington

Yellowstone National Park 1997. *Yellowstone's Northern Range: Complexity and Change in a Wildland Ecosystem*. NPS/Mammoth, WY.

Wilderness

Staff reviewer: Ivan Kowski Asst.

**Backcountry Manager, Dan Reinhart,
Resource Management Specialist**

www.wilderness.nps.gov

www.wilderness.net

www.LNT.org

National Park Service. 1972. *Wilderness Recommendation: Yellowstone National Park*.

National Park Service. 2003. NPS Annual Wilderness Report 2002-2003.

Wilderness Act of 1964. U.S. Code, 16: 1131-1136.

Wilderness Preservation and Management: NPS Reference Manual 41.
www.nps.gov/policy/DOrders/RM41.doc

Winter Use

Staff reviewer: Michael J. Yochim, Outdoor Recreation Planner

Aune, K. E. 1981. *Impacts of winter recreationists on wildlife in a portion of Yellowstone National Park, Wyoming*. Thesis. Montana State University, Bozeman.

Bishop, G. A. and D. H. Stedman. 1998. Preliminary snowmobile emission survey in Yellowstone National Park. Final report to Yellowstone National Park.

Bjornlie, D.D. and R. A. Garrott. 2001. Ecological effects of winter road grooming on bison in Yellowstone National Park. *Journal of Wildlife Management*, 65:423-435.

Creel, S. et al. 2002. Snowmobile activity and glucocorticoid stress responses in wolves and elk. *Conservation Biology*, 16:809-814.

Hardy, A. 2001. *Bison and elk responses to winter recreation in Yellowstone National Park*. Thesis, Montana State University, Bozeman.

Ingersoll, G.P. 1999. Effects of snowmobile use

on snowpack chemistry in Yellowstone National Park, 1998. Water-Resources Investigations Rep. 99-4148. Denver: USGS

Olliff, T. et al, eds. 1999. Effects of winter recreation on wildlife of the greater Yellowstone area: a literature review and assessment. Report to the Greater Yellowstone Coordinating Committee.

Wolf Restoration

Staff reviewer: Deb Guernsey; Douglas W. Smith, Wolf Project Leader

Bangs, E. E., and S. H. Fritts. 1996. Reintroducing the gray wolf to central Idaho and YNP. *Wildlife Soc. Bull.* 24(3):402-413.

Bangs, Edward et al. 2001. Gray wolf restoration in the northwestern United States. *Endangered Species Update* 18(4):147-152.

Carbyn, Ludwig et al. 1995. *Ecology and Conservation of Wolves in a Changing World*. Edmonton: U. of Alberta.

Creel, S. et al. 2002. Snowmobile activity and glucocorticoid stress responses in wolves and elk. *Cons. Biology* 16(3): 809-814.

Eberhardt, L.L. et al. 2003. Assessing the impact of wolves on ungulate prey. *Ecological Applications*. 13(3): 776-783.

Ferguson, Gary. 1996. *The Yellowstone Wolves: The First Year*. Helena, MT: Falcon Press.

Fischer, Hank. 1995. *Wolf Wars*. Helena, MT: Falcon Press.

Fritts, S.H. 2000. Review of Carnivores in Ecosystems: the Yellowstone Experience. *Ecology* 81(8): 2351-2352.

Gunther, K. A. and D.W. Smith. 2004. Interactions between wolves and female grizzly bears with cubs in YNP. *Ursus* 15(2):232-238.

Halfpenny, James C. 2003. *Yellowstone Wolves: In the Wild*. Helena, MT: Riverbend Press

Lopez, Barry. 1978. *Of Wolves and Men*. New York: Scribners.

McIntyre, Rick, ed. 1995. *War against the Wolf: America's Campaign to Exterminate the Wolf*. Stillwater, MN: Voyageur Press.

McIntyre, Rick. 1993. *A Society of Wolves: National Parks and the Battle over the Wolf*. Stillwater, MN: Voyageur Press.

McNamee, Thomas. 1997. *The Return of the Wolf to Yellowstone*. New York: Henry Holt.

MacNulty, D.R. et al. 2001. Grizzly bear usurps bison calf captured by wolves in YNP. *Can. Field Nat.* 115:495-498.

Mech, L. David et al. 2001. Winter severity and wolf predation on a formerly wolf-free elk herd. *J. Wildlife Mgt*, 65(4):998-1003.

Peterson, R.O. et al. 2002. Leadership behavior in relation to dominance and reproductive status in gray wolves, *Canis lupus*. *Can. J. Zool.* 80:1405-1412.

Phillips, Michael K. and Douglas W. Smith.

1998. Gray wolves and private landowners in the Greater Yellowstone Area. *Transactions 63rd North American Wildlife and Natural Resources Conference*.

Phillips, Michael K. and Douglas W. Smith. 1996. *The Wolves of Yellowstone*. Stillwater, MN: Voyageur Press.

Ruth, T.K. 2000. Cougar-wolf interactions in Yellowstone National Park: Competition, demographics, and spatial relationships. *Wildlife Conservation Society* August:1-28.

Smith, D. W. 2005. Meet five, nine, and fourteen: Yellowstone's heroine wolves. *Wildlife Conservation*, 108(1):28-33.

Smith, D.W. 2005. Ten years of Yellowstone Wolves. *Yellowstone Science*, 13(1):7-33.

Smith, D.W. and Gary Ferguson. 2005. *Decade of the Wolf: Returning the Wild to Yellowstone*. Guilford, CT: Lyons

Smith, Douglas and Michael K. Phillips. 2000. Northern Rocky Mountain wolf in *Endangered Animals*. Greenwood Press.

Smith, Douglas et al. Yellowstone Wolf Project Annual Report. Annual.

Smith, Douglas et al. 2004. Winter prey selection and estimation of wolf kill rates in YNP. *J Wildlife Mgt*. 68(1): 153-166

Smith, Douglas et al. 2003. Yellowstone after wolves. *BioScience*. April, 53(4): 330-340

Smith, Douglas et al. 2001. Killing of a bison calf by a wolf and four coyotes in YNP. *Can. Field Nat.* 115(2): 343-345.

Smith, Douglas et al. 2000. Wolf-bison interactions in YNP. *J Mammalogy*, 81(4): 1128-1135.

Smith, Douglas et al. 1999. Wolves in the GYE: Restoration of a top carnivore in a complex management environment in *Carnivores in Ecosystems*. New Haven: Yale U. Press.

Stahler, Daniel R. et al. 2002. The acceptance of a new breeding male into a wild wolf pack. *Can. J. Zoology*. 80:360-365.

U.S. Fish and Wildlife Service. 1994. Final EIS: The Reintroduction of Gray Wolves to YNP and Central Idaho.

Varley, John D. and Paul Schullery. 1992. Wolves for Yellowstone? A Report to the United States Congress.

Additional Information from Yellowstone National Park

www.nps.gov/yell

Yellowstone Science, published quarterly. Free; available from the Yellowstone Center for Resources, in the Yellowstone Research Library, or online at www.nps.gov/yell.

Yellowstone Today, park newspaper. Free at entrance gates and visitor centers.

Site Bulletins, published as needed, provide more detailed information on park topics such as bison management, lake trout, grizzly bears, and wolves. Free; available upon request from visitor centers.

MAJOR AREAS OF THE PARK

10

Canyon Area



Lower Falls

Grand Canyon of the Yellowstone

Formation

The Grand Canyon of the Yellowstone has been celebrated in paintings, photographs, poetry, and prose since the time it was first captured on canvas by painter Thomas Moran. Its depth and colors result from the combined forces of fire, ice, and water.

The current canyon dates back to the end of the last glaciation, 14,000 years ago. Melt waters associated with the last glaciation carved the current V-shaped valley. Water continues to erode hydrothermally-altered volcanic rocks. The hydrothermal activity makes the volcanic rocks easier to erode and causes the colors in the canyon's walls.

About the Falls

The Upper and Lower Falls are formed by the Yellowstone River as it flows over rhyolite rocks resistant to erosion. The first falls, Upper Falls, is 109 feet high; it can be seen from the Brink of the Upper Falls Trail, from the beginning of the Brink of the Lower Falls

FREQUENTLY ASKED QUESTIONS

Where can I see the canyon/falls?

Lower Falls: (Photo at left.) North Rim at Inspiration, Lookout & Red Rock Points, plus the brink overlook; South Rim at Artist Point, from Uncle Tom's Trail, and from a few places along the South Rim Trail.

Upper Falls: (Photo next page.) North Rim, at the beginning of Brink of the Lower Falls trail, from viewing area between exit of North Rim drive and entrance to South Rim Drive; South Rim, from two viewpoints at Uncle Tom's Parking Area.

What causes the different colors in the canyon?

The colors are caused by the oxidation of iron compounds in the rhyolite rock, which has been hydrothermally altered. You could say the canyon is "rusting."

Is there a place where I can see both falls at once?

No. The canyon bends between the Upper and Lower falls, so there is no location where they can be seen at the same time.

How tall are the falls?

Upper Falls: 109 ft; Lower Falls: 308 ft.

How big is the canyon?

The canyon is roughly 20 miles long. It varies from 800 to 1,200 feet deep, and is 1,500 to 4,000 feet wide.

How can I get to the bottom of the canyon?

Only one trail in this area leads to the bottom of the canyon—Seven Mile Hole Trail, a strenuous, steep round trip of 11 miles.

How much water goes over the falls?

The volume varies from 63,500 gallons per second at peak runoff to 5,000 gallons per second in the late fall.

What causes the green stripe in the Lower Falls?

A notch in the lip in the brink makes the water deeper and keeps it from becoming turbulent as it goes over the edge.

Who was Uncle Tom?

"Uncle Tom" Richardson was an early concessioner in the canyon area. He guided visitors to the canyon bottom down a steep trail using rope ladders. (This is the present Uncle Tom's Trail, which descends partway into the canyon via steep steel steps.) He lost his permit in 1906 after the Chittenden Bridge was completed.

What are the large birds that look like eagles?

They are osprey, and they nest in the canyon from late April until late August or early September. Look for nests from Grandview, Lookout, and Artist points.

10

Canyon

Trail, and from viewpoints at Uncle Tom's Parking Area. The Lower Falls is 308 feet high and can be seen from Lookout Point, Red Rock, Artist Point, Brink of the Lower Falls Trail, and from various points along the South Rim Trail. A third falls, Crystal Falls, enters the canyon between the Upper and Lower falls. It is a waterfall on Cascade Creek and can be seen from the South Rim Trail just west of Uncle Tom's parking area.



Above: The Upper Falls
Right: Glacial Boulder, on
the road to Inspiration
Point

Colors in the Canyon

The colors in the canyon are a result of hydrothermal alteration of iron compounds in the rhyolite. Exposure to the elements caused the rocks to change colors as they oxidized. The colors indicate the presence or absence of water in the individual iron compounds. Most of the yellows in the canyon result from iron and sulfur in the rock.

Wildlife

Look carefully among the canyon's rugged pinnacles for osprey soaring over the Yellowstone River or perched on their five-foot diameter nests. Since the mid-1980s, six to ten osprey nests have been occupied in the portion of the canyon near Canyon Village.

Adult osprey return here between mid-April and early May, depending on weather patterns. By mid-May, the female is incubating two to four tan-with-brown speckled eggs. The eggs hatch in about six to eight weeks. By mid- to late August, the young are nearly the size of their parents and become increasingly independent. Typically, the entire family abandons the canyon by September, probably roosting in trees nearer to the waters where they catch fish.

Sometime during autumn, the entire population of Yellowstone osprey heads south to wintering areas along the coasts of Mexico and Central America.



You may also see ravens, bald eagles, and swallows flying throughout the canyon. Away from the canyon rims, you may see mule deer, moose, red foxes, grizzly and black bears, coyotes, Steller's jays, and great gray owls. During the peak wildflower season in July, a variety of butterflies feast on the abundant flowers in the meadows.

Hayden Valley

The Yellowstone River flows through Hayden Valley between Yellowstone Lake and the Grand Canyon of the Yellowstone. The valley was once filled by a lake and, consequently, contains fine-grained lake sediments that are now covered with glacial till left from the most recent glacial retreat 14,000 years ago. Because the glacial till contains many different grain sizes, including clay and a thin layer of lake sediments, water cannot percolate quickly into the ground. Thus, Hayden Valley is marshy and has few trees.

Wildlife

Hayden Valley is one of the best places in the park to view a wide variety of large mammals. Grizzly bears are often seen in the spring and early summer when they may be eating winter-killed animals or preying upon elk calves. Large herds of bison may be viewed in the spring, early summer, and during the rut, which usually begins late July to early August. Coyotes can almost always be seen in the valley; wolves are also sometimes seen.

Birds are abundant. Shore birds feed in the mud flats at Alum Creek. A pair of sandhill cranes usually nests at the south end of the valley. Ducks, geese, and American white pelicans cruise the river. Bald eagles and osprey hunt for fish along the river; northern harriers fly low looking for rodents in the grasses. Great gray owls are sometimes seen searching the meadows for food (these birds are sensitive to human disturbance).

Mt. Washburn

Mt. Washburn, named for General Henry Dana Washburn, leader of the 1870 Washburn–Langford–Doane Expedition, is the highest peak in the Washburn Range. It rises 10,243 feet and can be seen from many locations in the park. It is a remnant of an extinct stratovolcano from the Absaroka Volcanics of about 50 million years ago. The volcano was literally cut in half by collapse of the Yellowstone Caldera 640,000 years ago. Only the northern part of the original volcano is still visible. Bighorn sheep and wildflowers can be seen on its slopes in the summer, and black and grizzly bears are sometimes seen here. And it is an excellent place to view the Yellowstone Caldera to the southeast.

DAY HIKES

Mary Mountain: Moderately strenuous due to length; 21 miles one way. Climbs gradually up over Mary Mountain and the park's Central Plateau to the Nez Perce trailhead between Madison and Old Faithful. Can be hard to follow because bison knock down trail markers; also sometimes closed due to bear activity. Trailhead: north of Alum Creek pullout, 4 miles south of Canyon Junction.

Howard Eaton, Canyon to Norris portion: Moderately easy; little vertical rise; 3 to 12 miles one way; 2 to 8 hours, depending on how far you go. Passes through forest, meadow, and marshland to Cascade Lake (3 miles), Grebe Lake (4¼ miles), Wolf Lake (6¼ miles), Ice Lake (8¼ miles), and Norris Campground (12 miles). Can be very wet and muddy through July with many biting insects. Trailhead: pullout ¼ mile west of Canyon Junction on the Norris–Canyon Road. *See also Ice Lake Trail in the Norris Area.*

Cascade Lake: Easy; 5 miles round trip; 3 hours. Passes through open meadows and over small creeks. Can be very wet and muddy through July. Trailheads: pullout ¼ mile west of Canyon Junction on the Norris–Canyon Road or Cascade Lake Picnic Area, 1½ miles north of Canyon Junction on the Tower–Canyon Road.

Observation Peak: Strenuous; 11 miles round trip. The trail passes through open meadows to Cascade Lake (*see above*), then climbs 1,400 feet in three miles to a high mountain peak for an outstanding view of the Yellowstone wilderness. No water available. Not recommended for persons with heart and/or respiratory problems. Trailheads: *See Cascade Lake, above.*

Grebe Lake: Moderately easy; little vertical rise; 6 miles round trip; 3 to 4 hours. Follows old fire road through meadows and forest, some of which burned in 1988. At the lake you can connect with the Howard Eaton Trail (*see above*). Trailhead: 3½ miles west of Canyon Junction on the Norris–Canyon Road.

Seven Mile Hole: Strenuous; 11 miles round trip; 6 to 8 hours. Follows the canyon rim for the first 1½ miles, at which point you can see Silver Cord Cascade across the canyon. After another half mile joins the Washburn Spur Trail; after another 3 miles, the trail drops off to Seven Mile Hole, a 1½ mile, 1,400 foot drop. **Caution:** watch your footing and conserve your energy. Be especially careful where the trail passes both dormant and active hot springs. Off-trail travel is prohibited. Not recommended for persons with heart and/or respiratory problems. Trailhead: Glacial Boulder pullout on Inspiration Point Road.

Major Areas: Lake & Fishing Bridge

FREQUENTLY ASKED QUESTIONS

Why can't we fish from Fishing Bridge?

Overfishing for cutthroat trout here contributed to their decline in the lake. The trout also spawn here. For these reasons, fishing is prohibited from the bridge.

What happened to the old campground at Fishing Bridge?

The National Park Service campground was located where bears came to fish, and many human/bear conflicts occurred. A recreational vehicle park, operated by a concessioner, still exists in the area.

How big is Yellowstone Lake? How deep? Is it natural?

The lake is natural and has 131.7 square miles of surface area and 141 miles of shoreline; it is 20 miles long by 14 miles wide. Its deepest spot is about 430 feet; its average depth is 140 feet. The lake's basin has an estimated capacity of 12,095,264 acre-feet of water. Because its annual outflow is about 1,100,000 acre-feet, the lake's water is completely replaced only about every eight to ten years. Since 1952, the annual water level fluctuation has been less than six feet.

Is Yellowstone Lake the largest lake in the world?

No, but it is the largest lake at high elevation (above 7,000 feet) in North America.

Where does the Yellowstone River begin? Where does it end?

It begins on the slopes of Younts Peak in the Absaroka Mountains southeast of the park and completes its 671-mile run by joining the Missouri River near the Montana/North Dakota border. Its waters then travel to the Mississippi River and into the Atlantic Ocean at the Gulf of Mexico. It is the longest undammed river in the United States.

What kind of fish live in the lake?

Yellowstone cutthroat trout, longnose dace, redbreasted shiners, longnose suckers, lake chubs, and lake trout. You can often see cutthroat trout and longnose suckers from Fishing Bridge; lake trout live in deeper waters; the others are minnows that are harder to see.

Which fish are natives?

Yellowstone cutthroat trout and the longnose dace are natives.

Where can I see moose?

In marshy areas, particularly at Fishing Bridge and along Pelican Creek, and in large meadows near Bridge Bay. The best time to look is at dawn and dusk.

What's that smell at Mud Volcano?

That "rotten egg" smell comes from hydrogen sulfide gas. Sulfur, in the form of iron sulfide, gives the features their many shades of gray.



Moose can be seen in this area

About Yellowstone Lake

The lake area lies in a stunning setting with the Absaroka Mountains as a backdrop to the east, but this area has not always been so peaceful. The lake's basin is part of the caldera formed after the last major volcanic eruption 640,000 years ago. Originally the lake was 200 feet higher than today and extended north across Hayden Valley to the base of Mt. Washburn. The arms of the lake were formed by uplift along fault lines and sculpting by glaciers.

Geologists think Yellowstone Lake originally drained south via the Snake River into the Pacific Ocean drainage. The lake now drains north from its outlet at Fishing Bridge. The elevation of the lake's north end does not drop substantially until LeHardys Rapids, which is considered the actual northern boundary of the lake.

One of the resurgent domes from the last major eruption—Sour Creek, east of LeHardys Rapids—currently has a net uplift of about one half-inch per year. This uplift is causing the lake to tilt southward. Larger sandy beaches can now be found on the north shore of the lake, and flooded areas can be found in the southern arms.

The area of the lake known as West Thumb is a caldera within a caldera. It was formed by a

volcanic explosion that occurred approximately 162,000 years ago. The resulting caldera later filled with water forming an extension of Yellowstone Lake. (*For more about the West Thumb area, see page 198.*)

Water Temperatures

During late summer, Yellowstone Lake becomes thermally stratified with several water layers having different temperatures. The topmost layer rarely exceeds 66°F, and the lower layers are much colder. Because of the extremely cold water, survival time for anyone in the lake is estimated to be only 20 to 30 minutes. In winter, ice thickness on Yellowstone Lake varies from a few inches to more than two feet with many feet of snow on top of the ice.

Yellowstone River

The Yellowstone River is the longest major undammed river in the lower 48 states, flowing 671 miles from its source southeast of Yellowstone National Park to the Missouri River. The river begins in the Absaroka Mountain Range on Younts Peak and flows through the Thorofare region into Yellowstone Lake. It leaves the lake at Fishing Bridge and flows north over LeHardys Rapids and through Hayden Valley. After this peaceful stretch, the river crashes over the Upper and Lower falls of the Grand Canyon. It then flows generally northwest, meeting the Lamar River at Tower Junction. The river continues through the Black Canyon and leaves the park near Gardiner, Montana. The Yellowstone River continues north and east through Montana and joins the Missouri River just over the North Dakota state line.

Wildlife

This area's abundant and diverse wildlife attracts many visitors. The lake is home to the largest population of Yellowstone cutthroat trout in North America, which are now threatened by non-native lake trout. The area around the lake is prime grizzly bear habitat. The Fishing Bridge area, including Pelican Valley to the north and east, is especially significant to bears and other wildlife because lake, river, and terrestrial ecosystems merge here to create a diverse natural complex. Bears visit numerous streams in the spring and early summer to eat spawning trout.

Hayden Valley is known for herds of bison. During the rut in August traffic can be stopped for hours by huge herds of milling bison. During the winter, Pelican Valley is another outstanding place to view bison. While river otters are elusive, they are seen with some regularity at the Bridge Bay Marina during the summer. American white pelicans, bald eagles, and osprey are commonly seen in the Lake area.



Viewing Fish

The original Fishing Bridge was built at the lake's outlet in 1902. It was a rough-hewn corduroy log bridge with a slightly different alignment from the current bridge. The existing bridge was built in 1937. Fishing Bridge, situated over a cutthroat trout spawning area, used to be a tremendously popular place to fish, but it was closed to fishing in 1973. Since that time, the bridge has become a popular place to observe fish.

Trout can also be viewed at LeHardys Rapids, three miles north of Fishing Bridge. In spring, cutthroat trout rest in the pools before leaping up the rapids on their way to spawn under Fishing Bridge. The rapids were named for Paul LeHardy, a member of the 1873 Jones Expedition. Harlequin ducks once frequented this area in spring, but have not been seen for several years. Nevertheless, the boardwalk is closed in early spring to protect the sensitive habitat.

A pre-1973 crowd on Fishing Bridge

Lake & Fishing Bridge

Historic Structures & Areas

*Fishing Bridge
Trailside Museum
Lake Fish Hatchery
Historic District
including Lake
Lodge
Lake Hotel*

*See Chapters 1 and 8
for more information on
historic areas in the
park.*

Mud Volcano/Sulphur Caldron

When the Washburn Expedition explored the area in 1870, Nathaniel Langford described Mud Volcano as the “greatest marvel we have yet met with.” Although the Mud Volcano can no longer be heard from a mile away (as it could then) nor does it throw mud from its massive crater, the area is still intriguing. A short loop trail from the parking lot passes the Dragon’s Mouth and the Mud Volcano and is wheelchair accessible. The half-mile upper loop trail via Sour Lake and the Black Dragon’s Caldron is relatively steep. A trail guide is available at the beginning of the boardwalk.

The hydrothermal features at Mud Volcano and Sulphur Caldron—primarily mudpots and fumaroles—are among the park’s most acidic. Hydrogen sulfide gas is present deep in the earth at Mud Volcano. As this gas combines with water and the sulfur is metabolized by thermophiles (heat-loving microorganisms), a solution of sulfuric acid is formed that dissolves the rock to create pools and cones of clay and mud. Along with hydrogen sulfide, other gases such as steam and carbon dioxide explode through the mud. The Sulphur Caldron is among the most acidic springs in the park with a pH of 1–2.

DAY HIKES

Pelican Creek: Easy; 1.3 mile round trip. Passes through a forest to the lake before looping back across the marsh along Pelican Creek to the trailhead. Scenic introduction to a variety of the park’s habitats and a good place for birding. Trailhead: west end of Pelican Creek Bridge, 1 mile east of Fishing Bridge Visitor Center.

Natural Bridge: Easy; 3 miles round trip. Meanders through the forest for about ¼ mile, then joins the Natural Bridge service road and continues to the right (west) for 1 mile to the Natural Bridge. The bridge is a 51-foot cliff of rhyolite rock cut through by Bridge Creek. A short but steep trail to the top of the bridge starts in front of the interpretive exhibit panel. The top of the bridge is closed to hiking. Trailhead: just south of the Bridge Bay Marina parking lot near the campground entrance road. Alternate route: Begin at the Natural Bridge service road, which is also a bicycle trail, ¼ mile south of Bridge Bay junction. Inquire at Fishing Bridge Visitor Center about trail closures before hiking or bicycling these trails; they are closed from late spring to early summer due to bears feeding on spawning trout in Bridge Creek.

Storm Point: Easy; 2.3 miles round trip. Passes by Indian Pond before turning right (west) into the forest. Continues through the trees out to scenic, windswept Storm Point (look for yellow-bellied marmots); then follows shoreline to the west, loops through lodgepole pine forest and returns to Indian Pond. Trailhead: Indian Pond pullout, 3 miles east of Fishing Bridge Visitor Center.

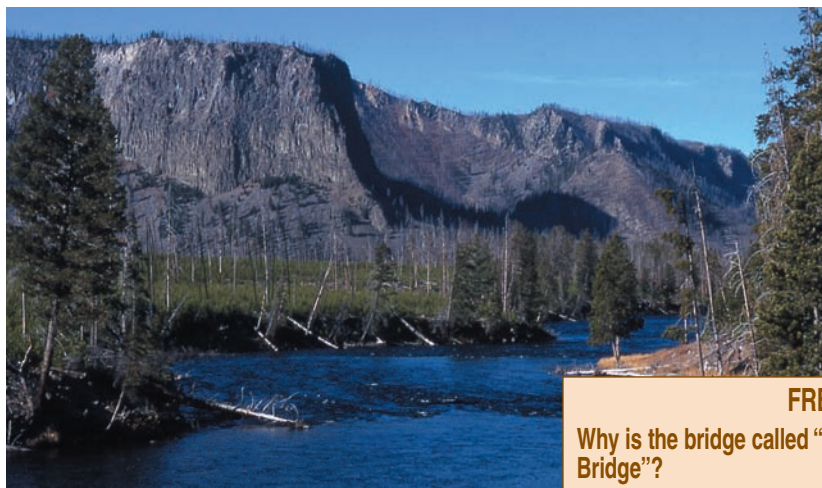
Elephant Back Mountain: Moderately strenuous 3.6 miles. Climbs 800 feet in 1½ miles through a dense lodgepole pine forest. At one mile, splits into a loop. Left fork is the shortest and least steep route. Overlook provides a panoramic view of Yellowstone Lake and the surrounding area. Trailhead: pullout 1 mile south of Fishing Bridge Junction.

Howard Eaton, Fishing Bridge portion: Easy; 7 miles round trip. Follows the Yellowstone River from Fishing Bridge for a short distance, joins a service road for ¼ mile, then meanders for 3 miles through meadow, forest, and sagebrush flats with frequent views of the river. Wildlife and waterfowl are commonly seen here. The last mile passes through a dense lodgepole pine forest before reaching an overview of LeHardys Rapids. Trail continues 12 miles to the South Rim Drive at Canyon, but is not well maintained and such a trip requires a full day and a car shuttle. Trailhead: east side of Fishing Bridge. Inquire at the Fishing Bridge Visitor Center about trail closures before hiking; the trail is often closed due to bear activity.

Avalanche Peak: Strenuous; 4 miles round trip. Climbs 1,800 feet in 2½ miles without switchbacks. Passes through forest and into old avalanche slide area, continues through whitebark pine forest to a small meadow at the base of the bowl of Avalanche Peak, affording some of the best panoramic views in the park. Continues up a scree slope along the narrow ridgeline. An unmarked trail drops down the northeast side of the bowl and returns to the meadow. Whitebark pine cones are a favored food of grizzlies in late summer and fall, so avoid this trail at that time. Trailhead: west end of Eleanor Lake across the road east of the small creek.

Pelican Valley: Moderately strenuous; 6.8 miles round trip. Travels through forest to Pelican Valley, then follows Pelican Creek upstream to a washed-out footbridge, which is a convenient turn-around point. Because Pelican Valley provides some of the best grizzly habitat in the lower 48 states, this trail does not open until July 4th and travel is restricted to specific times of day. Groups of four people or more are recommended but not required. Trailhead: end of a gravel road, which is 3 miles east of Fishing Bridge Visitor Center and across the road from Indian Pond.

Major Areas: Madison & West Entrance



National Park Mountain overlooking the Madison River

Geology and Vegetation

Mt. Jackson rhyolite, which is between 930,000–1,000,000 years old, forms the Madison Canyon, which lines the east half of the west entrance road. This lava flow predates the most recent eruption and collapse of the Yellowstone Caldera. Mt. Haynes (south of the road) and Mt. Jackson (on the opposite side of the road), at the west end of the canyon, prominently display columnar rhyolite, a striking form of lava that is rare in Yellowstone. Lava Creek tuff from the last caldera eruption caps the Mt. Jackson rhyolite on the north side of the canyon.

West of Seven-Mile Bridge, the low topography of the Madison Valley consists of glacial moraines, glacial outwash, and recent Madison River deposits. Extensive stands of young lodgepole pines now flourish in these soils. The pines grew as a result of the North Fork Fire, one of the largest of the 1988 fires, which burned the existing forests. As fire killed the lodgepole pines, it also caused the release of millions of seeds from abundant serotinous cones immediately after the fire. Subsequent growth of dense even-aged stands of lodgepole pines since 1988 attest to the high degree of serotiny along this part of the West Entrance Road. See Chapter 5 for more information on serotiny in lodgepole pines.

Wildlife

Several hundred elk live year-round along the Madison. During the fall rut, bull elk and their harems frequent the meadows from Seven-Mile Bridge to Madison Junction.

FREQUENTLY ASKED QUESTIONS

Why is the bridge called “Seven Mile Bridge”?

Seven Mile Bridge is located midway between (and seven miles from both) the West Entrance and Madison Junction. This landmark serves as a convenient reference point and separates the rugged lava-lined Madison Canyon east of the bridge from gentle hills to the west.

Why are there no bison around here from late June through August?

Bison that inhabit the Madison–Norris–West Entrance areas most of the year are part of the Mary Mountain herd. In summer, they travel to Hayden Valley, their traditional summer habitat and breeding area.

What is happening to so many of the young lodgepole pines in the dense stands west of Seven-Mile Bridge?

Why are the needles turning orange?

Scientists have determined that no disease or insect is causing the problem. They think the trees are showing effects of cumulative drought stress and low winter snow pack. These conditions can cause “winter burn”—trees can’t absorb enough water, and parts of the trees begin to die. New growth usually replaces the dead needles.

During spring, fall and winter, herds of bison favor the same meadows. Bison often use the entrance road to travel from one foraging area to another.

Bald eagles have nested in a snag south of the entrance road about one mile west of Seven-Mile Bridge in recent years. It was originally constructed by bald eagles at least 40 years ago, and has been used by Canada geese and osprey. Several pairs of ospreys nest along the Madison. A pair of trumpeter swans claimed a territory immediately east of Seven-Mile Bridge until the male died in the summer of 2001; the female remains in the area. Numerous trumpeter swans migrate from Canada to winter on the Madison. Canada geese, mallards and other waterfowl inhabit the Madison River year-round. Barrow’s goldeneyes gather on the Madison in winter.

Madison & West Entrance

Historic Structures & Areas

Madison Trailside Museum

See Chapters 1 and 8 for more information on historic areas in the park.

Madison Junction

At Madison Junction, the Gibbon River joins the Firehole River to form the Madison River. (The Gibbon River flows from Grebe Lake through the Norris area to Madison Junction. The Firehole River starts south of Old Faithful and flows through the park's major hydrothermal basins north to Madison Junction.) The Madison joins the Jefferson and the Gallatin rivers at Three Forks, Montana, to form the Missouri River.

Madison Junction lies within eroded stream channels that cut through lava flows after the last major volcanic eruption. National Park Mountain is actually part of the lava flows.

People have camped here and at Norris for thousands of years. Archeological digs in both campground areas have found campfire remnants, obsidian flakes, and bone fragments dating back at least 10,000 years.

Terrace Spring

This hydrothermal area lies north of Madison Junction and can be reached via a short boardwalk. The runoff from the springs passes under the road and flows down a long slope to the Gibbon River. Yellow monkey flowers line the runoff channels in season.

Gibbon Falls

Traveling north from Madison Junction past Terrace Springs, the road follows the Gibbon River upstream. Approximately 4 miles from Madison, the 84-foot Gibbon Falls marks in spectacular fashion one of the locations of remnants from the caldera rim. The actual rim is southwest about one-quarter mile.

Firehole Canyon Drive

Traveling south from Madison Junction, the road follows the Firehole River upstream. Approximately one mile from Madison, Firehole Canyon Drive (one way, south bound) winds past 800-foot-thick lava flows to 40-foot Firehole Falls. The West Yellowstone Rhyolite Flow is to the west and occurred 108,000 years ago; the Nez Perce Rhyolite Flow is to the east and occurred 153,000 years ago.

The unstaffed swimming area here is popular on warm summer days. Cliff diving is illegal. Swimming is usually prohibited during spring and early summer due to high water and strong current.

DAY HIKES

West Entrance Area

Riverside Trail: Easy; one mile. Leads from West Yellowstone to the Barns Road, which intersects the West Entrance Road one mile east of the West Entrance. The Riverside Trail provides hikers with easy access to the Madison River. This trail and the Barns Road are also open to bicycles. Trailhead: Boundary Street in West Yellowstone.

Gneiss Creek Trail: Easy; 14 miles one way. For the first mile, the trail follows the Madison River, then climbs over a ridge and heads north through forests and sagebrush meadows burned in 1988. The last few miles of the trail traverse aspen and Douglas fir forests where wildflowers and songbirds abound. Stream crossings are easy after the end of June. Trail ends at the Fir Ridge Trailhead on Highway 191, eight miles north of the West Entrance. Trailhead: Immediately east of Seven Mile Bridge. The west half of this trail is closed March 10–June 30 for bear management.

Two Ribbons: Easy; half-mile round trip. Boardwalk winds through burned lodgepole and sagebrush

communities next to the Madison River, with good examples of fire recovery and buffalo wallows, interpreted by wayside exhibits. Trailhead: large pullout approximately 3 miles east of West Entrance.

Madison Area

Purple Mountain: Strenuous; six miles round trip. Ascends 1,500 feet through intermittent burned lodgepole forest to views of Firehole Valley, lower Gibbon Valley, and Madison Junction area. Trailhead: ¼ mile north of Madison Junction along Mammoth–Norris Road.

Harlequin Lake: Easy; 1 mile round trip. Ascends through burned lodgepole forest to a small, marshy lake popular with mosquitoes and waterfowl (but not harlequin ducks). Trailhead: 1½ miles west of Madison Campground on West Entrance Road.

Gallatin Area

Excellent long-distance hikes available in the Gallatin area north of West Yellowstone. Consult a ranger at visitor centers or one of the trail guides available from the Yellowstone Association.

Major Areas: Mammoth Hot Springs



Travertine terraces at Mammoth Hot Springs

Formation

Even though Mammoth Hot Springs lies outside the caldera boundary, the hydrothermal activity here may be the result of the same magmatic system that fuels other Yellowstone hydrothermal areas. One idea is that a basalt body beneath Mammoth is heating the sources of underground water.

While most of the hydrothermal formations you see in the park are comprised of siliceous sinter and geyserite, the hot spring terraces here are formed of travertine, a rock made of calcium carbonate. Thermal waters rise through the limestone underlying this area, carrying high amounts of dissolved carbonate. When the mineral-rich water reaches the surface, it cools and its pressure decreases, gases are released, and the calcium carbonate is deposited as travertine, the chalky white rock of the terraces. Due to rapid deposition, these features change quickly and constantly, but the overall volume of discharged water fluctuates little.

Mammoth shows evidence of thousands of years of hydrothermal activity. Terrace Mountain has a thick cap of travertine estimated to be 400,000 years old—which would make it the oldest known hydrothermal deposit in Yellowstone National Park. The currently active area at Mammoth ranges from three to ten thousand years old.

Travertine deposits extend from Terrace Mountain to the hillside where we see them today, across the Parade Ground, and down to Boiling River. An old terrace formation, known as Hotel Terrace, underlies all of Fort Yellowstone and the Mammoth Hotel. Several large sink holes, which are fenced on the Parade Ground, provide visual evidence of the area's hollow foundation.

FREQUENTLY ASKED QUESTIONS

Are the springs drying up?

No, even though they may look different from the last time you saw them. These features change constantly and sometimes overnight, but the overall activity of the entire area and the volume of water discharge remain relatively constant.

Are the elk outside the visitor center tame?

No. They are wild and unpredictable. In the spring, cows with calves can be dangerous. In the late summer and fall, which is the mating season, cows are skittish and bulls are very aggressive. Each year visitors are chased, trapped, and sometimes injured by elk. Bull elk also sometimes attack cars.

What were these old buildings?

The row of stone and wood buildings across the street from the Mammoth Hotel were the officers' quarters for the U.S. Army from 1891 to 1918. A self-guiding trail takes visitors through Fort Yellowstone, a National Historic Landmark.

Can we swim in the hot springs?

No. Swimming is prohibited in park hydrothermal features because it damages the resource and is unsafe.

However, you may swim in bodies of water fed by runoff from hydrothermal features. An established spot is the "Boiling River" two miles north of Mammoth on the North Entrance Road. It is open only during daylight hours and is closed during times of high water.

What can we do at Mammoth during the winter?

You can take self-guided tours of Fort Yellowstone and the Mammoth Terraces, join a guided walk or tour, cross-country ski, snowshoe, ice skate (sometimes), rent a hot tub, soak in the Boiling River, watch wildlife, attend ranger programs, and visit the Albright Visitor Center. You can also drive the Northeast Entrance road through to Cooke City, Montana; coyotes, bison, elk, wolves, eagles, and other wildlife are often seen.

Approximately 8 miles east of Mammoth, on the northeast entrance road, you may be able to walk a self-guiding boardwalk trail, The Forces of the Northern Range. (Sometimes high snow banks prevent easy access.)

The Mammoth area also exhibits evidence of glacial activity. Glacial till from the Pinedale Glaciation (which ended 14,000 years ago) is found on the summit of Terrace Mountain. Thermal kames, including Capitol Hill and Dude Hill, are major features of the Mammoth area. East of Mammoth, streams at the edge of glaciers formed the small, narrow valleys where Floating Island Lake and Phantom Lake are found. In Gardner Canyon, the old bed of the Gardner River is covered by glacial till.

Mammoth Hot Springs



Elk are found in Mammoth year-round, and can be especially dangerous during the autumn rut.

Wildlife

Mammoth is lower in elevation than most of the rest of the park, and has always been used by elk in winter. Now elk are found in the area year-round. The development offers elk an ample supply of forage and usually provides refuge from most of their natural predators.

(However, wolves have killed a few elk in the developed area.)

Rivaling the elk in numbers, Uinta ground squirrels form large colonies every summer in front of the visitor center and among the hotel cabins.

45th Parallel Bridge & Boiling River

On the road from Mammoth to Gardiner, a sign marks the 45th parallel of latitude, which is an imaginary line circling the globe halfway between the Equator and the North Pole. This

same line passes through Minneapolis–St. Paul; Ottawa, Ontario, Canada; Bordeaux, France; Venice, Italy; Belgrade, Yugoslavia; and the northern tip of the Japanese islands. Here it also marks the Montana–Wyoming border.

A parking area on the east side of the road is used by people walking to one of the few legal thermal soaking areas in the park. Upstream about a half mile, a large hot spring, known as Boiling River, enters the Gardner River. Soaking is allowed during **daylight hours only** and at your own risk. Bathing suits are required and no alcoholic beverages are allowed. Thermal waters can harbor organisms that cause a fatal meningitis infection and Legionnaires' disease. Exposing your head to thermal water by immersion, splashing, touching your face, or inhaling steam increases the risk of infection. Boiling River is closed during hazardous high water.

Mt. Everts

Mt. Everts, 7,841 feet high, is the long ridge northeast of Mammoth. It is made up of distinctly layered sandstones and shales—rocks made of sediments deposited when this area was covered by a shallow inland sea, 70–140 million years ago. Fossils have been found here (*see Chapter 3*). Its steep cliffs—eroded by glaciers and floods—provide habitat for bighorn sheep, which sometimes can be seen in Gardner Canyon.

Mt. Everts was named for explorer Truman Everts, a member of the 1870 Washburn Expedition who became separated from the group and spent the next month starving, freezing, and hallucinating as he made his way through the wilderness. Everts never made it as far as Mt. Everts. He was found near what is now the Blacktail Plateau Drive and was mistaken for a black bear and nearly shot. His story remains Yellowstone's best known, lost-in-the-wilderness story.

Collecting rocks, fossils, or anything else is forbidden on Mt. Everts and throughout the park.

Bunsen Peak

Bunsen Peak is 8,564 feet high and has two popular trails, described on the next page. It is an intrusion of igneous material (magma) that formed during the same period as the Absaroka volcanics (*see Chapter 3*). The peak burned in 1886 and in 1988. Old photos show the creep of trees up Bunsen following the 1886 fires; new patterns of open space were created by the fires of 1988.

Bunsen Peak and the “Bunsen burner” were both named for the German physicist, Robert Wilhelm Bunsen. His students gave the burner that name because he was involved in pioneering research about geysers, and a “Bunsen burner” has a resemblance to a geyser. His theory on geysers was published in the 1800s, and it is still believed to be accurate.

Swan Lake Flat

South of Bunsen Peak is Swan Lake Flat, a large glaciated area now made up of meadows where visitors often see elk, bison, and sometimes grizzlies and wolves. It is also excellent for watching cranes, ducks, and other birds.

Mammoth Hot Springs

Obsidian Cliff

Obsidian Cliff, 11 miles south of Mammoth Hot Springs, rises 150 to 200 feet above Obsidian Creek. Obsidian, or “volcanic glass,” forms when rhyolitic lava cools very quickly, forming natural glass. The Obsidian Cliff rhyolite flow is dated at 183,000 years old. Forty rhyolite flows in the park contain obsidian, but only a few contain obsidian of tool quality. A massive outcrop the size of Obsidian Cliff is rare because obsidian is usually found as small sections of other rock outcrops.

Obsidian was important to native peoples. For centuries Native Americans made projectile points and other tools from obsidian, which fractures into round pieces with sharp

edges. Because there are so few sources of obsidian, it was a valuable trade item and is found throughout the continent, far from its source. (Obsidian begins to absorb moisture once it is exposed to the air. By measuring the amount of moisture that has been absorbed, obsidian can be dated, and its source can be located.)

In 1996, Obsidian Cliff was named a National Historic Landmark. The historic wayside exhibit structure here is one of the first of its kind in Yellowstone, built in the 1920s.

The Obsidian Cliff area is closed to hiking, collecting, and all entry to protect the resource.

DAY HIKES

Beaver Ponds: Moderately strenuous; 5 miles round trip. Climbs 350 feet up Clematis Gulch, then through sagebrush meadows and stands of aspen to a series of beaver ponds. Look for elk, mule deer, pronghorn, moose, beaver dams and lodges, the occasional beaver, and waterfowl. Be alert for bears: both black and grizzly bears forage in this area. Past the ponds, the trail travels through forest and grassland back to Mammoth. Trailheads: between Liberty Cap and the stone house (the Judge’s house) next to the Mammoth Terraces or behind the end of the guest wing of the hotel.

Bunsen Peak: Moderately strenuous; 4.2 miles round trip. Climbs 1,300 feet through forest and meadow to the summit of Bunsen Peak, which has panoramic views of the Blacktail Plateau, Swan Lake Flat, Gallatin Mountain Range, and the Yellowstone River Valley. Return by the same route. Trailhead: 5 miles south of Mammoth on the Mammoth–Norris Road.

Osprey Falls: Strenuous; 8 miles round trip. Follows Bunsen Peak Road (hiking/biking only) through grassland and burnt forest 2½ miles to Osprey Falls Trail (no bikes allowed), which descends switchbacks to the bottom of Sheepeater Canyon, one of the deepest canyons in Yellowstone. Trailhead: 5 miles south of Mammoth on the Mammoth–Norris Road.

Lava Creek: Moderately strenuous; 3½ miles one way. Follows Lava Creek downstream past Undine Falls (60 feet), descending gradually, passes the confluence of the creek and Gardner River, and crosses the river on a footbridge to a final climb out. Trailhead: Lava Creek picnic area on Mammoth–Tower Road; ends in a pullout north of Mammoth Campground on the North Entrance Road.

Rescue Creek: Moderately strenuous; 8 miles one way. Follows Blacktail Deer Creek Trail past the east end of Blacktail Pond then climbs up short hill, then veers left on the Rescue Creek Trail. Climbs gradually through aspens and meadows, then descends through forests to open sagebrush flats that lead to a footbridge across the Gardner River. Trailhead: 7 miles east of Mammoth on Mammoth–Tower Road; ends 1 mile south of the North Entrance Station

Sepulcher Mountain: Strenuous; 11 miles round trip. Follows the Beaver Ponds Trail (*see above*) to the Sepulcher Mountain Trail junction, then climbs 3,400 feet through forest and meadows to the 9,652 foot summit. Loop trail continues along the opposite side of the mountain through an open slope to the junction of Snow Pass Trail, which descends to the Howard Eaton Trail, which should be followed north to Mammoth Terraces and the trailhead. Trailhead: between Liberty Cap and the stone house (the Judge’s house) next to the Mammoth Terraces.

Wraith Falls: Easy; 1 mile round trip. Travels open sagebrush and Douglas-fir forest to the foot of Wraith Falls cascade on Lupine Creek. Trailhead: pullout ¼ mile east of Lava Creek Picnic area on the Mammoth–Tower Road.

Blacktail Deer Creek–Yellowstone River: Moderately strenuous; 12 miles one way. Follows Blacktail Deer Creek as it descends 1,100 feet through rolling, grassy hills and Douglas-fir forest to the Yellowstone River. Crosses steel suspension bridge spanning Yellowstone River then joins the Yellowstone River Trail, which continues downriver, passing Knowles Falls and into arid terrain until it ends in Gardiner, Montana. **Caution:** Very narrow, short stretch near Gardiner is slippery when wet. Trailhead: 7 miles east of Mammoth on Mammoth–Tower Road; ends in Gardiner, Montana.

Historic Structures & Areas

Mammoth Hot Springs Historic District—includes Albright Visitor Center

Fort Yellowstone Historic Landmark District

Obsidian Cliff National Historic Landmark

Obsidian Cliff Kiosk U.S. Post Office

See Chapters 1 and 8 for more information on historic areas in the park.

Also located in this area:

Administrative Headquarters of Yellowstone National Park

Yellowstone Heritage & Research Center in Gardiner, MT; houses the Yellowstone Research Library and Archives, open to the public.

Major Areas: Norris

When does Echinus Geyser erupt?

Once very predictable, Echinus's eruptions can vary from hours to days. As of March 2005, it was erupting every 3½ to 4 hours. If the pool is full and overflowing, an eruption may occur soon.

When will Steamboat Geyser erupt?

Steamboat's eruptions are entirely unpredictable and often many years apart. However, it has erupted seven times since May 2000—including March, April, and October 2003, and May 2005.

Full eruptions of the world's tallest active geyser are spectacular. The water column shoots twice as tall as the trees and drenches everything. A steam

phase continues for approximately 24 hours. Even its frequent "minor phase" eruptions eject water 10 to 40 feet high.

Why is this place so colorful?

The colors here, like in other hydrothermal areas, are due to combinations of minerals and life forms resistant to acidity and heat. Silica or clay minerals saturate some acidic waters, making them appear milky. Iron oxides, arsenic, and cyanobacteria create the red-orange colors. *Cyanidium* grows bright green. Mats of *Zygogonium* are dark purple to black on the surface where they are exposed to the sun, bright green beneath. Sulfur creates a pale yellow hue.



Constant Geyser in Porcelain Basin

Norris Geyser Basin

Norris Geyser Basin is the hottest, oldest, and most dynamic of Yellowstone's hydrothermal areas. The highest temperature yet recorded in any Yellowstone hydrothermal area was measured in a scientific drill hole at Norris: 459°F just 1,087 feet below the surface. Norris shows evidence of having had hydrothermal features for at least 115,000 years. The features in the basin change daily, with frequent disturbances from seismic activity and water fluctuations.

Activity in Norris's Back Basin increased dramatically in mid-2003. Because of high ground temperatures and new features beside the trail, much of Back Basin was closed until October. In 2004, the boardwalk was routed around the dangerous area and now leads you behind Porkchop Geyser.

Norris is so hot and dynamic primarily because it sits on the intersection of three major faults. One runs from Norris north through Mammoth to the Gardiner, Montana, area. The Hebgen Lake fault runs from northwest of West Yellowstone, Montana, to Norris. These two faults intersect with a ring fracture from the Yellowstone Caldera eruption 640,000 years ago.

Features

Norris Geyser Basin consists of three main areas: Porcelain Basin, Back Basin, and One



Congress Pool, in Porcelain Basin, cleared, filled, and overflowed much of the 2005 season.

Hundred Spring Plain. Most of the water here is acidic, and Norris has rare acidic geysers such as Echinus (pH 3.5 or so). Echinus is found in Back Basin, a wooded area with features scattered along a 1½ mile trail of boardwalk and dirt. Steamboat Geyser, the tallest active geyser in the world (300 to 400 feet) steams on the hillside between Back Basin and the Norris Museum. On the other side of the museum, Porcelain Basin provides a sensory experience in sound, color, and smell along its half-mile dirt, asphalt, and boardwalk trail. One Hundred Spring Plain is an off-trail section that is very acidic, hollow, and dangerous. Travel is discouraged without the guidance of knowledgeable staff.

Periodically, Norris Geyser Basin undergoes a large-scale basin-wide thermal disturbance lasting a few weeks. Water levels fluctuate, temperatures and pH change, color changes, and eruptive patterns change throughout the basin. During a disturbance in 1985, Porkchop Geyser continually jetted steam and water; during a disturbance in 1989, Porkchop apparently clogged with silica and blew up, throwing rocks more than 200 feet. In 2003, a park ranger observed it bubbling heavily, the first such activity seen since 1991 and a harbinger of the basin-wide activity that summer.

Geologists and chemists who have studied these disturbances have several theories about why they occur. They may be caused by a massive fluctuation in the underground reservoirs providing water to the basin. In the fall, they could be caused by less surface water mixing with water from deep underground, which holds more silica and clogs the cracks and crevices that supply water, thereby creating a “disturbance” as pressure builds.

The Ragged Hills that lie between Back Basin and One Hundred Spring Plain are thermally altered kames formed as glaciers receded. The underlying hydrothermal features melted remnants of ice and caused masses of debris to be dumped. These debris piles were then altered by steam and hot water flowing through them.

History

The area was named for Philetus W. Norris, the second superintendent of Yellowstone, who provided early detailed information about the hydrothermal features. Two historic buildings remain in this area: The Norris Geyser Basin Museum (*see Chapter 8*) and

the Museum of the National Park Ranger, which is housed in the Norris Soldier Station, one of the only remaining soldier stations in the park (*photo below*). The building was used as a ranger station and residence until the 1959 Hebgen Lake earthquake caused structural damage. The building was restored in 1991 and adapted to its current use.



Wildlife

The meadows adjacent to the Gibbon and Madison rivers are prime elk calving areas in the spring. Fall brings bull elk looking for females to mate with. Bison frequent the same meadows in the spring, summer, and fall and use the hydrothermal areas in the winter. Both black and grizzly bears pass through the Norris area. Grizzlies feed on carcasses of elk and bison that died in the hydrothermal areas during the winter.

Norris is one of the few areas in the park having lizards. The sagebrush lizard can survive here due to the influence of hydrothermal activity. Chorus frogs may be heard in the area in the spring (*see Chapter 7 for more about these animals*).

Killdeer are found in the basin year-round taking advantage of the brine flies and other insects that live in the warm waters.

Thermophiles

Because Norris is acidic, some forms of life especially suited to life in extremes of heat and acid have been found here. *Cyanidium* is one of the more unusual algae found here; look for the brilliant green streak near Whirligig Geyser. Elements such as arsenic also color the features. *See also Chapter 4.*

The Museum of the National Park Ranger, housed in the historic Norris Soldier Station, is staffed by volunteers, most of whom are retired National Park Service employees.

Historic Structures & Areas

Norris Soldier Station (now the Museum of the National Park Ranger)

Norris Geyser Basin Museum

See Chapters 1 and 8 for more information on historic areas in the park.

Roaring Mountain

North of Norris, Roaring Mountain is a large, acidic hydrothermal area (solfatara) with many fumaroles. In the late 1800s and early 1900s, the number, size, and power of the fumaroles were much greater than today. The fumaroles are most easily seen in the cooler, low-light conditions of morning and evening.

Virginia Cascades

A one-way, three-mile section of an older portion of the Grand Loop Road takes visitors past 60-foot high Virginia Cascades. The waterfall is formed by the Gibbon River as it crosses part of the rim of the Yellowstone Caldera. Lava flows formed the cliffs alongside the road.

On the main road east of the drive's entrance, a boardwalk takes visitors among lodgepole pines blown down by wind-shear in 1984. They are part of a 22-mile swath of forest flattened by this weather event. Four years later, they burned during the 1988 fires. The once blackened and barren landscape is now sprinkled with young lodgepoles.

Artists' Paintpots

Artists' Paintpots is a small but lovely hydrothermal area south of Norris Junction. A one-mile round trip trail takes visitors through a section of forest burned in 1988 to colorful hot springs and two large mudpots.

Monument Geyser Basin

This small basin may contain clues to recent discoveries under Yellowstone Lake. While the basin has no active geysers, its "monuments" are siliceous sinter deposits similar to the siliceous spires discovered on the floor of the lake. Scientists hypothesize that this basin's structures formed from a hot water system in a glacially dammed lake during the waning stages of the Pinedale Glaciation (*see Chapter 3*). The basin is on a ridge reached by a very steep one-mile trail just south of Artists' Paint Pots. **Caution:** Active hydrothermal features and thin crust; do not travel beyond the end of the trail or in the geyser basin.

DAY HIKES

Grizzly Lake: Moderately strenuous; 4 miles round trip. Passes through a lodgepole pine stand burned in 1976 and 1988, and through meadows to the long, narrow lake. Can be wet and mosquito laden before July. Trailhead: 1 mile south of Beaver Lake on Mammoth–Norris Road.

Solfatara Creek: Easy; 6.5 miles one way. Requires a car shuttle or returning the same route. Follows Solfatara Creek and soon passes the junction with the Howard Eaton (to Ice Lake, Wolf Lake, etc.). It parallels a power line for most of the way to Whiterock Springs; then climbs a short distance to Lake of the Woods (look off trail) and passes Amphitheater Springs and Lemonade Creek—small, but pretty hydrothermal areas. Trail continues to the Mammoth–Norris Road. **Caution:** Check at a visitor center for trail closures due to bear activity. Trailhead: Loop C of Norris Campground; ends ¾ miles south of Beaver Lake Picnic Area.

Ice Lake (direct route): Easy; 0.3 miles. Travels through lodgepole forest to Ice Lake, a small lake with a wheelchair accessible backcountry site. Hikers can continue on the Howard Eaton trail to Wolf Lake, Grebe Lake, Cascade Lake, and on to Canyon. (*See Canyon Area for descriptions.*) Trailhead: 3½ miles east of Norris on Norris–Canyon Road.

Wolf Lake Cut-off: easy; 6 miles round trip. Follows the Gibbon River past Little Gibbon Falls and through dense, partially burned lodgepole pine forest to Wolf Lake. Trail crosses the stream several times (no bridges) and is not regularly maintained. Trailhead: big pullout

about ¼ mile east of Ice Lake Trailhead on Norris–Canyon Road.

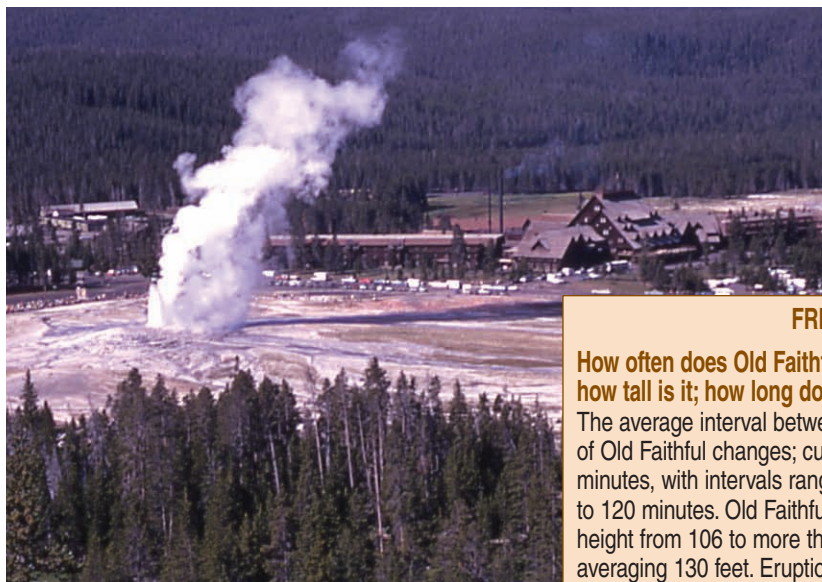
Cygnets Lakes: Easy; 8 miles round trip. Travels through intermittently burned lodgepole pine forest and past ephemeral ponds to lush meadows surrounding the small and boggy Cygnets Lakes. Trail continues, but is not maintained. **Caution:** Due to bear activity, trail is day-use only. Trailhead: pullout on south side of Norris–Canyon road approximately seven miles from Norris Junction.

Artists' Paintpots: Easy, with one steep uphill climb to the upper loop; 1 mile round trip. Passes through partially burned lodgepole forest and by a wet meadow then to colorful hot springs, small geysers, and two large mudpots. Trailhead: 2½ miles south of Norris on Norris–Madison Road.

Monument Geyser Basin: Strenuous; 2 miles round trip. Follows the Gibbon River, then turns sharply uphill and climbs 500 feet in one-half mile. Watch your footing; rocks are loose. *See description of geyser basin above.*

Caution: Active thermal features and thin crust here; do not travel beyond the end of the trail or within the geyser basin. Trailhead: 5 miles south of Norris just past Gibbon River Bridge.

Major Areas: Old Faithful



Old Faithful as seen from Observation Point

The Upper Geyser Basin

Yellowstone National Park has approximately half of the world's geysers—most of them in this area. One square mile contains at least 150 of these hydrothermal wonders. Five major geysers—Old Faithful, Castle, Grand, Daisy, and Riverside—are predicted regularly by the interpretive ranger staff. This basin contains many frequent, smaller geysers, and numerous hot springs

The hills surrounding Old Faithful and the Upper Geyser Basin are composed of rhyolite lava flows. These flows, occurring after the catastrophic caldera eruption of 640,000 years ago, flowed across the landscape like stiff mounds of bread dough due to their high silica content.

During the glacial periods 70,000–14,000 years ago, scientists estimate hydrothermal activity occurred in the Upper Geyser Basin. The glacial till deposits underlying this and other area geyser basins provide the storage area for the water necessary for geysers to occur. Many landforms, such as the Porcupine Hills north of Fountain Flats, are comprised of glacial gravel.

The Firehole River

The Firehole River originates from cold springs on the Madison Plateau and plunges over the 125-foot Kepler Cascades before reaching the Upper Geyser Basin. The river flows through three major geyser basins—Upper, Midway, and Lower—before joining

FREQUENTLY ASKED QUESTIONS

How often does Old Faithful erupt; how tall is it; how long does it last?

The average interval between eruptions of Old Faithful changes; currently it is 92 minutes, with intervals ranging from 45 to 120 minutes. Old Faithful can vary in height from 106 to more than 180 feet, averaging 130 feet. Eruptions normally last between 1½ to 5 minutes and expel from 3,700 to 8,400 gallons of water. At the vent, water is 204°F (95.6°C).

Is Old Faithful as “faithful” as it has always been?

Since its formal discovery in 1870, Old Faithful has been one of the more predictable geysers. However, like all geysers, Old Faithful is constantly changing and evolving due to ongoing processes within its “plumbing” and from earthquakes (see “Old Faithful,” below). Even so, Old Faithful remains one of the more predictable geysers.

See also the hydrothermal questions in the Introduction, and Chapter 3, Geology.

the Gibbon River at Madison Junction to form the Madison River.

The epicenter of the 1959 Hebgen Lake Earthquake was located west of the park near the Madison River. This earthquake, measured at 7.5 on the Richter scale, shook up the geothermal underpinnings of the geyser basins along the Firehole River. Hundreds of geysers erupted—including hot springs never known to erupt. This hyperactivity continued for months.

Old Faithful Geyser

Predicting any geyser's eruption is difficult because of the complex interactions of constantly changing factors. Old Faithful has been analyzed for years by mathematicians, statisticians, and dedicated observers. We now know a direct relationship exists between the duration of Old Faithful's eruption and the length of the following interval. During a short eruption, less water and heat are discharged; thus, they rebuild again in a short time. Longer eruptions mean more water and heat are discharged and they require more time to rebuild.

Over time, the average interval between Old Faithful's eruptions increases, in part due to ongoing processes within its plumbing. Changes also result from earthquakes. Prior to the Hebgen Lake Earthquake, the interval between Old Faithful's eruptions averaged more than one hour. Its intervals increased after that earthquake and again after the 1983 Borah Peak Earthquake, centered in Idaho. In 1998, an earthquake near Old Faithful lengthened the interval again; an earthquake swarm further increased intervals. As of March 2006, the average interval was 92 minutes. Intervals of approximately 65 minutes follow eruptions of 2.5 minutes or less.



Fountain Paint Pot,
Lower Geyser Basin

Wildlife

Hydrothermal basins provide important habitat for wildlife in the Old Faithful area. Large numbers of bison and elk live here year-round. In the winter, they take advantage of the warm ground and thin snow cover. During spring and fall, moose are sometimes seen during the early morning or late afternoon. Both black and grizzly bears are seen, especially during the spring when winter-killed carcasses are available. Yellow-bellied marmots are frequently seen in the rocks behind Grand Geyser and near Riverside Geyser. Thermophiles live in the runoff channels of hot springs and geysers, providing food for tiny black ephydrid flies. The flies, in turn, lay their eggs in salmon colored clumps just above the water surface where they are then preyed upon by spiders. Killdeer also feast on the adult flies.

Midway Geyser Basin

This geyser basin, across the Firehole River from the Grand Loop Road, is smaller in size than the Upper and Lower geyser basins. Excelsior Geyser is a gaping crater 200 x 300 feet that constantly discharges more than 4,000 gallons of water per minute into the river. Grand Prismatic Spring, Yellowstone's largest hot spring, is 370 feet in diameter and more than 121 feet in depth. A bridge across the Firehole River allows access to the basin.

Lower Geyser Basin

Activity of the Lower Geyser Basin can be viewed from two areas: Fountain Paint Pot (*shown at left, and described on next page*) and Firehole Lake Drive. The latter is a 2-mile, one-way drive where you will find the Great Fountain, the sixth geyser predicted by the Old Faithful staff in summer. Its eruptions send jets of water droplets bursting 100 to 200 feet in the air, while waves of water cascade down its sinter terraces.

Hydrothermal features extend throughout this area, including sites that researchers explore for thermophiles that might be useful in medicine and science. *For more on bio-prospecting, see Chapter 9.*

Fountain Flats Drive, a short side road immediately south of the Nez Perce Picnic Area, follows the Firehole River for 1½ miles to a trailhead. A hiking and biking trail continues along the old roadbed allowing access to the Sentinel Meadow and Fairy Falls trails (*see descriptions next page*). Also along this path is a wheelchair-accessible backcountry site at Goose Lake.

Old Faithful

WALKING THE GEYSER BASINS

After viewing Old Faithful, visitors can spend an hour or all day exploring the area from the safety of these established walkways.

Upper Geyser Basin Area

Numerous loops or one-way walks explore the Upper Geyser Basin; a few descriptions follow. Geysers such as Castle, Grand, Riverside, and Daisy plus Morning Glory Pool, Biscuit Basin, and Black Sand Basin can be reached by other trails described in *The Old Faithful Area Trail Guide*, available at trailheads and the visitor center. Obtain geyser prediction times at the visitor center.

Geyser Hill Loop

Boardwalks, foot paths; interpretive signs. Easy, 1½ mile round trip. Passes by Old Faithful, crosses the Firehole River, and then circles Geyser Hill where ten geysers erupt frequently, along with other geysers and hot springs. Trailhead: Old Faithful Visitor Center.

Observation Point Loop

Foot path.

Strenuous; 1.1 miles round trip. Climbs about 150 feet to an overlook of the Upper Geyser Basin. Trailhead: just past the footbridge behind Old Faithful Geyser.

Midway Geyser Basin

Boardwalk; interpretive signs.

Easy; half mile. Boardwalk loops by impressive features such as Excelsior Geyser and Grand Prismatic Spring. Trailhead: 6 miles north of the Old Faithful area.

Fountain Paint Pot

Easy; less than half mile. Boardwalk loops past Yellowstone's four types of hydrothermal features: geysers, hot springs, mudpots, and fumaroles. Trailhead: 8 miles north of the Old Faithful area.

DAY HIKES

Visit backcountry lakes and hydrothermal features on these day hikes. **Caution:** In hydrothermal areas, stay on the established trails for your safety and to protect fragile features.

Upper Geyser Basin Area

Mallard Lake: Moderately strenuous; 6.8 miles round trip. Climbs through lodgepole forest and along meadows and rocky slopes to Mallard Lake. Trailhead: south-east side of the Old Faithful Lodge cabins, near the Firehole River.

Lone Star Geyser: Easy; 5 miles round trip. Open to bicycles. Follows old service road along the Firehole River through lodgepole forests to the geyser, which erupts approximately every 3 hours. Visitors record geyser times and observations in a logbook located in a box near the geyser. Trailhead: 3 miles south of the Old Faithful area, just beyond Kepler Cascades parking area.

Mystic Falls: moderately strenuous; 2½ miles round trip. Follows a lovely creek through a lodgepole forest to the 70-foot falls. Turn around here or climb the switchbacks to an overlook of the Upper Geyser Basin, then loop back to the main trail. Trailhead: back of the Biscuit Basin boardwalk.

Midway and Lower Geyser Basin Area

Fairy Falls: Easy; 5 or 7 miles round trip. Two trails lead to this 200-foot waterfall. The shorter route approaches from the south, crossing the Firehole River then following the hiking/biking road approximately 1 mile to the Fairy Falls Trail. The longer route approaches from the north along hiking/biking road 1¼ miles to the Fairy Falls Trail. Trailheads: short route—1 mile south of Midway Geyser Basin; long route—at the end of Fountain Flat Drive, north of Fountain Paint Pot.

Sentinel Meadows: Moderate; 3 miles round trip (4 if you go to Queen's Laundry). Trail follows the Firehole River a short distance, then veers away from the river toward the meadows. Look for the large mounds of hot springs and for the remains of the old, incomplete bathhouse at Queen's Laundry, 1.9 mi from the trailhead. Begun in 1881, construction was abandoned as park administrations and priorities changed. Minerals from the hot springs preserved the structure, which was the first building constructed by the government for public use in any national park. Queen's Laundry is a National Historic Site. Trail is very wet in the spring and very buggy in the summer. Trailhead: 10 miles north of Old Faithful, at the end of Fountain Flat Drive—cross the footbridge over the Firehole River to the trailhead.

Historic Structures & Areas

Nez Perce National Historic Trail passes through the Lower Geyser Basin

*Old Faithful Inn
100 years old in 2004*

Old Faithful Historic District; including Old Faithful Lodge

F. Jay Haynes photo studio, built in 1897; originally in front of the Old Faithful Inn, now near the crosswalk at the Grand Loop Road.

The Klammer Store, also built in 1897, is the general store north of the Old Faithful Inn.

Queen's Laundry, begun in 1881 but never finished, in Sentinel Meadows (see trail description at left).

See Chapters 1 and 8 for more information on historic areas in the park.

Major Areas: Tower– Roosevelt

FREQUENTLY ASKED QUESTIONS

How tall is Tower Fall?
132 feet.

How did the rock columns form in the canyon?

The formation you see across the Yellowstone River was formed by a basaltic lava flow that cracked into hexagonal columns as it slowly cooled. You can see other basalt columns at Sheepeater Cliff along the Gardner River between Mammoth and Norris.

Can I hike to the bottom of Tower Fall?

Not anymore, due to severe erosion and dangerous conditions. You can still walk past the Tower Fall Overlook approximately $\frac{3}{4}$ mile, ending with a view of Tower Creek flowing into the Yellowstone River. If you have heart, lung, or knee problems, you may want

to enjoy the view from the overlook.

How did the petrified tree become petrified?

Two elements are required:

1. Rapid burial to minimize decay. In Yellowstone, trees were buried by volcanic deposits and mudflows 45–50 million years ago.
2. Groundwater with high concentrations of silica. The silica precipitates from ground water, filling the spaces within wood cells, and petrifies the tree. Erosion uncovered the tree. In Yellowstone, glacial ice, running water, and wind have uncovered vast areas of petrified trees.



Basalt columns near Tower Fall

ponds and huge boulders (erratics) between the Lamar and Yellowstone rivers were left by the retreating glaciers, as were several moraines.

Lamar Canyon

This canyon, east of Tower Junction, contains outcrops of granite and granitic gneiss that are among the oldest rocks known in the park—more than two billion years old. Little is known about their origin; time, heat and pressure have altered these rocks and obscured their early history. Only in the Gallatin Range are older outcrops found inside the park.

Tower Fall

Tower Creek drops 132 feet at Tower Fall, which is framed by eroded volcanic pinnacles. The idyllic setting has inspired numerous artists, including Thomas Moran.

Calcite Springs

These hydrothermal springs, located on a slope near river level, mark the downstream end of the Grand Canyon of the Yellowstone River. The heat driving these springs rises from a volcanic fracture zone beneath the area. Deposits of oil and other hydrocarbons exist in rocks beneath the springs; heat forces oil out of the deeper rocks to the surface.

Specimen Ridge

Many layers of petrified trees exist on Specimen Ridge. Located at the top of the ridge along the Northeast Entrance Road east of Tower Junction, the area also includes excellent samples of petrified leaf impressions, conifer needles, and microscopic pollen

Formation

The geology of the Tower area and its landforms are expressions of geologic events that helped shape much of the Yellowstone area. Mount Washburn and the Absaroka Range are both remnants of ancient volcanic events that formed the highest peaks in this area. Ancient eruptions 45 to 55 million years ago buried the trees of Specimen Ridge in ash and debris flows. The oldest basalt is the Junction Butte basalt, 2.2 million years old, which is exposed along the road north of Tower Fall. Across the Yellowstone River in this area (called the Narrows), the lower basalt is 1.5–2.2 million years old; the upper basalt is 1.2 million years old. The sediments between these basalts may show evidence of the oldest known glaciation in Yellowstone. Glacial boulders from the last major glaciation of Yellowstone—the Pinedale—rest on top of the youngest basalt.

Glaciers also scoured the landscape, exposing the petrified trees and leaving evidence of their passage throughout the area. The glacial

See Chapter 3 for more about Yellowstone's geology.

Tower– Roosevelt

Historic Structures & Areas

Lamar Buffalo Ranch

Northeast Entrance Station

*Roosevelt Lodge
Historic District*

**See Chapters 1 and 8
for more information on
historic areas in the
park.**

from numerous species no longer growing in the park. The Petrified Tree, west of Tower Junction, is an excellent example of an ancient redwood, similar to many found on Specimen Ridge, that is more accessible to park visitors.

Wildlife

The (relatively) low-elevation valleys of the this area provide critical winter range to some of the largest wild herds of bison and elk found in North America. Due to the large herds of wintering bison and elk, the Lamar Valley was chosen as a primary site for restoration of gray wolves into Yellowstone in 1995 (see Chapters 7 and 9). Historic accounts indicate that wolves inhabited nearly all portions of this area. Multiple wolf pack

territories currently exist here. Coyotes are also common, and an occasional bobcat, cougar, or red fox is reported.

The gorge and cliffs provide habitat for wildlife species such as bighorn sheep, osprey, peregrine falcons, and red-tailed hawks.

Both grizzly and black bears are sighted throughout the area, particularly in the spring. Black bears are more commonly seen around Tower Fall and Tower Junction. Grizzlies are frequently seen on the north slopes of Mt. Washburn, particularly in the spring when elk are calving. Road pullouts provide excellent places from which to watch wildlife.

DAY HIKES

Lost Lake: moderate; 4 miles round trip. Climbs 300 feet then joins the Roosevelt horse trail and continues west to Lost Lake. From Lost Lake, the trail follows the contour around the hillside to the Petrified Tree parking area, crosses the parking lot and continues up the hill, loops behind the Tower Ranger Station, across the creek, and back to the lodge. **Caution:** If you meet horses, move to the downhill side of the trail and remain still. Trailhead: behind Roosevelt Lodge.

Garnet Hill Loop: moderate; 7½ miles round trip. Trail follows the stagecoach road about 1½ miles to the cookout shelter, then follows Elk Creek almost to the Yellowstone River then turns upriver around Garnet Hill and back to the Northeast Entrance Road. Trailhead: park in the large parking area east of the service station at Tower Junction, then walk approximately 100 yards on the Northeast Entrance Road to the trailhead on the left.

Hellroaring: Strenuous; 4 miles round trip. The trail begins with a steep descent to Yellowstone River Suspension Bridge, then crosses a sagebrush plateau and drops down to Hellroaring Creek. The Yellowstone River and Hellroaring Creek are both popular fishing areas. **Caution:** This trail can be hot and dry during the summer months so take plenty of water. Watch your footing if you go off trail and onto the smooth river boulders along the Yellowstone River. You can also access this trail from Tower Junction by following the Garnet Hill Loop Trail (see above); roundtrip distance is 10 miles. Trailhead: Hellroaring parking area 3½ miles west of Tower Junction.

Yellowstone River Picnic Area: moderate; 3.7 miles round trip. Climbs steeply for a short distance, then follows the rim of the Grand Canyon of the Yellowstone upriver, with views of the Narrows of the Yellowstone,

the Overhanging Cliff area, the towers of Tower Fall, basalt columns, and the historic Bannock Ford. Watch your footing and beware of steep dropoffs into the canyon. Do not approach bighorn sheep; retreat or walk around them, keeping at least 25 yards between you and the animals. Above Bannock Ford, trail connects with the Specimen Ridge Trail and follows it a short distance to a left turn back to the Northeast Entrance Road. Once at the road, walk west 0.7 miles back to the picnic area. Trailhead: Yellowstone River Picnic Area.

Slough Creek: Moderately strenuous; 4 or 10 miles round trip. Actually a long-distance trail that leads into the Absaroka-Beartooth wilderness beyond Yellowstone, this trail is often used by anglers and hikers up to the first and second meadows. Trail follows historic wagon trail up Slough Creek, beginning with a climb up a moderately steep hill then down to the first meadow (2 miles); continues along the edge of the meadow to the second meadow (5 miles from trailhead.) Horse-drawn wagons also use this trail; they come from Silver Tip Ranch, a private ranch north of the park boundary that has a historic right of access. **Caution:** Be alert for bears; they frequent these meadows. Trailhead: On the road to Slough Creek Campground; where the road bears left, park beside the vault toilet.

Mt. Washburn: Moderately strenuous; 3 miles one way. Two trails lead to the summit of Mt. Washburn; both are popular and often crowded in the summer. The north approach follows a service road and is open to bicycles and service vehicles. The south approach is hiking only. For descriptions of this area, see the Canyon area. Trailhead for north approach: Chittenden Road parking area, 8.7 miles south of Tower Junction.

A note about the trail at Tower Fall:

The bottom third of the trail, which takes you to near the base of the waterfall, is closed because rock and mud-slides have made this portion unsafe. You can still view the waterfall from the upper platform and continue down the trail to see the confluence of Tower Creek and the Yellowstone River.

Major Areas: West Thumb

FREQUENTLY ASKED QUESTIONS

Why is this area called West Thumb?

The name "West Thumb" comes from Yellowstone Lake's resemblance to the shape of a human hand; the large southwestern bay represents the thumb. The bay is a caldera within a caldera. It was formed by a volcanic explosion that occurred about 162,000 years ago. The resulting caldera later filled with water forming an extension of Yellowstone Lake.

Where can I see wildlife?

In summer, look for bison, elk, and mule deer around West Thumb Geyser Basin and in meadows along Big Thumb Creek; waterfowl, bald eagles, and osprey along the lake shore; ground squirrels, marmots, red squirrels, and other small mammals throughout the area. In winter, look for river otters along the shores of West Thumb where under-water hydrothermal features melt holes in the ice.

How deep is Abyss Pool?

About 53 feet; Black Pool is about 35–40 feet deep.

How hot are the springs at West Thumb?

Temperatures vary from less than 100°F to just over 200°F.

The West Thumb Paint Pots aren't like they used to be. What happened?

Like all hydrothermal features in Yellowstone, the West Thumb Paint Pots change over time. They became less active and more fluid in the 1970s. In the 1990s, they became more active; new mud cones periodically throw mud into the air.

Why doesn't Grant Campground open before late June?

Grizzly and black bears frequent this area in spring when cutthroat trout spawn in five streams here. To help prevent bear/human conflicts, the campground opens after most of the spawn is over.

What happened to the development at West Thumb?

The gas station, marina, photo shop, store, cafeteria, and cabins were removed in the 1980s to protect the fragile hydrothermal features and improve the quality of visitor experience. The development at Grant took the place of most of these facilities.



Fishing Cone

Formation

The large circular bay of West Thumb is an excellent example of a volcanic crater or caldera. A powerful volcanic explosion about 162,000 years ago caused Earth's crust to collapse, creating the West Thumb Caldera. The depression produced by the volcano later filled with water to become this large bay of Yellowstone Lake.

The West Thumb Caldera lies within the Yellowstone Caldera, which encompasses the central and southern portions of the park.

West Thumb Geyser Basin

The West Thumb Geyser Basin, including Potts Basin to the north, is the largest geyser basin on the shore of Yellowstone Lake. The hydrothermal features here are found on the shore and under the lake. Several underwater hydrothermal features were discovered in the early 1990s and can be seen as slick spots or slight bulges in the summer. During the winter, the underwater hydrothermal features can prevent lake ice from forming.

Walter Trumbull of the 1870 Washburn Expedition described a unique event while a

man was fishing adjacent to what is now called Fishing Cone, a geyser on the lakeshore: “. . . in swinging a trout ashore, it accidentally got off the hook and fell into the spring. For a moment it darted about with wonderful rapidity, as if seeking an outlet. Then it came to the top, dead, and literally boiled.” Fishing Cone erupted frequently to the height of 40 feet in 1919 and to lesser heights in 1939. One fisherman was badly burned in Fishing Cone in 1921. Fishing at the geyser is now prohibited.

Early visitors would arrive at West Thumb via stagecoach from the Old Faithful area. They had the choice of continuing on the dusty, bumpy stagecoach or boarding the steamship “Zillah” to continue the journey by water to the Lake Hotel. The boat dock was located near the south end of the geyser basin near Lakeside Spring.

Wildlife

Elk cows and their new calves are frequently seen in May and June. Grizzly bears, though seldom seen, are here too—especially during trout spawning season, when they can easily catch fish in shallow streams. In winter, pine marten tracks cross the snow. On the frozen bay, river otters pop in and out of holes in the ice caused by underwater thermal vents. Coyotes eat the fish scraps, as do bald eagles. In the summer, bald eagles and osprey dive into the bay to catch cutthroat trout. Other summer birds include bufflehead and golden-eye ducks, and common loons. Ravens are year-round residents. In the winter, they can unzip and unsnap the packs of snowmobilers, flying off with whatever they find.

Heart Lake

Lying in the Snake River watershed east of Lewis Lake and south of Yellowstone Lake, Heart Lake was named sometime before 1871 for Hart Hunney, a hunter. Other explorers in the region incorrectly assumed that the lake’s name was spelled “Heart” because of its shape.

The Heart Lake Geyser Basin begins a couple of miles from the lake and descends along Witch Creek to the lakeshore. Five groups of hydrothermal features comprise the basin, and all of them contain geysers, although some are dormant.

The small range of mountains located just west of Heart Lake, the Red Mountains, includes 10,308-foot Mount Sheridan. Another peak, Factory Hill, was named because of the nearby steam vents, which N.P. Langford described in 1871: “Through the hazy atmosphere we beheld, on the shore of the inlet opposite our camp, the steam



Mt. Sheridan, as seen from Heart Lake

ascending in jets from more than fifty craters, giving it much the appearance of a New England factory village.”

Craig Pass

Craig Pass, at 8,262 feet on the Continental Divide, is about eight miles east of Old Faithful on the Grand Loop Road. In 1891, U.S. Army Corps of Engineers Captain Hiram Chittenden discovered Craig Pass while he was surveying. It was probably Chittenden who named the pass for Ida M. Craig (Wilcox), one of the first visitors to cross the pass on the new road.

Isa Lake, at the pass, was also named by Chittenden. At one time, it was probably the only lake on Earth that drained naturally to two oceans backwards, the east side draining to the Pacific and the west side to the Atlantic. If this still occurs, it is only at the peak of snow melt after winters with deep snowfall.

Shoshone Lake

Visible from an overlook near Craig Pass, Shoshone Lake is the park's second largest lake, the site of a geyser basin, and the source of the Lewis River. Fur trapper Jim Bridger may have been the first European American to visit this lake, in 1833. Fellow trapper Osborne Russell certainly reached the lake in 1839. In 1872, Frank Bradley of the second Hayden Survey gave the lake its official name—the same name that area tribes gave the Snake River.

Shoshone Lake is thought to be the largest lake in the lower 48 states that cannot be reached by road. Its maximum depth is 205 feet and it has an area of 8,050 acres. Originally, the lake was barren of fish because they were blocked by waterfalls on the Lewis River. Lake and brown trout were planted beginning in 1890, and the Utah chub was apparently introduced by bait anglers.

The Shoshone Geyser Basin, reached by hiking or by boat, contains one of the highest concentrations of geysers in the world—more than 80 in an area 1,600 x 800 feet. Hot springs and mudpots dot the landscape between the geyser basin and the lake.

Snowy River

The Snowy River is a major tributary of the Columbia River and has its headwaters just inside Yellowstone on the Two Ocean Plateau. Its source was debated for a long time. The problem was to find the longest branch in the Two Ocean Plateau, which is thoroughly crisscrossed with streams. Current maps show the head of the Snowy to be about 3 miles north of Phelps Pass, at a point on the Continental Divide inside Yellowstone National Park. A number of springs gush forth upon the hillside, which is about two miles above sea level. Uniting, they form a small stream, which flows through Idaho, joins the Columbia in Washington, and then to the Pacific. The Snowy River is 1,040 miles long; 42 miles of it are in Yellowstone National Park.

DAY HIKES

Yellowstone Lake Overlook: Moderately strenuous; 2 miles round trip. Follows mostly level terrain then climbs 400 feet to an overlook in a high mountain meadow with a commanding view of the West Thumb of Yellowstone Lake and the Absaroka Mountains. Trailhead: West Thumb Geyser Basin parking area.

Duck Lake: Moderately strenuous; 1 mile round trip. Climbs a small hill to a view of Duck and Yellowstone lakes and the expanse of the 1988 fires that swept through this area. Trailhead: West Thumb Geyser Basin parking area.

Shoshone Lake (via DeLacy Creek): easy; 6 miles round trip. Follows a forest edge and passes through open meadows to the shores of Yellowstone's largest backcountry lake. Trailhead: 8.8 miles east of West Thumb Junction.

Riddle Lake: easy; 5 miles round trip. Crosses the Continental Divide and passes through small mountain meadows and forests to the shores of a picturesque little lake. Look for moose in the marshy meadows and for birds near the lake. Due to grizzly activity, this trail does not open until July 15th and groups of four people or more are recommended but not required. Trailhead: approximately 3 miles south of the Grant Village intersection, just south of the Continental Divide sign.

Lewis River Channel/Dogshead Loop: moderately strenuous; 7 or 11 miles round trip. Travels through a fairly level forested and burned area to the Lewis River Channel. Look for eagles and osprey fishing for trout in the shallow waters. Turn around at this point for the shorter trip or continue on. Trail follows the channel to Shoshone Lake and returns via the Dogshead Trail. Trailhead: approximately 5 miles south of the Grant Village intersection, just north of Lewis Lake on west side of the road.