Yellowstone Resources & Issues 2010

Clockwise: Old Faithful Geyser, Morning Glory Pool, bull bison near Old Faithful.

The new Old Faithful Visitor Education Center will feature exciting and interactive exhibits that explore the park's hydrothermal features, its underlying volcanism, and life in extreme environments.

Division of Interpretation • Yellowstone National Park • National Park Service

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Reviewers

Resources & Issues is reviewed annually by Yellowstone National Park staff. The park experts responsible for the information in this edition are listed at the end of each chapter in "For More Information."

Editing, design, production

Carolyn Duckworth, Publications Specialist
Division of Interpretation

Managing Editor

Linda Young, Chief of Interpretation

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CONTENTS

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Preface

In this book, you will find concise information about the park's history, natural and cultural resources, and issues. This material was provided and reviewed by National Park Service staff.

How the Book Is Organized

The book is organized to provide you with a quick introduction to Yellowstone information, and chapters about major topics. Thus, the book begins with "Park Facts," followed by "Frequently Asked Questions" and a brief introduction. More detailed information follows in the chapters.

How the Chapters Are Organized

- 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.

Updating the Information

Information about Yellowstone constantly changes; the information provided here is current as of January 1, 2010. For updates:

- www.nps.gov/yell
- www.greateryellowstonescience.org
- park publications and exhibits

The interpretive rangers who staff visitor centers also have updated information.

We welcome your feedback and comments.

Arrows point to new or changed information

Park Facts

Yellowstone National Park was established on March 1, 1872.

Yellowstone is the world's first national park.

2 pages & new information

VISITORS

2009—a record-breaker!
3,295,187 recreational visits to the park

2008–2009 winter: 86,784 recreational visits

GEOGRAPHY

3,472 square miles or 8,987 sq. km

2,221,766 acres or 899,139 hectares

Note: No area figures for the park have been scientifically verified. These figures have been used for many years & in different references. Efforts to confirm the total park area continue.

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 Rhode Island & Delaware combined

Approximately 5% of park covered by water; 15% by grassland; and 80% by forests

Precipitation

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

Temperature

Average at Mammoth:
January: 9°F
July: 80°F

Records:
High: 99°F, 2002 (Mammoth)
Low: –66°F, 1933 (West Entrance, Riverside Station)

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: 410 feet

GEOLOGY

An active volcano

One of the world's largest calderas at 45 x 30 miles

1,000–3,000 earthquakes annually

More than 10,000 hydrothermal features

More than 300 active geysers

Approximately 290 waterfalls

Tallest waterfall near a road: Lower Falls of the Yellowstone River at 308 ft.

WILDLIFE

67 species of mammals, including:
7 species of native ungulates
2 species of bears

322 species of birds (148 nesting species)

16 species of fish (5 non-native)

6 species of reptiles

4 species of amphibians

2 threatened species: Canada lynx, grizzly bear

1 endangered species: gray wolf

FLORA

7 species of conifers

±80% of forest is lodgepole pine

±1,150 species of native vascular plants

>210 species of exotic (non-native) plants

186 species of lichens

At least 406 species of thermophiles

CULTURAL RESOURCES

26 associated Native American tribes

Approximately 1,600 archeological sites

More than 300 ethnographic resources (animals, plants, sites)

More than 24 sites, landmarks, and districts on the National Register of Historic Places

1 National Historic Trail

More than 900 historic buildings

More than 379,000 cultural objects and natural science specimens

Thousands of books (many rare), manuscripts, periodicals

90,000 historic photographs

Park Facts

EMPLOYEES

National Park Service

Permanent: 355
- Full time, year-round: 210
- Full time, seasonal: 139
- Part time: 6

Term (variable duration): 36
Seasonal: 429

Concessioners

Approximately 3,200 people work for concessioners at peak summer levels

FACILITIES

9 visitor centers, museums, and contact stations

9 hotels/lodges (2,000+ hotel rooms/cabins)

7 NPS-operated campgrounds (450+ sites)

5 concession-operated campgrounds (1,700+ 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 miles paved)

More than 15 miles of boardwalk

Approximately 1,000 miles of backcountry trails

92 trailheads

301 backcountry campsites

Budget

Fiscal Year 2009 (in millions)

Total: $66.4

Federal Funding

Congressional Annual Appropriations:
- Operations & staff (base): $34.5
- Wildland Fire: $1.9

Other Appropriations: $9.1

Other Funding

Donations & Grants: $1.4

Fees: $11.4

Reimbursable: $8.1

Distribution of Budget

Administration: 16%

Includes human resources, contracting, budget & finance, property management, telecommunications & information technology

Facility Operations & Maintenance: 35%

Includes utilities, roads, trails, structures, historic preservation coordination, construction management

Resource Preservation: 21%

Includes research & monitoring of natural and cultural resources, invasive species management

Visitor Services: 28%

Includes interpretation & education, law enforcement, emergency medical services, search & rescue, entrance station operations, structural fire activities, and managing park concessions

American Recovery & Reinvestment Act of 2009 (ARRA)

Yellowstone National Park is receiving $15 to $19 million in project funding from ARRA. The projects address critical park needs, improve visitor experience, implement sustainable green technologies, and stimulate economic activity in the region.

Approved Projects

- Demolish and replace Madison Wastewater Facility
- Demolish and replace roof of wastewater management lift station
- Improve restroom facilities to eliminate contamination issues
- Realign segments of the Shelf Lake Trail
- Rehabilitate and repave South Rim Drive
- Rehabilitate the Observation Peak Trail
- Repair boardwalks near thermal features
- Repair deteriorating trails and footbridges
- Replace deteriorating spring and reservoir to ensure clean drinking water
- Replace leaking underground fuel storage tanks and remediate soil contamination
- Construct micro hydropower facility at Mammoth Hot Springs

Completed Projects

- Resurface South Entrance Road
- Repair hazardous propane service line at Fort Yellowstone

Frequently Asked Questions

See also Park Facts, pages 7 & 8.

The golden walls of the Grand Canyon of the Yellowstone River, above. Yellowstone National Park is sometimes confused with Yosemite National Park (below), which is in California and was not the first national park.

How did Yellowstone get its name?

Yellowstone National Park is named after the Yellowstone River, the major river running through the park. According to French-Canadian trappers in the 1800s, they asked the name of the river from the Minnetaree tribe. They responded "Mi tse a-da-zi," which literally translates as "Rock Yellow River." (Historians do not know why the Minnetaree gave this name to the river.) The trappers translated this into French as "Roche Jaune" or "Pierre Jaune." In 1797, explorer-geographer David Thomson used the English translation—"Yellow Stone." Lewis and Clark called the Yellowstone River by the French and English forms. Subsequent usage formalized the name as "Yellowstone."

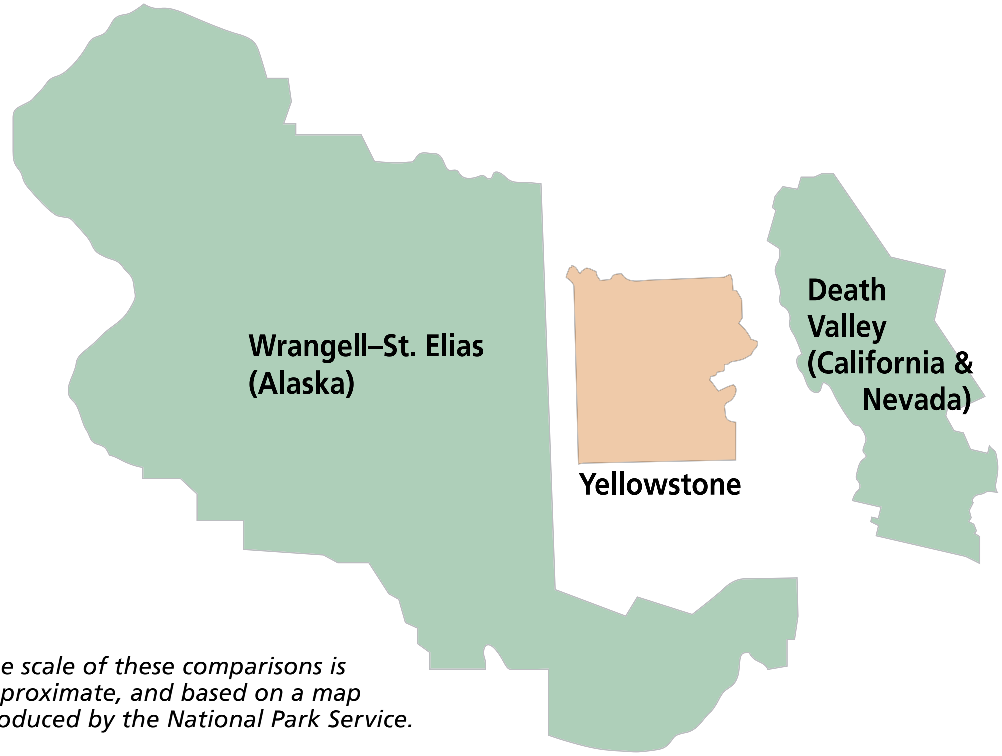
Did other national parks exist before Yellowstone?

Some sources list Hot Springs in Arkansas as the first national park—it was set aside in 1832, forty years before Yellowstone was established in 1872—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,



The scale of these comparisons is approximate, and based on a map produced by the National Park Service.

Yellowstone (at 2.2 million acres) was the largest national park in the contiguous United 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 8, "Wilderness.")*

Why is Yellowstone called a Biosphere Reserve and a World Heritage Site?

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

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 Forest Service is mandated to wisely manage resources for many sustainable uses. Six national forests surround Yellowstone National Park, shown in the map on page 48.

The Man and the Biosphere Program designates Yellowstone as a Biosphere Reserve & World Heritage Site.

To find out more:

www.cr.nps.gov/worldheritage

whc.unesco.org/

www.unesco.org/mab

How many rangers work in Yellowstone?

In Yellowstone, approximately 780 people work for the National Park Service during the peak summer season; approximately 355 year-round. Park rangers perform duties in interpretation, education, resource management, law enforcement, emergency medical services, and backcountry operations. Other park employees perform duties in research, maintenance, management, administration, trail maintenance, fire management, and fee collection.

Is Yellowstone the most visited national park?

No. Great Smoky Mountains National Park has the most visits—more than nine million. The Grand Canyon and Yosemite also receive more visits than Yellowstone.

Is Yellowstone open in winter?

Yes. You can drive into the park through the North Entrance year-round. At Mammoth, you can take self-guiding tours of Fort Yellowstone and the Mammoth Terraces, join a guided walk or tour, crosscountry 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 arrange for tours to Norris Geyser Basin, Old Faithful, and the Grand Canyon of the Yellowstone River.

From Mammoth, you can drive past Blacktail Plateau, through Lamar Valley, and on to Cooke City, Montana. You may see coyotes, bison, elk, wolves, eagles, and other wildlife along the way. You can also stop to crosscountry ski or snowshoe a number of trails that begin along this road.

If the interior of the park is open for winter use, you can tour the lower half of the park by guided snowmobile or snowcoach trips.

You can also stay at Old Faithful Snow Lodge, from which you can walk, snowshoe, or ski around the geyser basin; take shuttles to crosscountry ski trails; or join a tour to other parts of the park such as West Thumb, Hayden Valley, and the Grand Canyon of the Yellowstone River.

Can we swim in Yellowstone's rivers and lakes?

Swimming is not recommended because most lakes and streams are extremely cold. Firehole Canyon, near Madison Junction, has a swimming area popular in summer. The area known as the Boiling River, north of Mammoth Hot Springs, is one of the few legal thermal soaking areas; soaking is allowed during daylight hours only and at your own risk.

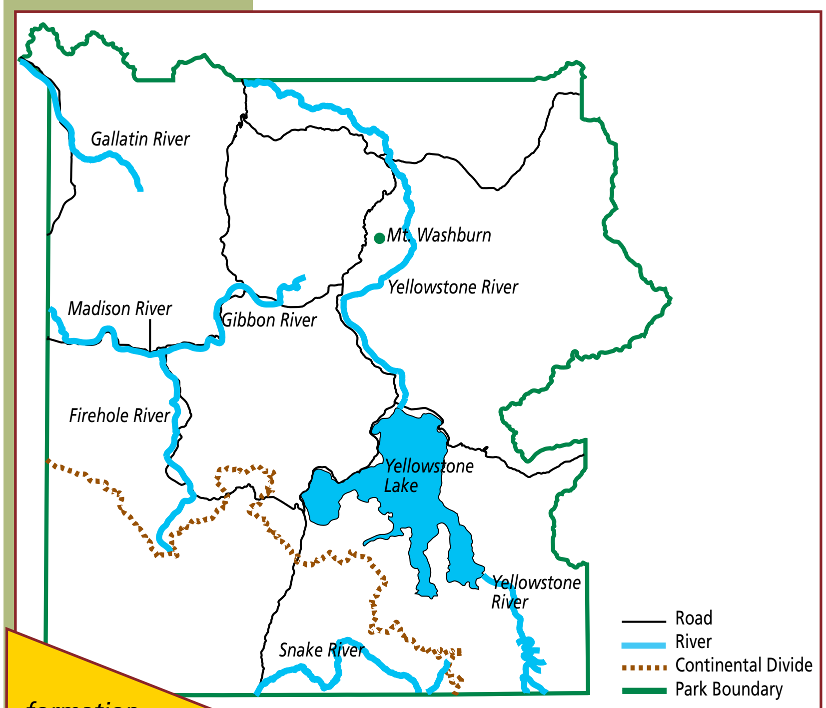
FAQ: Geography

What is the highest peak in the park?

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

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. You cross the Continental Divide three times between the South Entrance and Old Faithful. Craig Pass is the highest crossing, at 8,262 feet.



formation of canyon

How cold is Yellowstone in winter?

Average winter highs are 20–30°F; average lows are 0–9°F. The record low was –66°F at Riverside Ranger Station, near the West Entrance, on February 9, 1933.

Where does the Yellowstone River flow?

The river begins outside the park on Younts Peak and flows into Yellowstone Lake. It leaves the lake at Fishing Bridge, and continues north-northwest until it 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.

Does the Missouri River begin here?

No, but its three tributaries begin in the Greater Yellowstone area. The Jefferson begins in the Centennial Mountains, west of the park. The Madison River forms inside the park at Madison Junction, where the Gibbon and Firehole rivers join. The Gallatin River also begins inside the park north of the Madison River. It flows north through Gallatin Canyon and across the Gallatin Valley, joining the Madison and Jefferson rivers at Three Forks, Montana, to form the Missouri River.

Does the Snake River begin here?

Yes, the Snake River—a major tributary of the Columbia River—has its headwaters just inside Yellowstone on the Two Ocean Plateau, at a point on the Continental Divide. The river flows through Idaho and joins the Columbia in Washington. The Snake River is 1,040 miles long; 42 miles of it are in Yellowstone National Park.

How did Mt. Washburn form?

At 10,243 feet, this peak can be seen from many locations in the park. It is a remnant of an extinct volcano from the Absaroka Volcanics of about 50 million years ago. The volcano was literally cut in half by a volcanic eruption 640,000 years ago. *(See next page and Chapter 3.)* Only the northern part of the original volcano is still visible.

How did the Grand Canyon of the Yellowstone River form?

Scientists continue to evolve their theories about its formation. After the Yellowstone Caldera eruption, 640,000 years ago, lava flows and volcanic tuffs buried the canyon area; but hydrothermal gases and hot water weakened the rock. The river eroded this rock, carving a canyon in the Yellowstone River beginning at Tower Fall and heading upstream to Lower Falls.

How did Yellowstone Lake form?

The lake's main basin is part of the Yellowstone Caldera, which was formed 640,000 years ago; West Thumb was formed by a later, smaller eruption. The arms of the lake were formed by uplift along fault lines and sculpting by glaciers. The lake drains north at Fishing Bridge. Some scientists consider LeHardys Rapids to be the geologic northern boundary of the lake because the periodic rise and fall of that site appears to control lake outflow.

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

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 *(see at right)* marks the rim of the Yellowstone Caldera, created by a massive volcanic eruption approximately 640,000 years ago. Subsequent lava flows filled in much of the caldera, and it is now measured at 30 x 45 miles. Its rim can best be seen from the Washburn Hot Springs overlook, south of Dunraven Pass. Gibbon Falls, Lewis Falls, and Flat Mountain Arm of Yellowstone Lake are part of the rim.

Is Yellowstone's volcano still active?
Yes. The park's numerous hydrothermal features attest to the heat still beneath this area. 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.

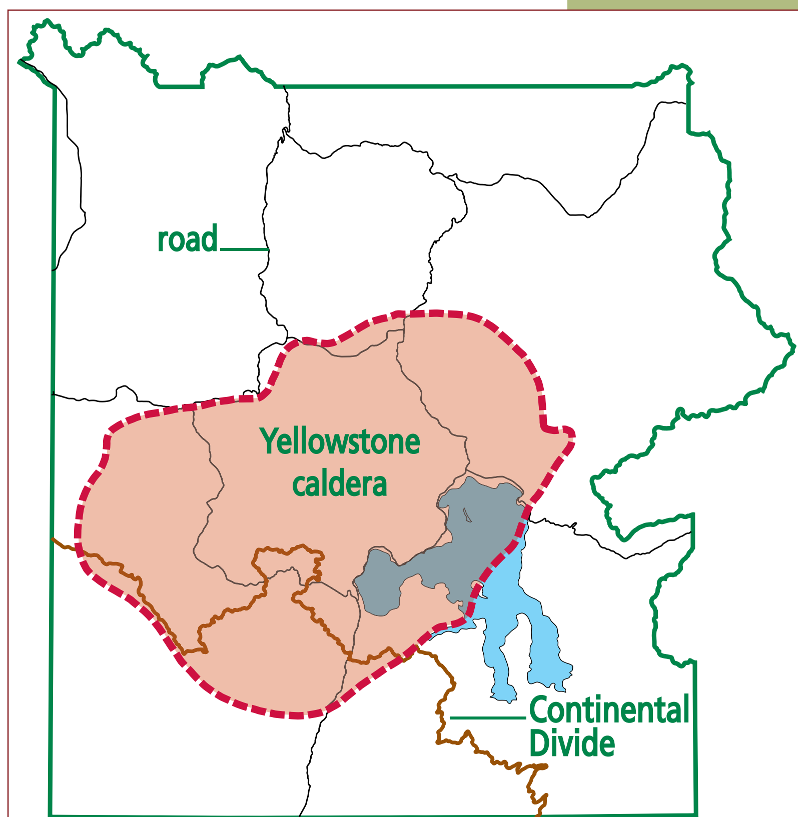
Where can I see volcanic flows?
Almost everywhere you look in Yellowstone! Prominent locations include Sheepeater Cliff (columnar basalt); Tuff Cliffs (ash flow); Virginia Cascades (ash flow, lava); Firehole Canyon (lava); Mt. Haynes and Mt. Jackson, along the road between Madison and West Entrance (columnar rhyolite, Lava Creek tuff); north of Tower Fall (several different basalt formations); Obsidian Cliff (lava).

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 the Yellowstone volcano erupt soon?
Current geologic activity at Yellowstone has remained relatively constant since scientists first started monitoring more than 30 years ago. Another caldera-forming eruption is theoretically possible, but it is very unlikely 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 the Yellowstone volcano won't erupt?
Scientists from the Yellowstone Volcano Observatory (YVO) watch 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 the hazards of the Yellowstone volcano. To view current data about earthquakes,



ground movement, and stream flow, visit the YVO website at 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: Hydro-thermal Geology

geothermal energy question

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 heat; ample rain and snowfall seep deep underground to supply the water; and underground cracks and fissures form the plumbing. Hot water rises through the plumbing to surface as hydrothermal features in Yellowstone, including geysers *(See Chapter 3.)*

What exactly is a geyser basin?

A geyser basin is a geographically distinct area containing a "cluster" of hydrothermal features that may include geysers, hot springs, mud-pots, 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.

Where can I see mudpots?

Small mudpot areas occur at West Thumb Geyser Basin, Fountain Paint Pot, and Artist Paintpots. The largest group of mudpots can be found at Mud Volcano, at the southern end of Hayden Valley.

What is the most active thermal area in the park?

Norris Geyser Basin is the hottest, oldest, and most dynamic of Yellowstone's *active* 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 change often, with frequent disturbances from seismic activity and water fluctuations. Norris is so hot and dynamic primarily because it sits at the intersection of three major faults, two of which intersect with a ring fracture from the Yellowstone Caldera eruption 640,000 years ago.

What is the oldest thermal area in the park, active or inactive?

Terrace Mountain, at Mammoth Hot Springs, is a dormant thermal area that has been dated to 406,000 years old.

Is Yellowstone's geothermal energy used to heat park buildings?

Yellowstone National Park's thermal areas cannot be tapped for geothermal energy because such use could destroy geysers and hot springs, as it has done in other parts of the world. *(See Chapter 8, "Greening," for more information.)*

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. In the few places pets are permitted, they must be leashed 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 burned when they have broken through the fragile surface. Some people have died.

Why can't I smoke in the geyser basins?

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

Were Native Americans afraid of geysers?

Native Americans in general were not afraid of geysers. Many of the associated tribes of Yellowstone say 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 Chapter 1 for more about Native Americans in Yellowstone.*

Did glaciers ever cover Yellowstone?

Yes, Yellowstone has experienced glaciers many times. Scientists estimate that 18,000 years ago, for example, most of the park was under 4,000 feet of ice. *(See page 64.)* During this glacial era, called the Pinedale, glaciers flowed down from the Beartooth Plateau and other high country, following river corridors such as the Lamar, Yellowstone, and Madison. An ice cap also formed. The glaciers and ice cap retreated and advanced several times at least, and finally retreated 13,000–14,000 years ago.

Where can I see their evidence?

Hayden Valley: The valley was filled by a lake at least once and, consequently, contains fine-grained lake sediments that are now covered with glacial till left from the most recent glacial retreat 13,000–14,000 years ago. Because 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.

Norris Geyser Basin: The Ragged Hills, which are northwest of Porcelain Basin, are thermally altered kames (hills of glacial debris) formed as glaciers receded. The underlying hydrothermal features melted remnants of ice and caused masses of debris to be dumped, which were then altered by steam and hot water.

Tower Fall area: North of Tower Fall, sediments between layers of basalts may show evidence of the oldest known glaciation in Yellowstone. Plus, glacial boulders from the last major glaciation of Yellowstone—the Pinedale—rest atop the youngest basalt.

Lamar Valley: The huge boulders (erratics) and most of the ponds between the Lamar and Yellowstone rivers were left by glaciers, as were several moraines (ridges of debris).

Madison Valley, west of Seven Mile Bridge: Glacial moraines, glacial outwash, and recent Madison River deposits can be seen.

Mammoth Hot Springs: 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. Mount Everts and Bunsen Peak were both overidden by ice.

Swan Lake Flat: South of Mammoth, this area was glaciated and is now meadows and wetlands where people often see elk, bison, sometimes grizzlies and wolves, and water birds. Electric Peak, to the northwest *(and in photo below),* was also carved by glaciers.

Upper Geyser Basin: Glacial deposits underlying this and other area geyser basins store the water necessary for geysers to occur and allow the water to percolate up from depth.

Fountain Flats: The Porcupine Hills are thermal kames.

FAQ: The Fires of 1988

How much of the park burned in 1988?

The 1988 fires affected 793,880 acres or 36 percent of the park. 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.

Visitors came throughout the summer of 1988.

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 measurable 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 the fires of 1988, a national policy review team examined the national fire policy again, and concluded that natural fire policies in national parks and wilderness areas were basically sound. It also recommended improvements that were incorporated into the National Park Service's fire policy of June 1990 and into Yellowstone National Park's fire management plan of 1992. *For more about the evolution of fire policy and where it stands today, 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.

Why doesn't the park remove burned trees?

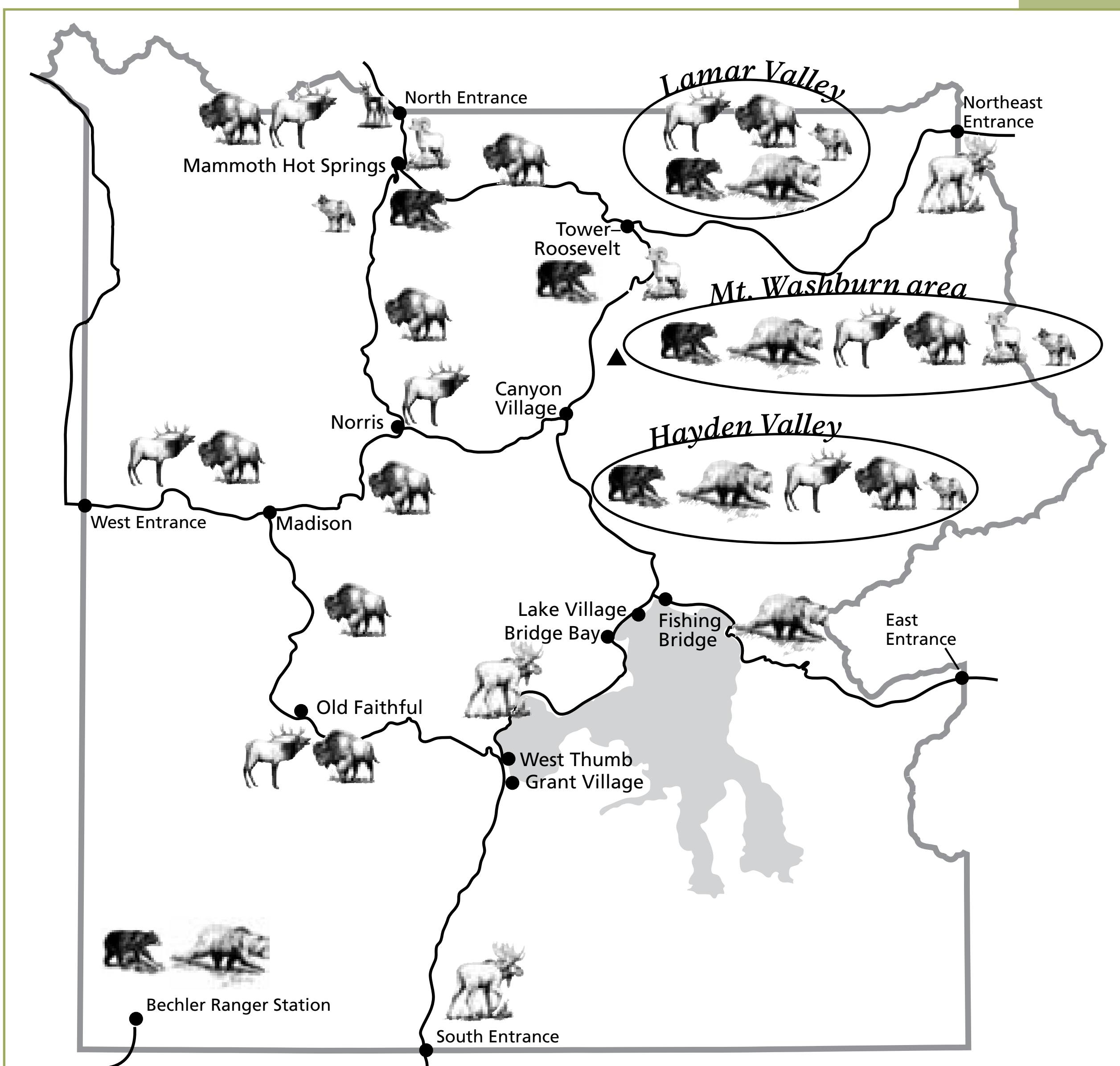
Burned trees and those that have died for other reasons still contribute to the ecosystem. For example, dead standing trees provide nesting cavities for many types of animals; fallen trees provide food and shelter for animals and nutrients for the soil. However, park managers will remove dead or burned trees that pose safety hazards along roads or in developed areas.

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. Bison graze on grasses and sedges, and mate in August, so you are likely to see them in big, noisy herds in the Hayden and Lamar valleys.

Hydrothermal basins provide important habitat for wildlife. For example, many bison and elk live in the Old Faithful area year-round. In the winter, they take advantage of the warm ground and thin snow cover. Both black and grizzly bears visit these areas during the spring when winter-killed animals are available.

Rangers at the visitor centers can tell you more about where wildlife have been seen recently.

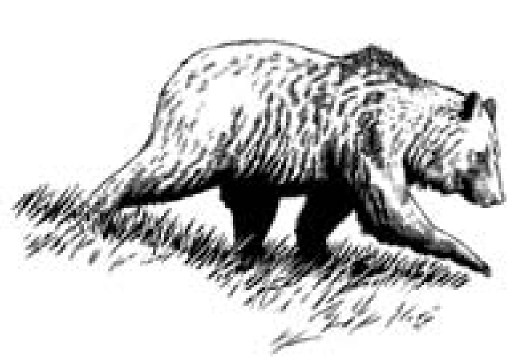


Animal illustrations © Zachary Zdinak

FAQ: Wildlife, General

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 bears was very popular with park visitors, it was not good for the people or the bears. *(See Chapter 8.)* 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 and property damage. The measures included installing bear-proof garbage cans and closing garbage dumps in the park.



Drawing © Zachary Zdinak

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.

Are grizzly bears considered threatened or endangered?

The Yellowstone grizzly population was removed from the federal threatened species list in 2007, and relisted in 2009. Regardless of its listing status, scientists will continue to monitor the long-term recovery goals for grizzly bears. *(See Chapter 8.)*

See Chapter 7 for more information about wildlife in Yellowstone, and Chapter 8 for more about issues involving wildlife.

What is the difference between a bison and a buffalo?

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."

Where are good birding locations?

That depends on what kind of birds you want to see, what time of day you are looking, and where you are in the park.

Hayden Valley is one of the best places to view water birds and birds of prey. Shore birds feed in the mud flats at Alum Creek. Sandhill cranes often nest in 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).

Blacktail Lakes, between Mammoth and Tower Junction, and the Madison River west of Madison Junction are also good places to look for birds.

Why is fishing lead-free in Yellowstone?

Birds, such as loons, waterfowl, cranes, and shorebirds, are vulnerable to lead poisoning. 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.)

FAQ: Canyon Village Area

Grand Canyon of the Yellowstone River

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Mount Washburn

•

Hayden Valley

How big is the Grand Canyon of the Yellowstone River?

This huge canyon is roughly 20 miles long, more than 1,000 feet deep, and 1,500 to 4,000 feet wide.

What causes the different colors in the canyon?

You could say the canyon is “rusting.” The colors are caused by oxidation of iron compounds in the rhyolite rock, which has been hydrothermally altered (“cooked”). 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. *(See Chapter 3.)*

Where can I see the canyon and falls?

North Rim Drive: Accessible walkways at the Brink of the Lower Falls Trail lead to views of both waterfalls. You can also see the Lower Falls from Lookout, Red Rock, and Inspiration points.

South Rim Drive: See the Lower Falls at Artist Point, from Uncle Tom’s Trail, and from a few places along the South Rim Trail; see the Upper Falls from two viewpoints at Uncle Tom’s Point.

You can also see the brink of the Upper Falls from a viewing area on the Grand Loop Road south of Canyon Junction, between the entrances to North and South Rim drives.

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 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.

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.

This area has a point and a trail named after “Uncle Tom”; who was he?

“Uncle Tom” Richardson was an early concessioner in the canyon area. From 1898–1905, he guided visitors to the canyon floor down a steep trail using rope ladders. Today the trail descends partway into the canyon via steep steel steps.

What animals can I see in this area?

Inside the canyon, look for osprey soaring over the river or perched on their five-foot diameter nests. Generally, six to ten osprey nests are occupied in the canyon near Canyon Village. They nest here from late April until late August or early September. Also look for ravens, bald eagles, and swallows.

Away from the canyon, look for mule deer, moose, red foxes, grizzly and black bears, coyotes, Steller’s jays, and great gray owls. During July, a variety of butterflies feast on the abundant flowers in the meadows.

Hayden Valley, which begins approximately 5 miles south of Canyon Junction, 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 in August. Coyotes can almost always be seen in the valley; wolves are also sometimes seen.

Mt. Washburn is another excellent place for viewing wildlife. Bighorn sheep and marmots can be seen on its slopes in the summer. Wolves and black and grizzly bears are sometimes seen. Elk and bison frequent the valley north of the mountain, and coyotes are often seen there too.

Pick up the *Canyon Area Trail Guide* at visitor centers or at viewpoints in the Canyon area. 50¢ donation requested.

FAQ: Fishing Bridge & Lake

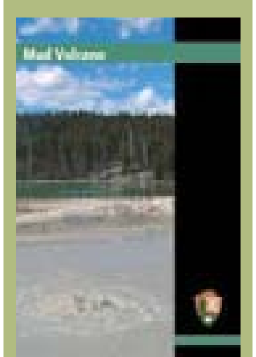
Historic Areas & Structures

Fishing Bridge Trailside Museum

Lake Fish Hatchery Historic District including Lake Lodge

Lake Hotel

See Chapter 1 for more information on historic areas in the park.



Pick up the *Mud Volcano Area Trail Guide* at visitor centers or at the area. 50¢ donation requested.

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.

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 410 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.

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. It was closed in 1989. A recreational vehicle park, operated by a concessioner, still exists in the area. Only hard-sided camping units or RVs are allowed at this campground.

How cold is Yellowstone Lake?

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.

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.

What animals can I see in this area?

The lake is home to the largest population of Yellowstone cutthroat trout in North America. You can see these trout and longnose suckers from Fishing Bridge. *See chapters 7 and 8 for more about aquatic life in the lake.* Also look for white pelicans, bald eagles, osprey, and a variety of ducks and other water birds.

In spring, you might be able to see trout leaping upstream at LeHardys Rapids, three miles north of Fishing Bridge.

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. A bison herd winters in Pelican Valley, and individuals can be seen throughout the area. Moose used to be seen in the Yellowstone Lake area much more than they are today; look along water edges and in marshes. At Bridge Bay Marina, look for river otters.

How did Madison Junction get its name?

Here, 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.

What forms the cliffs around Madison Junction?

Part of what you see is the rim of the Yellowstone Caldera, plus later lava flows. National Park Mountain is actually part of the lava flows. Some of these lava flows come down to the road through Firehole Canyon, approximately one mile south of Madison Junction. Gibbon Falls, four miles north of the junction, drops 84 feet over a remnant of the caldera rim. *(See Chapter 3.)*

Why is the bridge between Madison and the West Entrance 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.

What animals can I see in this area?

Along the Madison River, approximately 100 elk live year-round. The meadows adjacent to the Madison and Gibbon rivers are prime elk calving areas in the spring. During the fall rut, elk frequent the meadows from Seven Mile Bridge to Madison Junction.

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. In summer, they move to Hayden Valley, their traditional summer habitat and breeding area.

Bald eagles have nested in a tree about one mile west of Seven Mile Bridge in recent years; they fledged one young in 2009. Several pairs of ospreys also nest along the Madison. You might also see trumpeter swans, Canada geese, mallards, Barrow's goldeneyes, and other water birds.

Is the story about National Park Mountain true?

The legend, which you can read about on page 27 and at the Madison Information Station, tells of explorers camping here in 1870 and deciding Yellowstone should be set aside as a national park. It is a wonderful legend, but it isn't true. Explorers did camp at the junction in 1870, but they apparently did not discuss the national park idea.

They camped in a location where people have camped for thousands of years. Archeologists have found campfire remnants, obsidian flakes, and bone fragments dating back at least 10,000 years.

FAQ: Madison & West Yellowstone Areas

Historic Areas & Structures
Madison Trailside Museum

See Chapter 1 for more information on historic areas in the park.

FAQ: Mammoth Area

source of heat

Historic Areas & Structures

Mammoth Hot Springs Historic District

Fort Yellowstone Historic Landmark District

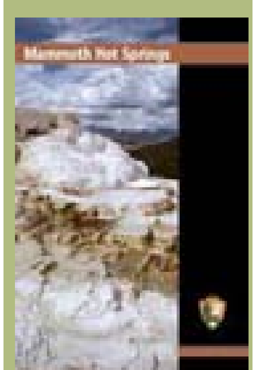
Obsidian Cliff National Historic Landmark

U.S. Post Office

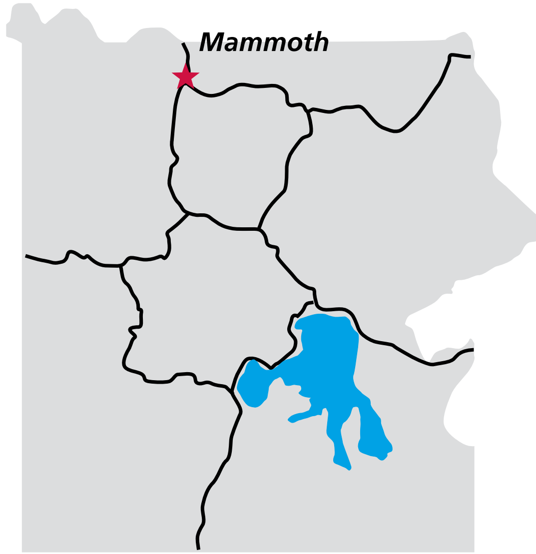
See Chapter 1 for more information on historic areas in the park.

Also here:

Administrative Headquarters of Yellowstone National Park



Pick up the *Mammoth Area Trail Guide* at visitor centers or at the terrace trailheads. 50¢ donation requested.



Is Mammoth Hot Springs in the Yellowstone Caldera?

No, it lies north of all three calderas.

Where does the heat for the hot springs come from?

Scientists continue to study this question. A large fault system runs between Norris Geyser Basin and Mammoth, which may allow thermal water to flow between the two. Also, multiple basalt eruptions have occurred in this area. Thus, basalt may be a heat source for the Mammoth area.

Why are the dry springs so white?

Limestone, a form of calcium carbonate, underlies this area. Water dissolves the mineral, which is deposited at the surface to form travertine. This rock is naturally white; colors in the hot springs come from heat-loving microorganisms called thermophiles. *(See chapters 3 and 4.)*

Are the springs drying up?

No, the overall activity and volume of water discharge remain relatively constant; most of the water flows underground.

How was Bunsen Peak formed?

At 8,564 feet high, Bunsen Peak (south of Mammoth) is an intrusion of igneous material (magma) formed approximately 50 million years ago. *(See Chapter 3.)* Bunsen Peak and the "Bunsen burner" were named for physicist Robert Wilhelm Bunsen. He was involved in pioneering geyser research in Iceland. His theory on geyser activity was published in the 1800s, and it is still considered accurate.

What were these old buildings?

Most of these buildings belong to Fort Yellowstone, built by the U.S. Army from 1891 to 1918, when it managed the park. *(See Chapter 1.)* You can walk a self-guiding trail through this National Historic Landmark District.

Can we soak in the hot springs?

No. You may soak in bodies of water fed by runoff from hydrothermal features, such as at "Boiling River" two miles north of Mammoth. It is open during daylight hours and is closed during times of high water.

What is the 45th parallel?

On the road between the North Entrance and Mammoth, a sign marks the 45th parallel of latitude, which is halfway between the Equator and the North Pole. Contrary to popular belief, the majority of the Montana/Wyoming state line does not follow the 45th parallel through the park.

What forms the canyon north of Mammoth?

The canyon is the face of Mt. Everts, 7,841 feet high. It consists of layered sandstones and shales—sedimentary deposits from a shallow inland sea, 70–140 million years ago. Fossils have been found here. Its steep cliffs—eroded by glaciers, floods, and landslides—provide habitat for bighorn sheep.

Mt. Everts was named for explorer Truman Everts, a member of the 1870 Washburn Expedition who became lost in the wilderness. He was found east of the mountain, near Blacktail Plateau.

Why is Obsidian Cliff a National Historic Landmark?

For centuries Native Americans came to this cliff to make projectile points and other tools from obsidian, which fractures into round, sharp pieces. Obsidian from this site has been found as far east as Ohio, providing evidence of its trade value. Also, in the 1920s, a wayside exhibit structure was built here, one of the first of its kind in the park.

What animals can I see in this area?

Elk live here all year, and are wild and unpredictable. Each year visitors are chased, trapped, and sometimes injured by elk. Look for Uinta ground squirrels in front of the visitor center and among the hotel cabins during summer. You might see bighorn sheep in the canyon north of Mammoth Hot Springs. South of Bunsen Peak is Swan Lake Flat, where visitors often see elk, bison, and sometimes grizzlies and wolves. It is also an excellent place for watching cranes, ducks, and other birds.

FAQ: Norris Area

Norris, Virginia Cascade

Is Norris Geyser Basin within the Yellowstone Caldera?

Norris is not in the Yellowstone Caldera, but it is in the *first* caldera. The northern edge of the first caldera lies near the southern base of Mount Holmes, which is north of Norris. The Yellowstone Caldera's rim is south and east of Norris. *(See also page 14 & Ch. 3.)*

When does Echinus Geyser erupt?

Once very predictable, Echinus's eruptions can vary from days to months.

When will Steamboat Geyser erupt?

Steamboat's major eruptions (more than 300 feet high) are unpredictable and often many years apart. Its most recent major eruption occurred May 2005. Its frequent "minor phase" eruptions eject water 10 to 40 feet high.

Why is Norris so colorful?

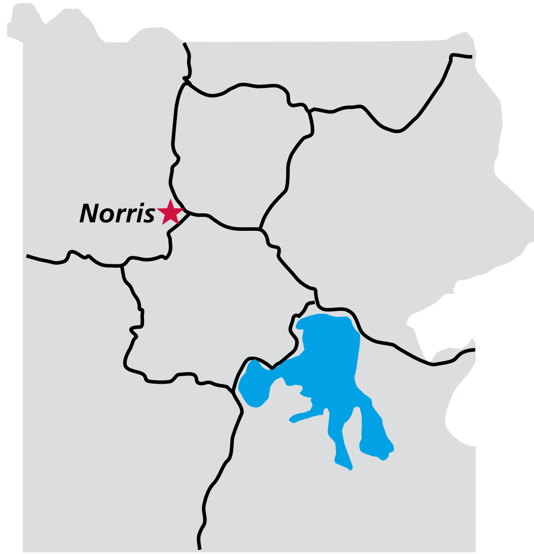
The colors here, like in other hydrothermal areas, are due to combinations of minerals and life forms that thrive in extreme conditions. At Norris, silica or clay minerals saturate some acidic waters, making them appear milky. Iron oxides, arsenic, and cyanobacteria create the red-orange colors. *Cyanidium* 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. *(See Chapter 4.)*

What is the "thermal disturbance" at Norris that people talk about?

Periodically, Norris Geyser Basin undergoes a large-scale basin-wide thermal disturbance lasting a few days to a few weeks. Water levels fluctuate, temperatures and pH change, color changes, and eruptive patterns change throughout the basin. No one is sure what causes a thermal disturbance. It might be caused by a massive fluctuation in the underground reservoirs providing water to the basin's features. In the fall, this could happen when decreased surface water mixes 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.

How did Norris get its name?

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 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. *(See Chapter 1.)*

Did Roaring Mountain used to roar?

Visitors during the late 1800s and early 1900s would say so. Roaring Mountain is a large, acidic hydrothermal area (solfatara) with many fumaroles. 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.

What will I see on Virginia Cascade Drive?

This one-way drive east of Norris was once part of the Grand Loop Road. It follows the Gibbon River upstream, alongside outcrops of volcanic rock (Lava Creek Tuff). Here, you are close to the Yellowstone Caldera's rim. Virginia Cascade is formed by the Gibbon River as it crosses the tuff, which formed as the caldera collapsed.

Are mudpots in this area?

Yes, at Artists Paintpots, which is 3.8 miles south of Norris Junction. The trail to the mudpots is steep, and one mile round-trip.

What animals can I see in this area?

Black and grizzly bears are sometime seen. 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 where sagebrush lizards live. They can survive here due to warmth of hydrothermal activity. Listen for chorus frogs in spring.

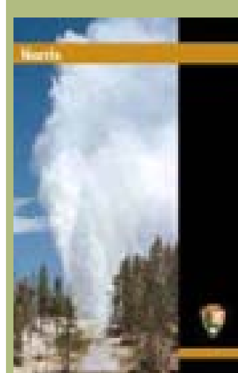
Killdeer are found in the basin year-round taking advantage of the brine flies and other insects that live in the warm waters.

Historic Areas & Structures

Norris Soldier Station (now the Museum of the National Park Ranger)

Norris Geyser Basin Museum

See Chapter 1 for more information on historic areas in the park.



Pick up the *Norris Area Trail Guide* at visitor centers or at Norris. 50¢ donation requested.

FAQ: Old Faithful Area

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Upper, Midway, & Lower Geyser Basins

Historic Areas & Structures

Nez Perce National Historic Trail

Old Faithful Inn

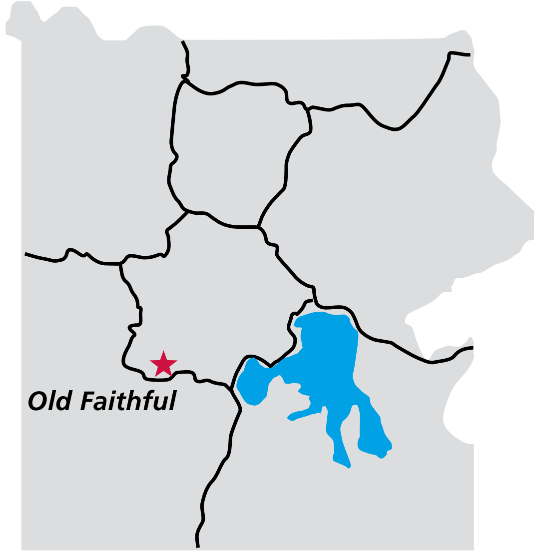
Old Faithful Historic District

General store north of the Old Faithful Inn

Queen's Laundry, begun in 1881 but never finished, in Sentinel Meadows

See Chapter 1 for information on historic areas.

Pick up the *Old Faithful Area Trail Guide* at visitor centers or at area geyser basins. 50¢ donation requested.



How often does Old Faithful Geyser erupt; how tall is it; how long does it last?

The average interval between eruptions of Old Faithful Geyser changes; as of January 2010, the usual interval is 90 minutes ± 10 minutes, with intervals ranging from 51 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 204ºF (95.6ºC).

Is Old Faithful Geyser as "faithful" as it has always been?

Since its formal discovery in 1870, Old Faithful has been one of the more predictable geysers. Over time, the average interval between Old Faithful's eruptions has increased, in part due to ongoing processes within its plumbing. Changes also result from earthquakes. Prior to the Hebgen Lake Earthquake (1959), the interval between Old Faithful's eruptions averaged more than one hour. Its average interval 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; subsequent earthquake swarms further increased intervals.

How can you predict it, if it changes so much?

Old Faithful Geyser has been analyzed for years by mathematicians, statisticians, and dedicated observers. We know a 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. Currently, staff uses eruption data from a temperature logger to determine the interval.

What else can I see at this geyser basin?

The Upper Geyser Basin has 150 geysers in one square mile, plus hundreds of hot springs. Five large geysers are predicted regularly by the interpretive ranger staff. You can reach them and other features on boardwalks that loop through this basin. Walk or drive to nearby Black Sand Basin and Biscuit Basin to view their features.

What will I see at Midway Geyser Basin?

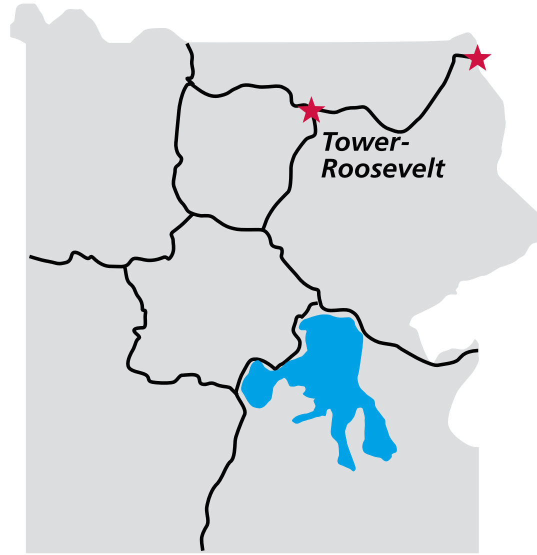
This geyser basin, 6 miles north of the Old Faithful area, is small but spectacular. Excelsior Geyser is a 200 x 300 foot crater that constantly discharges more than 4,000 gallons of water per minute into the Firehole River. Grand Prismatic Spring, Yellowstone's largest hot spring, is 200–330 feet in diameter and more than 121 feet deep.

Can I see mudpots in this area?

You'll see all four types of thermal features (geysers, hot springs, fumaroles, and mudpots) at Fountain Paint Pot, 8 miles north of Old Faithful and 2 miles north of Midway Geyser Basin. Be sure to drive the Firehole Lake Drive, where you can walk past hot cascades, hot springs large and small, and view geysers such as White Dome and Great Fountain.

What animals can I see in this area?

Hydrothermal basins provide important habitat for wildlife in the Old Faithful area. Bison and elk live here year-round. In the winter, they take advantage of the warm ground and thin snow cover. Both black and grizzly bears are seen, especially during the spring when winter-killed animals 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.



Why is this area called "Tower"?
The area is named for its major waterfall, Tower Fall, which is named for the tower-like rock formations at its brink.

How tall is Tower Fall?
132 feet.

Old pictures show a big boulder at the brink of Tower Fall. When did it fall?
W.H. Jackson's photograph in 1871 clearly shows the boulder *(see page 35)*. For more than a century, visitors wondered when it would fall. It finally did in June 1986.

Can I hike to the bottom of Tower Fall?
No, the lower part of the trail is closed because of severe erosion. You can walk past the Tower Fall Overlook ¾ 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.

What formed the rock columns in the canyon north of Tower Fall?
The rock columns were 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.

How did the Petrified Tree become petrified?
The Petrified Tree, west of Tower Junction, is an excellent example of an ancient redwood. Petrification of this and other trees occurred for two main reasons. They were buried rapidly by volcanic deposits and mudflows 45–50 million years ago, which minimized decay. The volcanic deposits also contributed high amounts of silica to the groundwater. Over time, the silica precipitated from ground water, filled the spaces within the trees' cells, and petrified the trees.

In Yellowstone, glacial ice, running water, and wind have uncovered vast areas of petrified trees. You can see some of these areas from the road that follows the base of Specimen Ridge, east of Tower Junction.

Did Teddy Roosevelt really stay at Roosevelt Lodge?
No, but President Theodore Roosevelt camped nearby during his visit to Yellowstone in 1903. The lodge opened in 1920. The area is registered as the Roosevelt Lodge Historic District. *(See Chapter 1.)*

What animals can I see in this area?
Elk, bison, deer, and pronghorn thrive in the grasslands of this area, known as the northern range. In fact, some of the largest wild herds of bison and elk in North America are found here. The northern range is critical winter habitat for these large animals, which in turn provide food for several packs of wolves. Coyotes are also common, and an occasional bobcat, cougar, or red fox is reported.

The gorge and cliffs between the junction and Tower Fall provide habitat for 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 sometimes seen in the Lamar Valley and 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.

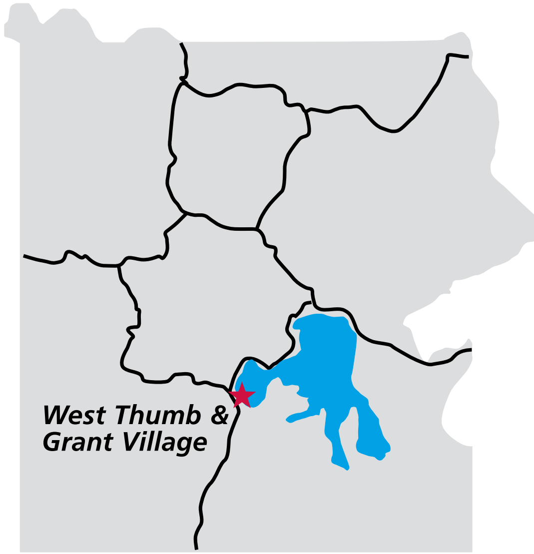
Historic Areas & Structures
Lamar Buffalo Ranch

Northeast Entrance Station

Roosevelt Lodge Historic District

See Chapter 1 for more information on historic areas in the park.

FAQ: West Thumb & Grant Village Area



Why is this area called West Thumb?

Yellowstone Lake resembles the shape of a human hand; West Thumb is the large western bay that would be the thumb. The bay is a caldera within a caldera. It was formed by a volcanic eruption approximately 174,000 years ago. The resulting caldera later filled with water forming an extension of Yellowstone Lake.

New West Thumb date

West Thumb is also the largest geyser basin on the shore of Yellowstone Lake—and its hydrothermal features lie under the lake too. The heat from these features can melt ice on the lake's surface.

How did Fishing Cone get its name?

People learned they could stand on this shoreside geyser, catch a fish in the cold lake, and cook it in the hot spring. Fortunately for anglers, this geyser has only two years of known eruptions: In 1919, it erupted frequently to 40 feet and in 1939 to lesser heights. Fishing here is now prohibited.

How hot are the springs at West Thumb?

Temperatures vary from less than 100°F to just over 200°F.

How deep are Abyss & Black pools?

Abyss is about 53 feet deep; nearby Black Pool is 35–40 feet deep.

The mudpots here aren't like they used to be. What happened?

Like all hydrothermal features, the West Thumb Paint Pots change over time. During the 1970s and 1980s, they were less active; they became more active in the 1990s.

What happened to the development at West Thumb?

West Thumb was center of visitor activity until the 1980s. Early visitors would arrive at West Thumb via stagecoach from the Old Faithful area. They could continue on the stagecoach or board the steamship "Zillah" to reach the Lake Hotel.

Later, a gas station, marina, photo shop, store, cafeteria, and cabins were built here. They were removed in the 1980s to protect the hydrothermal features and improve visitor experience. Grant Village now provides most of these facilities. West Thumb still has restrooms, picnic tables, and a bookstore and information station in the historic ranger station.

Why does Grant Campground open so late in the year?

Grizzly and black bears frequent this area in spring when cutthroat trout spawn in five streams here. To protect bears and people, the campground opens after most of the spawn is over.

Isn't there a unique lake nearby?

That's Isa Lake, at Craig Pass. At one time, it was probably the only lake on Earth that drained naturally backwards to two oceans, 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.

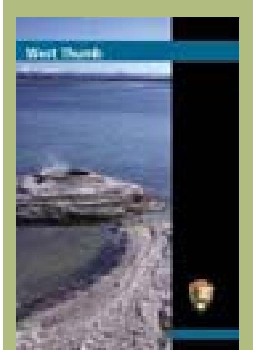
What's that big lake you see south of Craig Pass?

Shoshone Lake is the park's second largest lake, and 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. The Shoshone Geyser Basin contains one of the highest concentrations of geysers in the world—more than 80 in an area 1,600 x 800 feet.

What animals can I see in the West Thumb area?

In addition to the bears that frequent this area in spring *(see above)*, elk cows and their new calves are often seen here in May and June. Bald eagles and osprey dive into the bay to catch cutthroat trout. Other birds include ravens, common loons, and bufflehead and goldeneye ducks.

In winter, pine marten are sometimes seen. River otters pop in and out of holes in the ice; coyotes and bald eagles eat their fish scraps.



Pick up the *West Thumb Area Trail Guide* at visitor centers or at the trail. 50¢ donation requested.

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.

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, we 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 January 2010: 392

81 Historic sites

73 Monuments

58 Parks

42 Historical parks

29 Memorials

24 Battlefield parks & sites, & military parks

20 Preserves & reserves

18 Recreation areas

15 Rivers, wild & scenic rivers, & riverways

14 Lakeshores & seashores

4 Parkways

3 Scenic trails

11 Sites of other designation

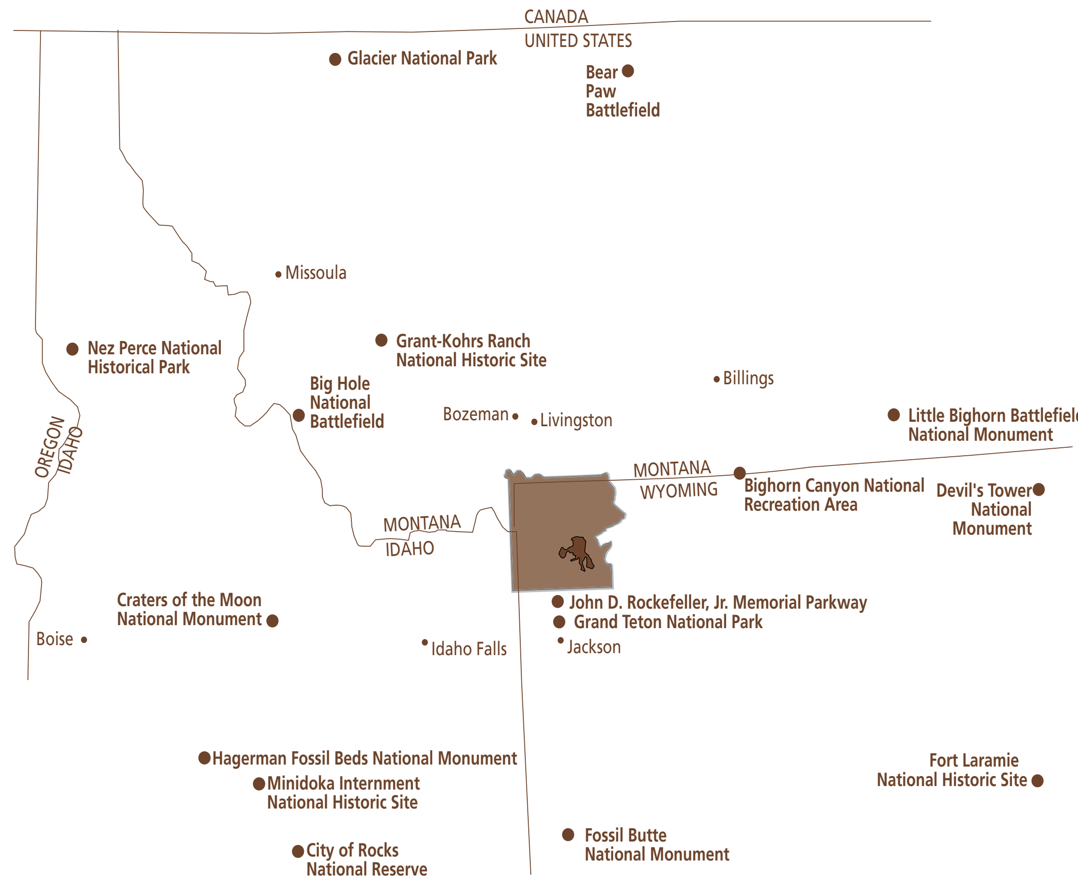
For a detailed list of NPS units, visit www.nps.gov/pub_aff/refdesk/index.html

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 a unit in the national park system.

- 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



Implementing the NPS Mission

Systemwide

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.
- **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.

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.

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

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 described in Chapter 8.

Mission Statement: 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.

Purpose Statement

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.

Significance of Yellowstone National Park

- International symbol of natural preservation.
- A Biosphere Reserve and a World Heritage Site. *(See page 10.)*
- 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 8.)*
- 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.
- As of January 2009, home to one endangered species—the gray wolf, and two threatened species—the Canada lynx and the grizzly bear.
- 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 3.)*
- Location of largest lake above 7,000 feet in North America—Yellowstone Lake. *(See Chapter 3.)*
- 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.

History of the Park

1

HIGHLIGHTS OF YELLOWSTONE'S HISTORY

- People have been in Yellowstone more than 11,000 years, as shown 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: New bear management plan eliminates open-pit garbage dumps in park.
- 1988: "Summer of Fire."
- 1995: Wolves restored to the park.
- 1996: Federal buyout of gold mine northeast of Yellowstone protects the park.
- 2006: Canyon Visitor Education Center opens.
- 2009: Science agenda established for the Greater Yellowstone Ecosystem.

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 13,000–14,000 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 left behind rivers and valleys 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 11,000 years ago. 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 years ago, 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 prickly pear cactus. They may have also established a distinct home territory in the valleys and surrounding mountains.

B.P = Before Present
C.E. = Common Era (replaces A.D.)
B.C.E. = Before Common Era (replaces B.C.)

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

1

History

PaleoIndian Period (B.P.= Before Present)

13,500 B.P.

A Clovis point from this period was found near Yellowstone and was made from obsidian obtained at Obsidian Cliff.

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

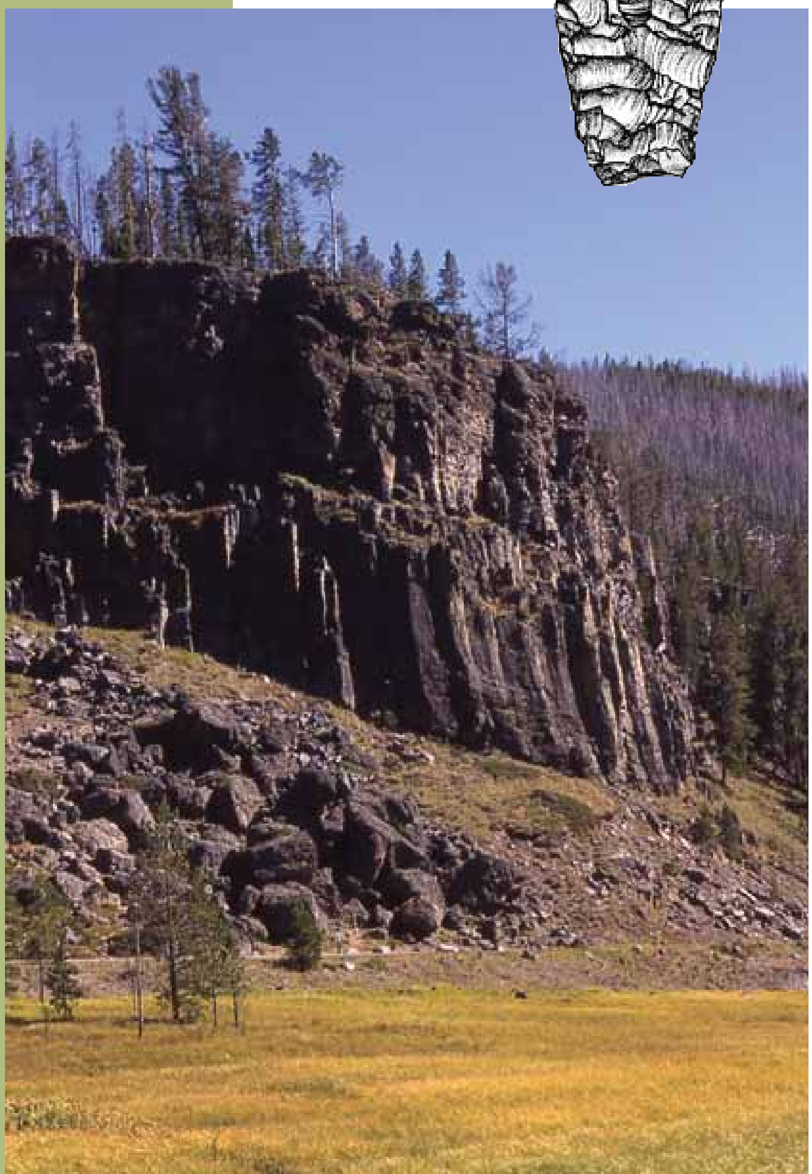
10,000 B.P.

Folsom people were in the 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.

9,350 B.P.

A site on the shore of Yellowstone Lake has been 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.



Obsidian Cliff, formerly a major source of obsidian for Native Americans, as seen from the Grand Loop Road, between Mammoth and Norris. It 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.

Approximately 1,600 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 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 began to use 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, and used both near the park, and perhaps in it. This increased use of Yellowstone may have occurred when the environment was warmer, favoring extended seasonal use on and around the Yellowstone Plateau.

Archaic Period (7000 BP–200 CE)

7000 B.P.

Vegetation similar to what we find today begins to appear. Projectile points begin to be notched.

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

3000 B.P.

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

1500 B.P.

Bow and arrow begins to replace atlatl (throwing spear); sheep traps (in the mountains) and bison corrals (on the plains) begin to be used in the Rocky Mountain region.

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. *(See also Chapter 8, "Climate Change.")*

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.

Historic Tribes

Tribal oral histories indicate more extensive use during the Little Ice Age. Kiowa stories place their ancestors here from around 1400 to 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. The Shoshone say family groups came to Yellowstone to gather obsidian, which they used to field dress buffalo. Some tribes used the Fishing Bridge area as a rendezvous site.

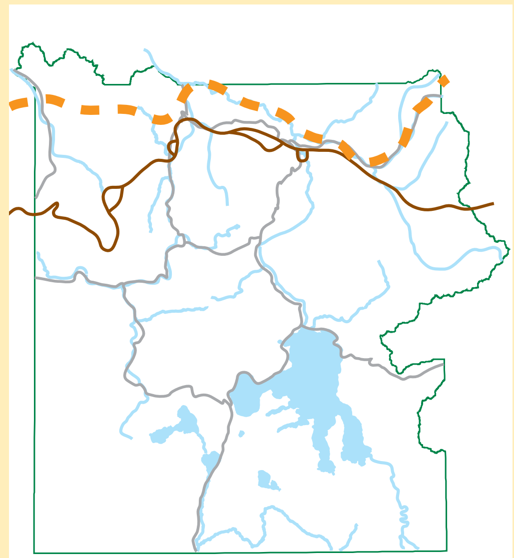
The Crow occupied the country generally east of the park, and the Blackfeet occupied the country to the north. The Shoshone, Bannock, and other tribes of the plateaus to the west traversed the park annually to hunt on the plains to the east. Other Shoshonean groups hunted in open areas west and south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



Above: An ancient trail, now called the Bannock Trail, is shown in two possible locations. Physical evidence of the trail is extremely difficult to find; historic maps and journals do not match modern maps; and oral histories of tribes do not always match what little evidence exists of the trail. The solid line shows the trail's location as interpreted in the 20th century. Today, many scholars think the dashed line shows the more accurate location, which is based on an 1869 map by Henry D. Washburn.

Below: Wickiups provided temporary shelter for some Native Americans while they were in Yellowstone. None are know to remain.

C.E. 1000–1700s

- **1400** — Oral histories of the Kiowa place their ancestors in the Yellowstone area from this time through the 1700s.
- **1450** — Little Ice Age begins.
- **1600s** — North American tribes in the southwest begin acquiring horses in the mid- to late 1600s. Ancestors of the Crow may have come into Yellowstone during this time.
- **1700s** — Lakota Sioux begin exploring the Yellowstone area.
- **late 1700s** — Fur traders travel the rivers into the Yellowstone region. Tribes in the Yellowstone area begin using horses.

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

and implements. For example, they soaked sheep horn in hot springs to make them pliable for bows. 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.

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. Raynolds 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.

1800–1850s

- **1804–1806** The Lewis and Clark Expedition passes within 50 miles of Yellowstone.
- **1807–1808** John Colter explores part of Yellowstone.
- **1812** The War of 1812.
- **1820s** Trappers return to Yellowstone area.
- **1834–1835** Trapper Osborne Russell encounters Sheep Eaters in Lamar Valley.
- **1840s** Trapper era ends.
- **1850s** Little Ice Age ends, climate begins to warm.

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."

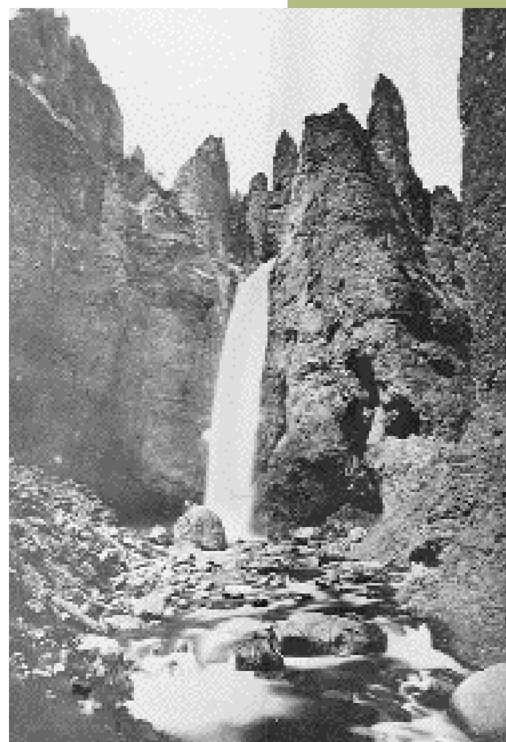
The 1870 Washburn-Langford-Doane Expedition

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.



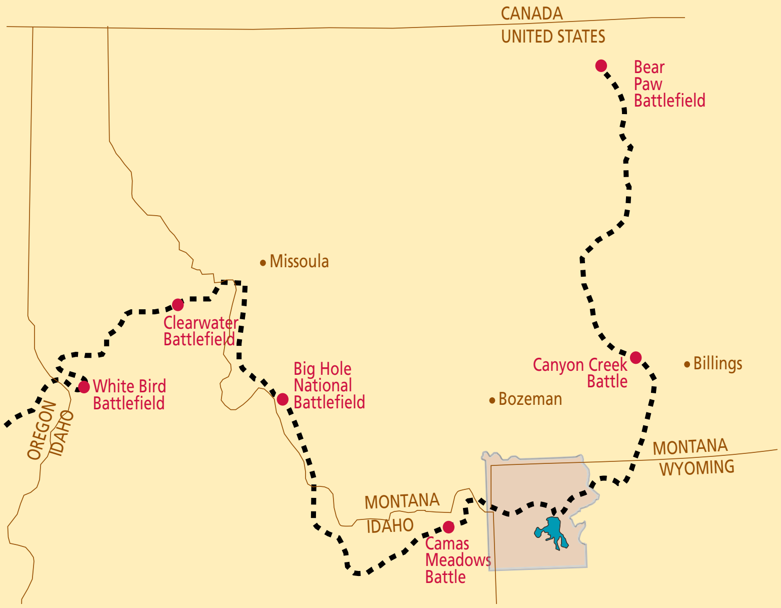
This photo of Tower Fall was one of many taken by W.H. Jackson during the 1871 Hayden Survey. His photos helped to bring public attention to the wonders of Yellowstone. Both the 1870 and 1871 expeditions spread the word through newspaper and magazine articles, speaking tours, and other publicity.

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

1860s–1870s

- 1860 — First organized expedition attempts but fails to explore the Yellowstone Plateau.
- 1861 — Civil War begins.
- 1862 — Gold strike northwest of Yellowstone.
- 1865 — Civil War ends.
- 1869 — Folsom–Cook–Peterson Expedition.
- 1870 — Washburn–Langford–Doane Expedition; Old Faithful Geyser named.
- 1871 — First Hayden Expedition.
- 1872 — Yellowstone National Park Protection Act establishes the first national park.
- 1877 — Nez Perce (Nee-me-poo) flee U.S. Army through Yellowstone.



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 August 23. During the two weeks they crossed the park, the Nez Perce encountered all 25 visitors in the park, some more than once. Warriors took hostage or attacked several of these tourists, killing two. 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 Chief Joseph said, "From where the sun now stands, I will fight no more forever." The 1,170-mile flight had ended.

Their flight is commemorated at 39 sites in Washington, Oregon, Idaho, Montana, and Yellowstone National Park as part of the Nez Perce National Historical Park. To learn more about the Nez Perce National Historic Trail, visit the website at www.fs.fed.us/npnht.

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. (He earned his living elsewhere.) He entered the park at least twice during five years in office—as part of the 1872 Hayden Expedition and to evict a squatter in 1874. Langford did what he could without laws protecting wildlife and other natural features, and without money to build basic structures and hire law enforcement rangers.

Political pressure forced Langford's removal in 1877. Philetus W. Norris was appointed the second superintendent, and the next year, Congress authorized appropriations "to protect, preserve, and improve the Park."

Norris constructed roads, built a park headquarters at Mammoth Hot Springs, hired the first "gamekeeper," and campaigned against hunters and vandals. Much of the primitive road system he laid out remains 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, but the myth endured.

Norris fell victim to political maneuvering and was removed from his post in 1882. He

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.

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.

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 Yellowstone.

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

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

Touring the Park

At first, travel to and within the park was difficult. Visitors had to transport themselves or patronize a costly transportation enterprise. In the park, they found only a few places for food and lodging. Access improved in 1883 when the Northern Pacific Railroad reached Cinnabar, Montana, a town near the North Entrance.

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 hotel, they toured the hot springs. For the next four days, they 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 trips. They recommended the tour to their friends, and each year more of them came to Yellowstone to see its wonders. When the first automobile entered in 1915, Yellowstone truly became a national park, accessible to anyone who could afford a car.

Early 20th century

- **1903** — President Theodore Roosevelt dedicates arch at the North Entrance in Gardiner.
- **1906** — *The Antiquities Act provides for the protection of historic, prehistoric, and scientific features on and artifacts from federal lands.*
- **1908** — *Union Pacific train service begins at West Yellowstone.*
- **1915** — *Private automobiles are officially admitted to the park.*
- **1916** — *The National Park Service Organic Act establishes the National Park Service.*
- **1918** — *U.S. Army turns over park management to the National Park Service.*

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.

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 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 , which increased the Army's authority for protecting Yellowstone's treasures. (This law is known as the Lacey Act, and is the first of two laws with this name.)

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 in the late 1800s and early 1900s was separately administered, resulting in uneven management, inefficiency, and a lack of direction.

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 p. 29.

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.

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 management framework that guided administration of Yellowstone for decades.

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

1920s–1940s

1929 — *President Hoover signs first law changing park's boundary.*

1932 — *President Hoover expands the park again.*

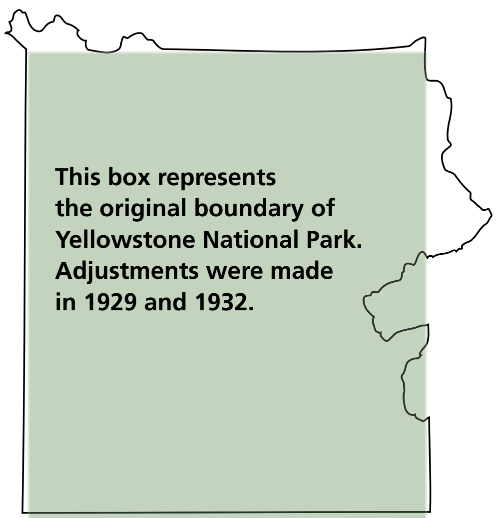
1933 — *Civilian Conservation Corps established, works in Yellowstone through 1941.*

1934 — *NPS Director's Order prohibits killing predators.*

1935 — *The Historic Sites Act sets a national policy to "preserve for future public use historic sites, buildings, and objects."*

1948 — *Park receives one million visitors.*

1949 — *Nineteen snowplane trips carry 49 passengers into the park in winter.*



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 issued an executive order that added more than 7,000 acres between the north boundary and the Yellowstone River, west of Gardiner. These lands provided winter range for elk 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 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 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.

This Mission 66 era visitor center was renovated and remodeled into the Canyon Visitor and Education Center, which opened in 2006.

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.

1950s–1970s

1955 — *Mission 66 initiated.*
The first concession-run snowcoach trips carry more than 500 people into the park in winter.

1959 — *Magnitude 7.5 earthquake strikes on August 17 west of Yellowstone, killing campers in Gallatin National Forest and affecting geysers and hot springs in the park.*

1963 — *The Leopold Report is issued.*

1966 — **Thermus aquaticus** *discovered in a Yellowstone hot spring (see Chapter 8, "Bioprospecting").*

1970 — *New bear management plan begins, which includes closing open-pit dumps in park (see Chapter 8).*

1971 — *Overnight winter lodging opens in park.*

1975 — *Grizzly bear listed as threatened species in the lower 48 states.*

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 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*.

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 (NEPA)**, 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 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.*

Involving Native Americans

Yellowstone National Park has 26 associated tribes *(see map next page)*. Each tribe has evidence of its ancestral presence in Yellowstone National Park through ethnohistoric documentation, interviews with tribal elders, or ongoing consultations. Many places and resources remain important to these tribes' sense of themselves and in maintaining their traditional practices.

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. Tribes also comment on park projects that could affect their ethnographic resources.

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; some of these issues are presented in Chapter 8.

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

Late 20th Century

1988 Public Law 100-443 protects hydrothermal features in national parks from geothermal development on adjacent federal lands.

Summer of Fire: more than 790,000 acres affected by fires in Yellowstone.

1991 *Clean Air Act Amendments require air quality monitoring at sites including Yellowstone, a Class I airshed— one of the purest in the nation.*

1994 *Congress enacts a law allowing a percentage of park entrance fees to be kept in the parks.*

1995 *Wolves are restored to the park.*

1996 *Federal buyout of gold mine on Yellowstone's northeast border is authorized.*

1998 *The National Parks Omnibus Management Act.*

mining company was authorized in 1996.

In an effort to resolve other park management issues, Congress passed the National Parks Omnibus Management Act in 1998. This law requires using high quality science from inventory, monitoring, and research to understand and manage park resources.

Park facilities are seeing some improvements due to a change in funding. In 1994, as part of a pilot program, Yellowstone National Park was authorized to increase its entrance fee and retain more than half of the fee for park projects. (Previously, park entrance fees did not specifically fund park projects.) In 2004, the U.S. Congress extended this program until 2015 under the Federal Lands Recreation Enhancement Act. Projects funded in part by this program include a major renovation of Canyon Visitor Education Center, campground and amphitheater upgrades, preservation of rare documents, and studies on bison.

Preserving the Park's History

Adding to the complexity of management, Yellowstone's mission includes preserving historical materials and sites.

Archeological Sites

More than 1,600 prehistoric sites exist in Yellowstone. The oldest known site is on the shore of Yellowstone Lake, and is eroding. Rather than stopping that natural process, archeologists excavated the site in 2000 and 2002. They found evidence of early North

Associated Tribes of Yellowstone National Park
as of January 2010

Assiniboine & Sioux
Blackfeet
Cheyenne River Sioux
Coeur d'Alene
Comanche
Confederated Salish & Kootenai Tribes
Confederated Tribes of the Colville Reservation
Confederated Tribes of the Umatilla Reservation
Crow
Crow Creek Sioux
Eastern Shoshone
Flandreau Santee Sioux
Gros Ventre and Assiniboine
Kiowa
Lower Brule Sioux
Nez Perce
Northern Arapaho
Northern Cheyenne
Oglala Sioux
Rosebud Sioux
Shoshone-Bannock
Sisseton-Wahpeton Sioux
Spirit Lake Sioux
Standing Rock Sioux
Turtle Mountain Band of the Chippewa
Yankton Sioux

Note: Map shows each tribe's reservation; it does not show their historic territory.

Early 21st Century

- **2002** — National Academy of Sciences confirms effectiveness of Ecological Process Management (aka natural regulation).
- **2004** — Park fee program renewed until 2015.
- **2006** — Canyon Visitor Education Center opens with exhibits about supervolcano.
- **2007** — Yellowstone's grizzly bears removed from federal threatened species list. New winter use plan approved for winters beginning in 2008.
- **2008** — Gray wolf delisted & relisted to endangered species list. Judges rule against the new winter use plan.
- **2009** — Grizzly bears returned to threatened species list. Wolves in Wyoming returned to endangered species list. Interim winter use plan approved for winters 2009–2011. Bioprospecting final EIS completed. Science agenda established for Greater Yellowstone Ecosystem.

YELLOWSTONE'S CULTURAL RESOURCES

- More than 300 ethnographic resources (animals, plants, sites)
- Approximately 1,600 prehistoric and historic Native American archeological sites and historic European American archeological sites
- More than 2 dozen sites, landmarks, and districts listed on the National Register of Historic Places; many more eligible for listing
- More than 900 historic buildings
- 1 National Historic Trail
- Museum collection of more than 379,000 cultural objects and natural science specimens available to researchers
- Archives containing thousands of 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 used by staff, scholars, authors, and filmmakers

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.

Cultural Landscapes

Cultural landscapes—geographic areas associated with historic events, activities, or people—also reflect 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 and the Old Faithful area, and areas significant to Native American cultures, such as sacred sites. Yellowstone's cultural landscapes are being inventoried to ensure new undertakings are compatible with them and to identify landscapes eligible for the National Register.

Ethnographic Resources

Yellowstone National Park has more than 300 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.

Historic Structures & Districts

Mammoth Hot Springs/Fort Yellowstone

The Mammoth Hot Springs Historic District includes Fort Yellowstone, where 35 structures remain from the 1890s and early 1900s when the U.S. Army administered the park. Significant conservation policies were developed here that led to the origin of the National Park Service. Fort Yellowstone is also listed as a National Historic Landmark District, the highest designation.

Right: Albright Visitor Center, in the Mammoth Hot Springs Historic District and Ft. Yellowstone Historic Landmark District, housed the first "information office" (visitor center).

Lake Hotel

The Lake Hotel is the oldest operating hotel in the park. When it opened in 1891, the building resembled other hotels financed by the Northern Pacific Railroad. In 1903, the architect of the Old Faithful Inn, Robert Reamer, designed the ionic columns, extended the roof in three places, and

Historic Park Buildings still in use

1891	1903	1903–04	1906	1908	1909	1918–28
Lake Hotel, National Historic Site	*Roosevelt Arch, in the Ft. Yellowstone Historic Landmark & North Entrance Road Historic District*	*Old Faithful Inn, National Historic Landmark; in the Old Faithful Historic District*	*Lamar Buffalo Ranch, National Historic District*	*Norris Soldier Station, now the Museum of the National Park Ranger, in Ft. Yellowstone Historic Landmark District*	*Albright Visitor Center, in Mammoth Historic District & Ft. Yellowstone Historic Landmark District*	*Old Faithful Lodge, in the Old Faithful Historic District*

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. The National Historic Landmarks program draws upon the expertise of National Park Service staff who evaluate potential landmarks and provide assistance to existing landmarks.

Lake Hotel

added the 15 false balconies, which caused it to be known for years as the "Lake Colonial Hotel." By 1929, additional changes—dining room, porte-cochere (portico), sunroom, plus interior refurbishing—created the landmark we see today.

Roosevelt Arch

The Roosevelt Arch rises in the North Entrance Road Historic District and part of the Fort Yellowstone Historic Landmark District. 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 in 1903. 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 (President Theodore Roosevelt had camped nearby) view much the same landscape seen by visitors when the lodge opened in 1920. The area is registered as the Roosevelt Lodge Historic District.

The Buffalo Ranch

The Lamar Buffalo Ranch Historic District overlooks Lamar Valley. The ranch, in operation from 1906 until the 1950s, was the center of efforts to increase the herd size of bison in Yellowstone. Remnants of irrigation ditches, fencing, and water troughs can still be found, and four buildings from the original ranch compound remain *(center photo)*—two residences, the bunkhouse, and the barn. Newer cabins, which blend with the historic buildings, house students attending Yellowstone Association Institute classes or the National Park Service's residential education program.

Buffalo Ranch

Old Faithful Inn

Historic Park Buildings still in use

- **1919–20; 1925–26** — *Lake Lodge, part of Lake Fish Hatchery Historic District*
- **1920** — *Roosevelt Lodge, in the Roosevelt Lodge Historic District*
- **1929–32** — *Four trailside museums built; three are still used: Madison, Norris, and Fishing Bridge. They are National Historic Landmarks.*
- **1937** — *Mammoth Hot Springs Hotel, part of the Mammoth Hot Springs Historic District*

Old Faithful Inn & Historic District

Most people who step into the Old Faithful Inn 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. Nearby, the Old Faithful Lodge is a result of numerous changes made 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. An interpretive structure should blend in with its surroundings and its exhibits explain but not 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, and the only one no longer standing. It opened in 1929 to acclaim for its quality materials and construction, and for the way it blended into its surroundings.

The Norris Museum, built in 1930, still serves as a gateway to the Norris Geyser Basin. Visitors first glimpse the area's hydrothermal features from a breezeway; they learn about the area from exhibits in the wings as well as from trailside exhibits and a trail guide.

The Madison Museum *(photo above)*, 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 original exhibits as an example of early National Park Service displays. On the south side of the museum, visitors can cross a flagstone terrace overlooking Yellowstone Lake and descend steps to the shore.

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 razed in 1895.

Fountain Hotel opened in 1891 north of Fountain Paint Pot. This was one of the first Yellowstone hotels where bears were fed for the entertainment of guests. The hotel closed after 1916 and was torn down in 1927.

Yellowstone on the National Register of Historic Places

This is a partial list.

National Historic Landmark District:
Fort Yellowstone

National Historic Landmarks:
Fishing Bridge, Madison, and Norris Trailside Museums

Northeast Entrance Station

Obsidian Cliff

Old Faithful Inn

National Register Historic Districts:
Lake Fish Hatchery

Mammoth Hot Springs

North Entrance Road

Old Faithful Area

Roosevelt Lodge

National Historic Sites:
Lake Hotel

Lamar Buffalo Ranch

Obsidian Cliff Kiosk

Queen's Laundry Bath House

Mammoth Post Office

Four lodging facilities were built at Norris. Three were built between 1886 and 1892; the first two burned. The last hotel at Norris, which overlooked Porcelain Basin, served the public from 1901 to 1917.

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 1958 due to financial and 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 past visitor use in the park.

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, including 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 the country's natural wealth—in the form of lumber, grazing, minerals, and recreation lands—would not be consumed at once by the greed of a few, but would perpetually benefit all.

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.

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.*

Construction Dates for Other Park Buildings

Tower General Store 1932, 36, 61

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 1929–30

South Entrance Ranger Station Duplex 1928

West Thumb Ranger Station 1925; now an information station

1

For More Information

www.nps.gov/yell

www.greateryellowstone-science.org/index.html

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.

Site Bulletins, published as needed, provide more detailed information on park topics such as trailside museums and the grand hotels. Free; available upon request from visitor centers.

Staff reviewers: Tobin Roop, Chief of Cultural Resources; Lee Whittlesey, Historian

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Greater Yellowstone Ecosystem

2

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 distribution 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 vegetation, 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:

67 mammals
322 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
±1,150 species of native vascular plants

Management Challenges

- Global climate change
- Landscape changes due to climate change
- Invasive Species

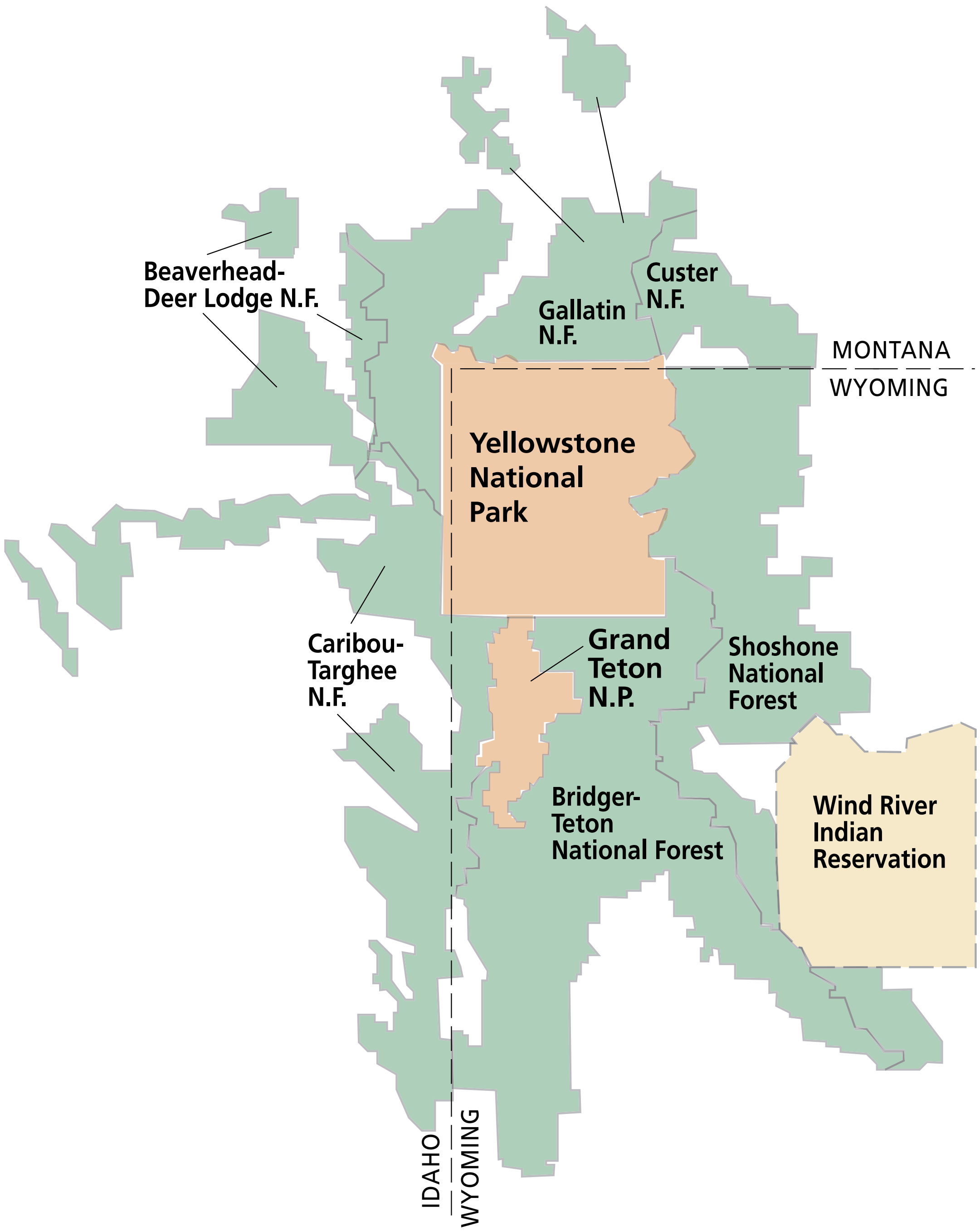
See page 53 and Chapter 8 for more about these challenges.

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

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.

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.

The Greater Yellowstone Ecosystem



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 contiguous 48 states.

Significantly, Greater Yellowstone's natural diversity is 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). *(See Chapter 4.)* 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.

Knowledge of the park's biodiversity expanded in 2009 with Yellowstone's first bioblitz. *See page 53 for more about this event.*

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.

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.

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. Some cones of lodgepole pines pop open only 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 chapters 5 & 6.)*

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

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 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." Most researchers agree that wolves have caused elk to change their behavior. For example, elk don't linger in willow or aspen areas. Some researchers say this behavioral change is the reason why recent willow growth has been strong. Not all scientists agree with this conclusion. However, 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—or if it is one of many factors at work. For example, ecologists have documented a substantial rise in temperature in the northern range: From 1995 to 2005, the number of days above freezing increased from 90 to 110 days. Changes in precipitation and effects of global climate change are also affecting vegetation growth. Ongoing, long-term scientific research will continue to examine these complicated interweavings of the Greater Yellowstone Ecosystem. *(See page 53 & Chapter 8.)*

Balancing Nature?

In some 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 increased 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 continue to adjust to the pressures and opportunities they face, as will their wild neighbors, large and small.

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 conserve heat.
- Deer mice huddle together to stay warm.
- 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 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 Adaptations

- 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' 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. 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.

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 snowpack settles.

Rime Frost
forms when supercooled 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.

Yellowstone as a Laboratory

Before and after its inception, Yellowstone has attracted scientists as a unique outdoor laboratory for research. For example, dozens of comprehensive studies were completed in the twenty years following the 1988 fires. According to Monica Turner, speaking at the 9th Biennial Scientific Conference, "The 1988 fires presented an unprecedented opportunity to study the landscape-scale ecological effects of an infrequent natural disturbance—a large, severe fire in this case—in an ecological system minimally affected by humans." *(See Chapter 6.)* A similar flurry of reseach began with the restoration of wolves in 1995 and continues today. This active volcanic ecosystem also fuels a wide variety of geologic studies. Many of these scientific studies have ramifications far beyond Yellowstone National Park.

In 2009, more than 200 permits were on file for research in the park. Current research examples include:

- Determining if willow growth is related to changes in climate, elk populations, or hydrology. *(See Chapter 8.)*
- Inventorying reptiles and amphibians. *(See Chapter 7.)*
- Using earthquake monitoring stations to detect the numerous daily tremors in the Yellowstone region, and studying the patterns to develop an understanding of the geodynamics of Yellowstone's hotspot.
- Surveying rare and unusual plants such as mosses, liverworts, lichens, and aquatic species.
- Monitoring the effects of human recreation on wildlife, air quality, and wilderness soundscapes.
- Studying the ecology and life-history strategies of non-native plants and aquatic organisms to better understand how to eradicate those that threaten native communities.
- Understanding how large-scale fires affect carbon cycling on our planet.
- Collecting thermophiles—microorganisms that can live in extreme environments—from hydrothermal features to study their heat-resistant enzymes, which may help in producing biofuels, decontaminating toxic waste, and assisting other organisms with heat tolerance. *(See chapters 4 & 8.)*

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.

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

BioBlitz

BioBlitz! *24 hours to search for species*

On August 28 & 29, 2009, more than 120 scientists, citizen scientists, students, and park staff worked in teams to count species around Mammoth Hot Springs. It was Yellowstone's first "BioBlitz"—document species at one point in time, which can serve as a benchmark of environmental conditions. Scientists reported finding 1079 species, including:

373 plant species, including a grass new to Yellowstone

86 mushroom species, including two new to Yellowstone

300 insects, including 128 fly species, 24 butterfly species, and 46 bee species

90 nematode genera, some of which may be new to science

45 different lichens, including a species new to Yellowstone

13 mollusk species, possibly one new to the park

Specimens have been sent to scientists around the world for closer examination and identification; the total species count will likely increase as this phase is completed.

BioBlitz teams shared their findings at a "Discovery Tent" in front of the Albright Visitor Center at Mammoth. They had a great time talking to the public, answering questions, and showing off their specimens. Visitors had a rare opportunity to talk with scientists and to observe up close some of the diversity that Yellowstone protects.

Ecosystem Management Challenges

Despite the size of the ecosystem, Greater Yellowstone's biodiversity is not guaranteed. 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 comprehensive inventories have not been completed. Carnivorous species—including the grizzly bear, wolverine, and lynx—represent more than half of the mammals in danger.

Yellowstone's resource managers deal with three drivers that are specific to the GYE:

Heat: Volcanic activity drives the ecosystem; wild fire influences the species that live here; and political heat also affects decisions. *(See chapters 3, 6, and 8.)*

Space: The GYE spans different climate regimes and vegetation zones; crosses multiple jurisdictional boundaries; and is the last remaining large native ecosystem in the contiguous United States.

The park's geographic location also attracts humans who want to occupy increasing amounts of space in the ecosystem. This leads to habitat modification, which poses a serious threat to both biodiversity and to ecosystem processes. For example, when homes are built close to wilderness boundaries, they fragment habitats and isolate populations of plants and animals, cutting them off from processes necessary for survival.

Time: Yellowstone National Park was created before the surrounding states existed, which makes its relationship to its neighbors different from many national parks. This park has exclusive jurisdiction over managing wildlife; wildlife decisions are driven by National Park Service mandates rather than state wildlife management objectives. However, the park chooses to work with the states on most issues, including wolf and bison management. *(See Chapter 8.)*

Time also refers to how this ecosystem changes and at what pace. What are the intervals between volcanic eruptions? Between fires? How has forest composition changed in the past 100 years? How will climate change alter these patterns? These are the types of "time" questions that influence management of Yellowstone.

Ecosystem managers face these challenges by addressing the whole ecosystem, including preserving individual components and the relationships and linkages between them. Maintaining healthy, functioning ecosystems preserves species more effectively than do emergency measures to bring back threatened species from the brink of extinction.

Science Agenda

Greater Yellowstone Coordinating Committee

In 1964, the managers of the two national parks and six national forests in the Greater Yellowstone Ecosystem formed the Greater Yellowstone Coordinating Committee to seek solutions to common issues. In 2000, two national wildlife refuges in the GYE joined the committee. During its four decades, the GYCC has provided guidance and decisions for managing the GYE.

Currently, GYCC is helping the agencies develop a science agenda to focus research in the GYE over the next 10–12 years. This process began in 2009 when federal agency managers, scientists from the U.S. Geological Survey and from universities, met to identify the external drivers threatening to dramatically alter the GYE: climate change, land-use change, and invasive species. In addition, they identified these research needs:

- How will the ecosystem respond to climate change—especially aquatic systems, alpine and treeline communities, changing snow and soil moisture, and disturbance processes such as drought, flood, fire, insect infestations, and diseases?
- How do humans affect the ecosystem? For example, how can human settlement be managed to minimize impacts on wildlife ecology; how do activities such as grazing, mining, and energy development change land use and the ecosystem?
- What is driving the spread of invasive species; how do these species affect the GYE; how will climate change and land-use change affect invasive species and their management?

The GYCC also recognizes that sustainable natural resources management and sustainable operations are closely tied together. For more about this, see climate change in Chapter 8.

For More Information

www.nps.gov/yell.

www.greateryellowstonescience.org/index.html

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.

Site Bulletins, published as needed, provide more detailed information on park topics such as wildflowers. Free; available upon request from visitor centers.

Staff reviewer: Glenn Plumb, Acting Chief, Yellowstone Center for Resources

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Yellowstone to Yukon: www.Y2Y.net

GEOLOGY

3

Major changes through p. 58

Yellowstone National Park's 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 wonders such as the Grand Canyon of the Yellowstone River.

What Lies Beneath

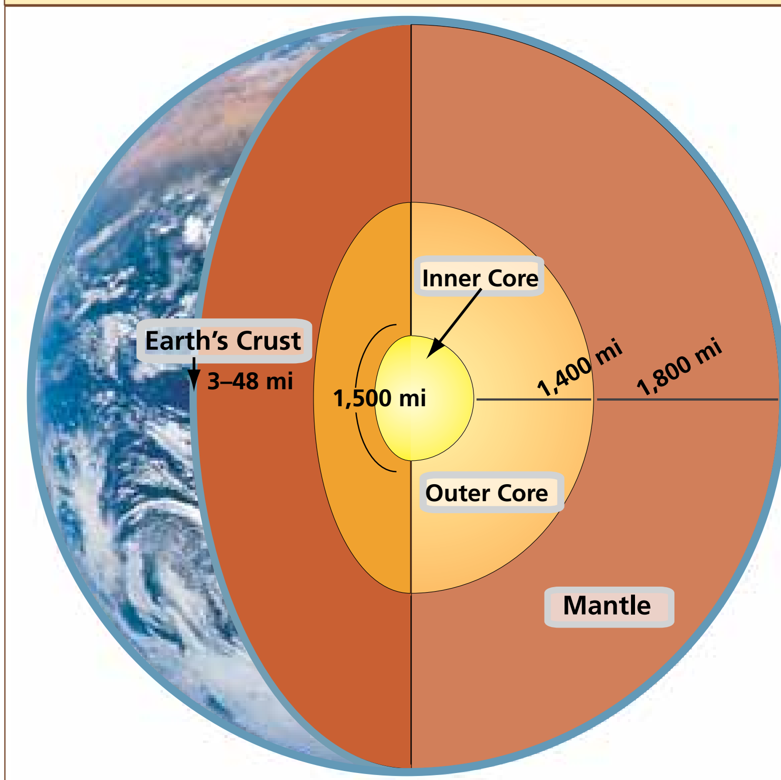
Yellowstone's geologic story provides examples of how geologic processes work on a planetary scale. The foundation to understanding this story begins with the structure of the Earth and how this structure gives rise to forces that shape the planet's surface.

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; *see illustration next page*) 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 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.

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.
- The most undisturbed hydrothermal features left in the world.
- 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.



Illustrations on pages 55–58 & page 64 adapted with permission from Windows Into the Earth, *Dr. Robert Smith and Lee J. Siegel, 2000.*

Yellowstone Geologic History (mya=millions of years ago)	
570 to 66 mya, area covered by inland seas	50–40 million years ago —Absaroka Volcanics—

Most of Earth's history (from the beginning to approximately 570 million years ago) is known as the Precambrian time. Rocks of this age are found in northern Yellowstone and in the hearts of the Teton, Beartooth, Wind River, and Gros Ventre ranges. During the Precambrian and the subsequent Paleozoic and Mesozoic eras (570 to 66 million years ago), the western United States was covered at times by oceans, sand dunes, tidal flats, and vast plains. Near the end of the Mesozoic, 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. 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 with long north-south valleys) characterizing much of the West—including around Yellowstone.

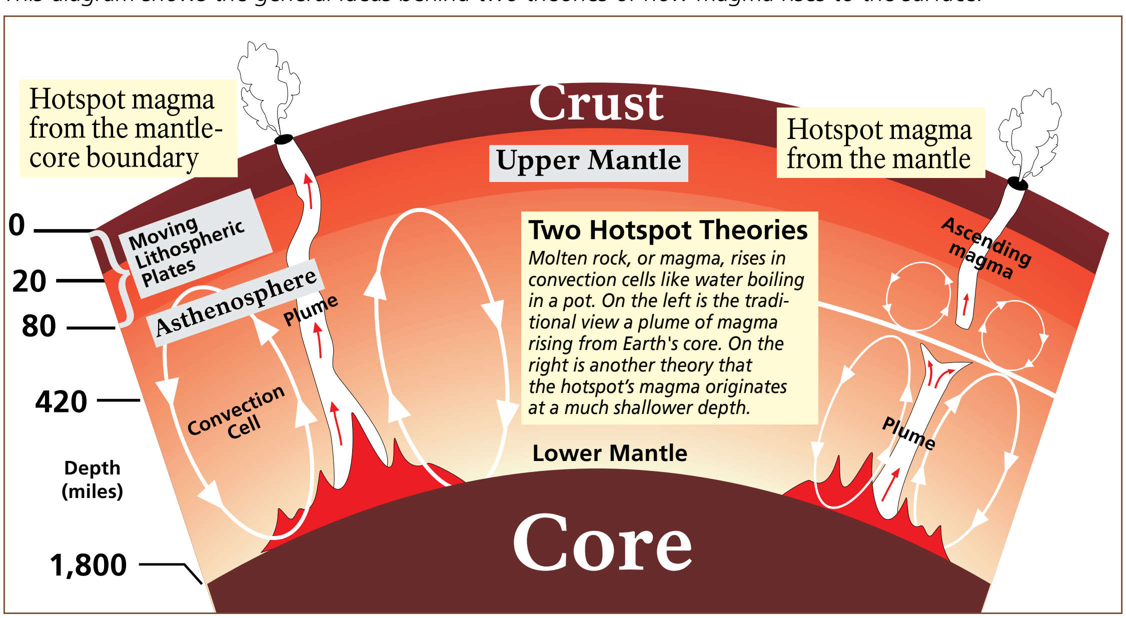
About 16.5 million years ago, an intense period of volcanism appeared near the area now marked by the convergence of the Nevada, Oregon, and Idaho state lines. Repeated volcanic eruptions can be traced across southern Idaho into Yellowstone National Park. This 500-mile trail of more than 100 calderas was created as the North American plate moved in a southwestern direction over a shallow body of magma. About 2.1 million years ago, the movement of the North American plate brought the Yellowstone area into proximity with the shallow magma body. ***This volcanism remains a driving force in Yellowstone today.***

What is a hotspot? *Over the years, the definition of hotspot has shifted back and forth; many scientists refer to a hotspot as the source of the heat fueling the volcanism. However, Yellowstone National Park geologists use the original definition: A hotspot is the surface manifestation of longlived volcanism.*

Magma & Hotspots

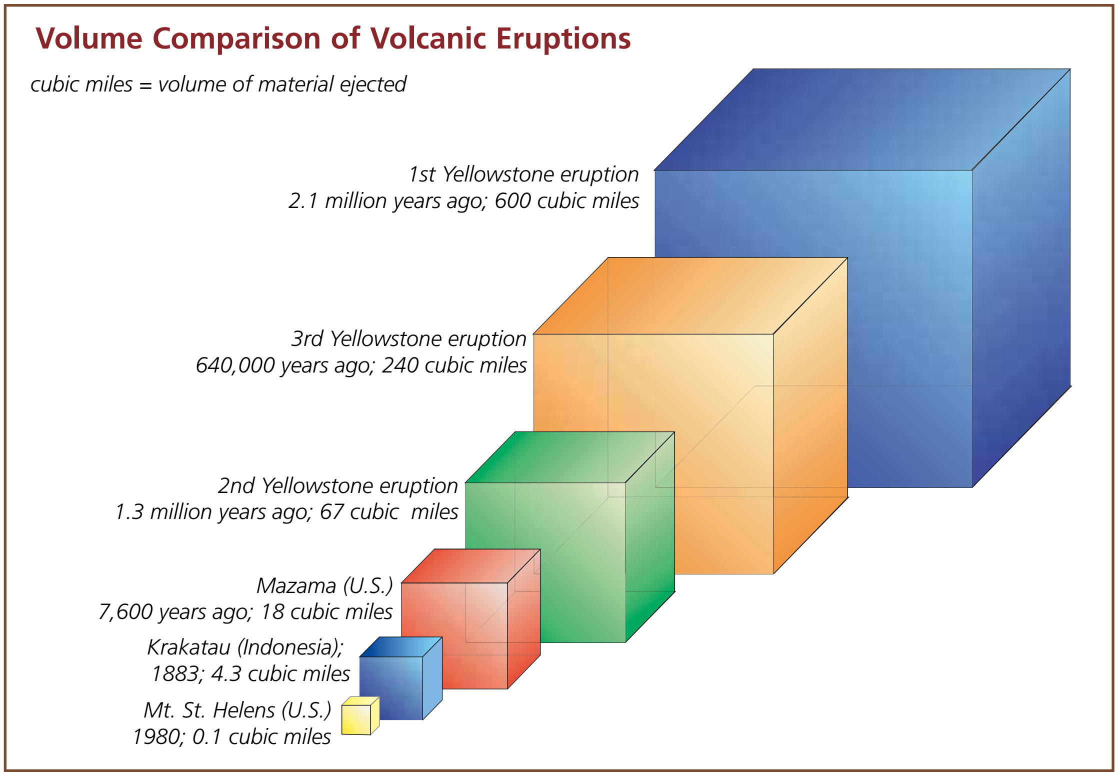
Magma (molten rock from Earth's mantle) has been close to the surface in Yellowstone for more than 2 million years. Its heat melted rocks in the crust, creating a magma chamber of partially molten, partially solid rock. Heat from this shallow magma caused the upper crust to expand and rise, forming what we know as the Yellowstone Plateau and which is the surface manifestation of the long-lived volcanism. The pressure also caused rocks overlying the magma to break, forming faults and causing earthquakes. Eventually, these faults reached the deep magma chamber. Magma oozed through these cracks, releasing pressure within 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-

This diagram shows the general ideas behind two theories of how magma rises to the surface.



30 mya to present. "Basin & Range" forces creating Great Basin topography

16 mya, volcanics begin again in present day Nevada and Idaho

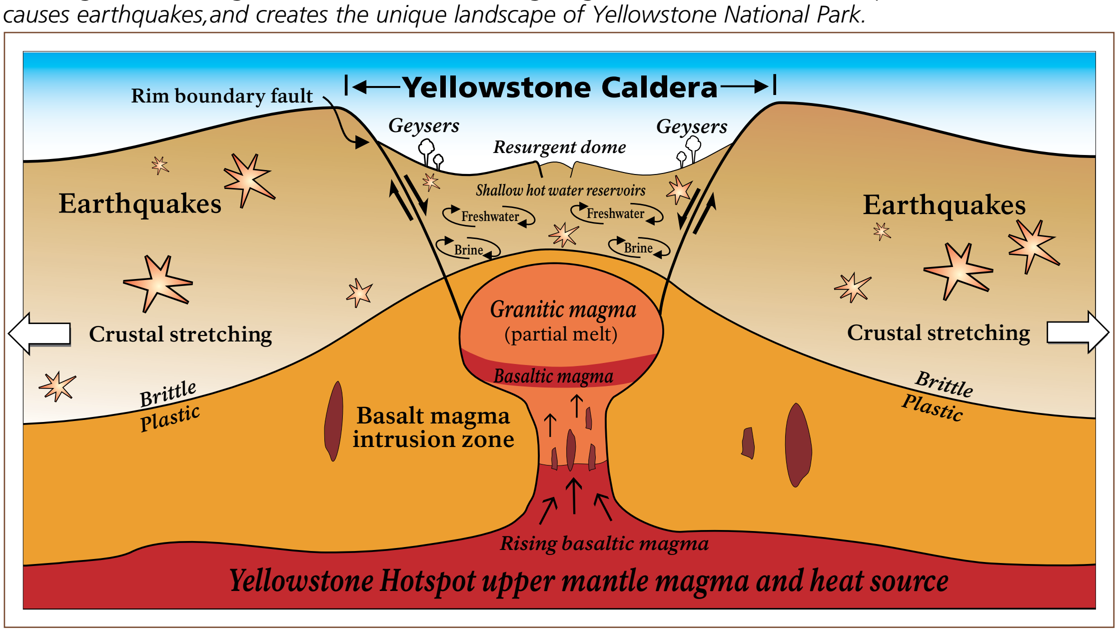


moving superhot debris (pyroclastic) flows on the ground. As the underground magma chamber emptied, the ground above it sunk, creating the first of Yellowstone's three calderas.

The volume of material ejected during this first eruption is estimated to have been 6,000 times the size of the 1980 eruption of Mt. St. Helens in Washington, and ash has been found as far away as Missouri.

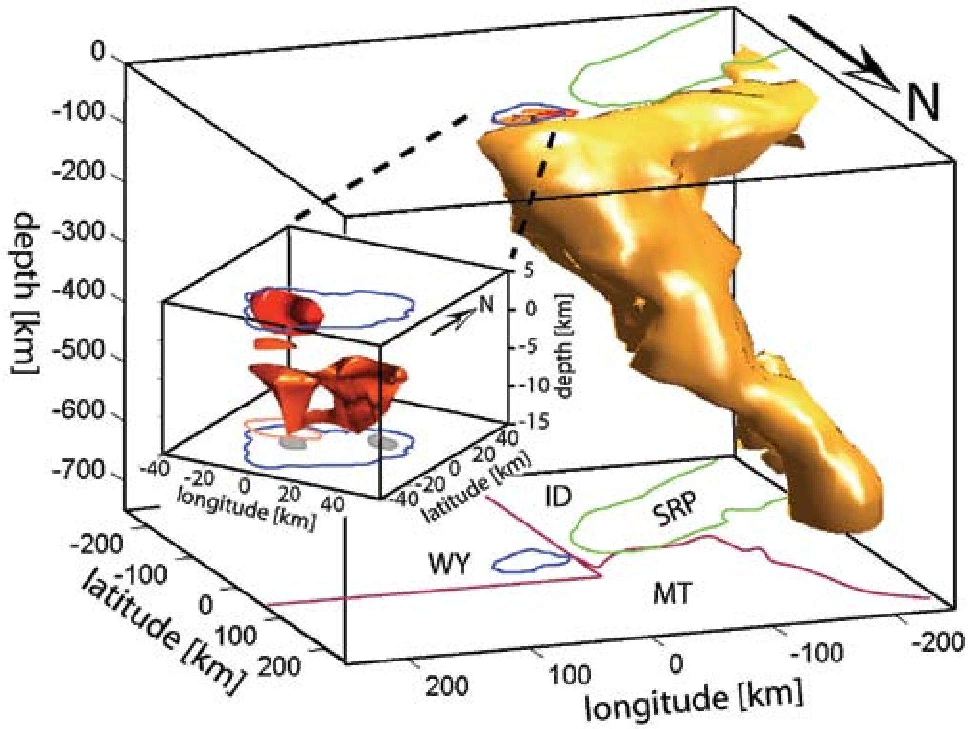
Approximately 1.3 million years ago, a second, smaller volcanic eruption occurred on the western edge of the first caldera. Then 640,000 years ago, a third massive volcanic eruption Yellowstone created the Yellowstone Caldera, 30 by 45 miles in size. A much smaller eruption approximately 174,000 years ago created what is now the West Thumb of Yellowstone Lake. In between and after these eruptions, lava has

This diagram shows a general idea of how the rising magma forms the volcanic hotspot, causes earthquakes, and creates the unique landscape of Yellowstone National Park.



Yellowstone Geologic History (mya=millions of years ago)

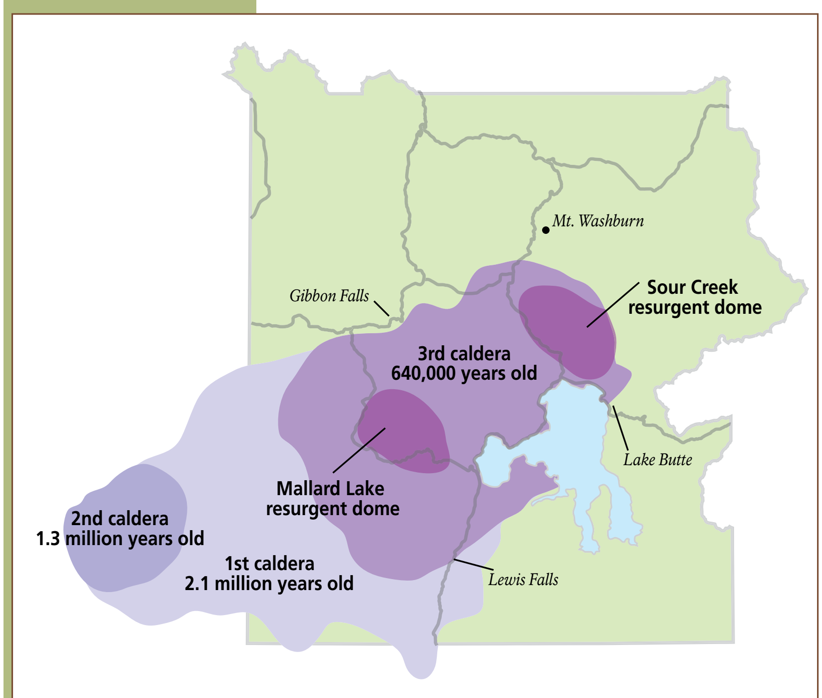
2.1 mya: 1st Yellowstone eruption *1.3 mya: 2nd Yellowstone eruption*



The magma diagram at right is courtesy Dr. Robert B. Smith; it appeared in the Journal of Volcanology & Geothermal Research, 2009. The caldera illustration, below, is from Smith & Seigel, 2000. See "For More Information" for the full citations.

Above: *New technology has allowed scientists to map a magma plume (orange) originating several hundred miles away from Yellowstone, and far deeper than previously thought. It feeds magma into a reservoir (red in detail) beneath Yellowstone.*

Below: *The locations of Yellowstone's three calderas and two resurgent domes.*



flowed—with the last being approximately 70,000 years ago.

Over time, the pressure from magma has created two resurgent domes inside the Yellowstone Caldera. Magma may be as little as 3–8 miles beneath Sour Creek Dome and 8–12 miles beneath Mallard Lake Dome; they both lift up and subside as magma or hydrothermal fluids upwell or subside beneath them. The entire caldera floor lifts up or subsides, too, but not as much as the domes. In the past century, the net result has been to tilt the caldera floor toward the south. As a result, Yellowstone Lake's southern shores have subsided and trees stand in water.

Future Volcanic Activity

Will Yellowstone's volcano erupt again? Over the next thousands to millions of years, probably. In the next few hundred years? Not likely.

The most 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. No scientific evidence indicates such a lava flow will occur soon.

(ka= kiloannum, or one thousand years ago)

640 ka: 3rd Yellowstone eruption

174 ka: West Thumb eruption

140 ka: Bull Lake Glaciation underway

18–16 ka: Pinedale Glaciation maximum

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 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 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 journey back to the surface following the cracks, fissures, and weak areas through rhyolitic lava flows. As hot water travels through this rock, the high water 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 natural "plumbing" system that can withstand the great pressure needed to produce a geyser. At the surface, silica precipitates to form siliceous sinter, creating the scalloped edges of hot springs and the seemingly barren landscape of hydrothermal basins. When the silica rich water splashes out of a geyser, the siliceous sinter deposits are known as geyserite.

siliceous sinter, geyserite

***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 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.*

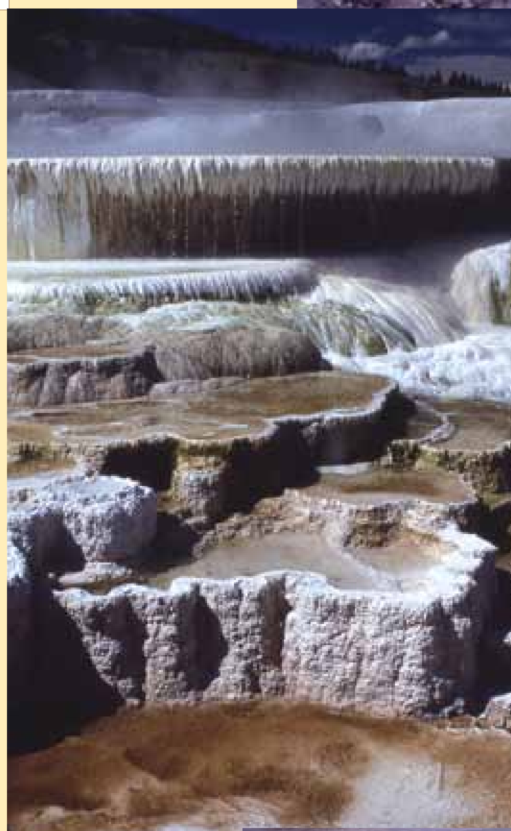
***Cone geysers,** such as Riverside in Upper Geyser Basin (above) erupt in a narrow jet of water, usually from a cone. **Fountain geysers,** such as Echinus in Norris Geyser Basin (right) shoot water in various directions, typically from a pool.*

3

Hydrothermal Features

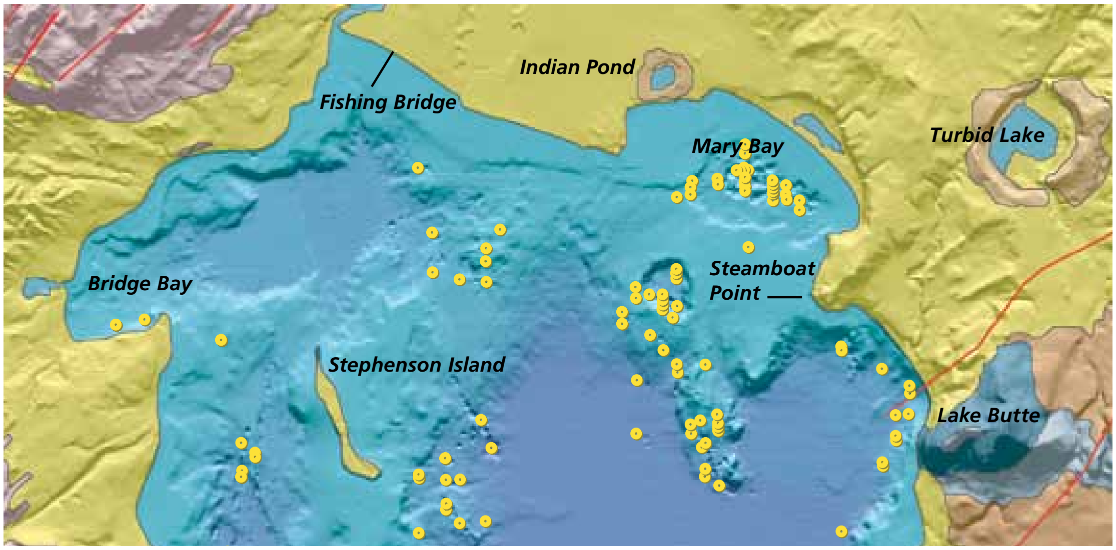
Fumaroles *or steam vents, are the hottest hydrothermal features in the park. They have so little water that it all flashes into steam before reaching the surface. At places like Roaring Mountain (right), the result is a loud hissing of steam and gases.*

Travertine terraces, *found at Mammoth Hot Springs (right), are formed from limestone (calcium carbonate). Water rises through the limestone, carrying high amounts of dissolved calcium 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 microorganisms 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.*



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 were discovered in 1996. They seem to be very old hydrothermal vents.

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 as they took 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, then 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 confirmed the northern half of the lake is 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. It also mapped 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. 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.

These new surveys give an accurate picture of the geologic forces shaping Yellowstone Lake and determine geologic influences affecting the present-day aquatic biosphere.

Yellowstone Lake has existed since the end of the Pinedale glaciation. Some glacial meltwaters flowed south via the Snake River into the Pacific Ocean drainage.

All of the lake now drains north from its outlet at Fishing Bridge, into the vast Atlantic Ocean drainage via the Yellowstone River. The elevation of the lake's north end does not drop substantially until LeHardys Rapids, which is considered the northern geologic boundary of the lake.

For example, hydrothermal explosions formed craters at Mary Bay and Turbid Lake. Spires may form similarly to black smoker chimneys, which are hydrothermal features associated with oceanic plate boundaries.

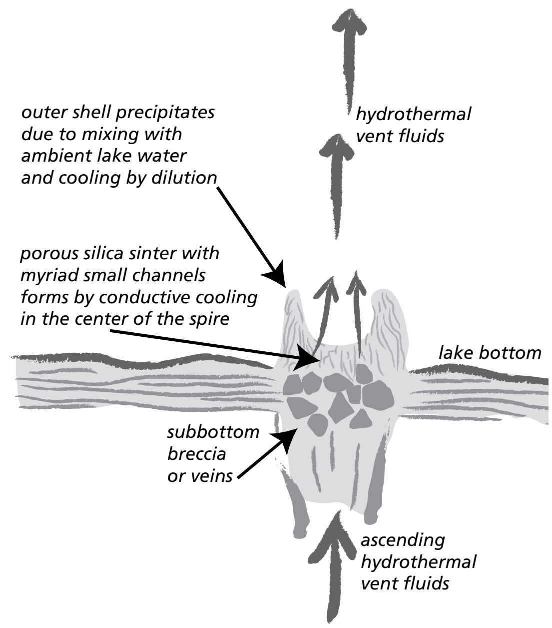
Spire Analysis

With the cooperation of the National Park Service, scientists from the University of Wisconsin–Milwaukee collected pieces of spires and a complete 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.

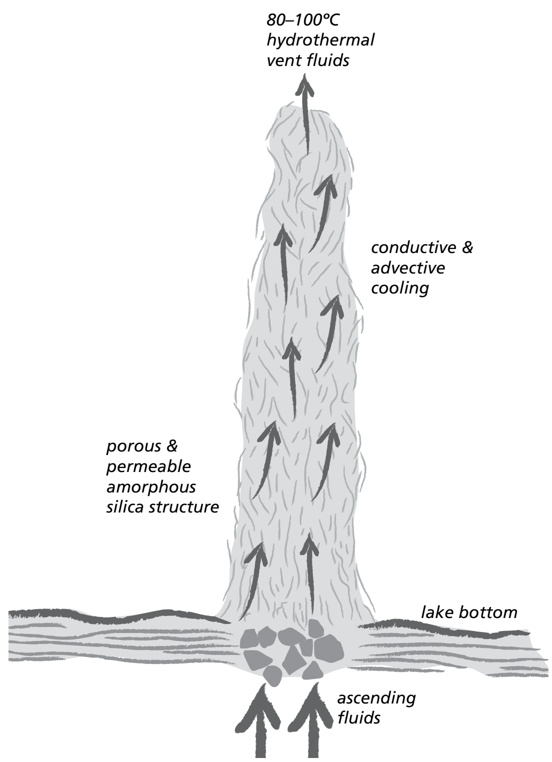
Tests by the U.S. Geological Survey show that the spire is about 11,000 years old, which indicates it was formed after the last glaciers retreated. In addition to silica, the spire contains diatom tests (shells) and silica produced by underwater hydrothermal processes. The spire's interior shows evidence of thermophilic bacteria. Scientists say this suggests that silica precipitated on bacterial filaments, thus playing an important role in building the spire.

Both research projects 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

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. They result from the enormous number of faults associated with the volcano.

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. 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.

In Yellowstone, earthquakes help to maintain hydrothermal activity by keeping the "plumbing" system open. Without 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.

Sometimes Yellowstone experiences an "earthquake swarm." Dr. Jake Lowenstern of the Yellowstone Volcano Observatory defines this as "a packet of earthquakes close in time and space but with no large earthquakes relative to the others." The most active swarm since 1985 began on December 26, 2008 under Yellowstone Lake, and lasted one week. More than 500 earthquakes were recorded; the largest was 3.9 magnitude. No changes in hydrothermal activity were detected.

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.

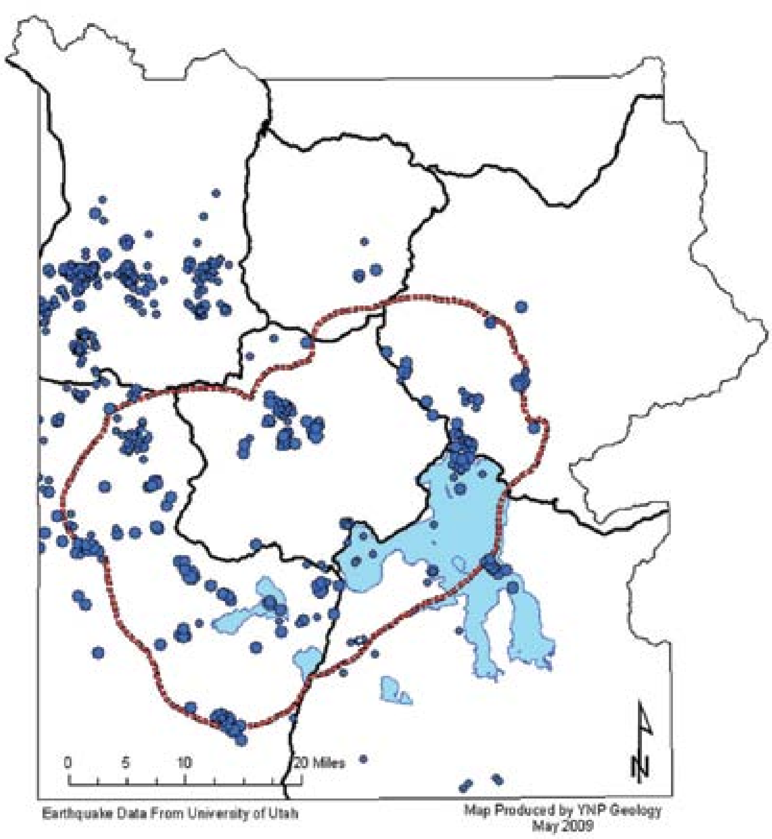
Earthquakes in the Yellowstone area, 2008

Approximately 2,317 earthquakes occurred in 2009.

Blue dots = earthquakes

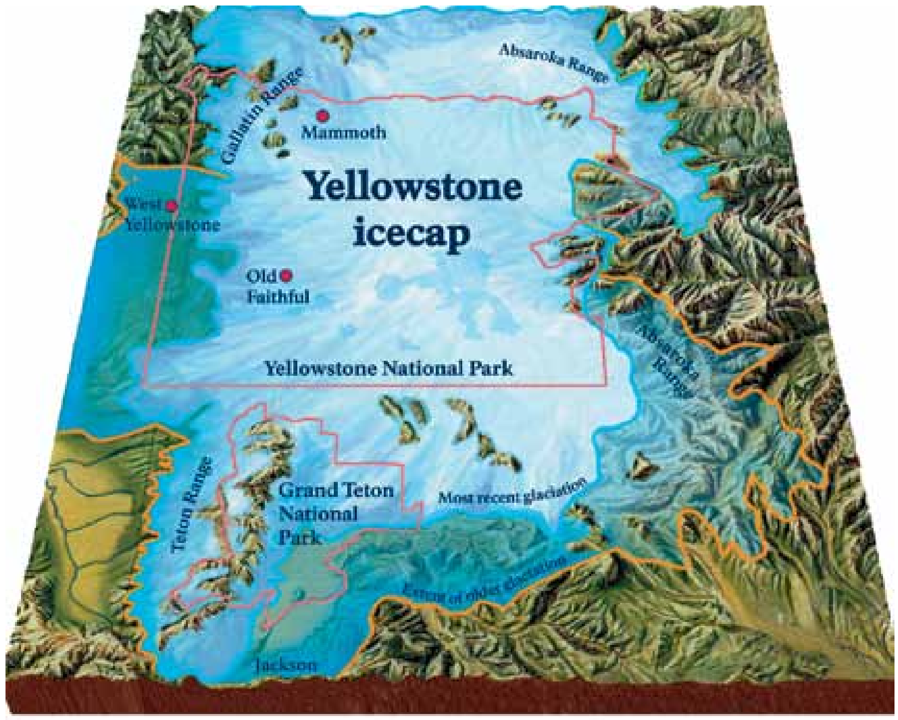
Red dotted line = Yellowstone caldera

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



Scales of Magnitude

On the Richter Magnitude scale, the amplitude of shaking goes up by a factor of 10 for each unit. Thus, 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 ways to measure magnitude from seismograms, partially because each method only works over a limited range of magnitudes and with different types of seismometers. But, all methods are designed to agree well over the range where they overlap.



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

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. In Yellowstone, a glacial deposit near Tower Fall dates back 1.3 million years. Evidence of such ancient glaciers is rare.

The Bull Lake Period glaciers covered the region about 136,000 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 surface evidence of it is found to the north and east. This indicates that the Pinedale Glaciation covered or eroded surface evidence of Bull Lake Glaciation in these areas.

New Pinedale information

The Yellowstone region's last major glaciation, the Pinedale, is the most studied. Its beginning has been hard to pin down because field evidence is missing or inconclusive and dating techniques are inadequate. However, scientists can say with some confidence that the Pinedale reached maximum 18,000–16,000 years ago and ended 13,000–14,000 years ago.

During this period, glaciers advanced and retreated from the Beartooth Plateau, scouring the landscape we know today as the northern range. Glacial dams backed up water over Hayden Valley that deposited glacial sediment. Such dams also backed up water over Lamar Valley; when the dams lifted, catastrophic floods helped to form the the modern landscape around the North Entrance of the park.

During the Pinedale's peak, nearly all of Yellowstone was covered by an ice cap 4,000 feet thick *(see above).* Mount Washburn and Mount Sheridan were both completely covered by ice. This ice cap was not part of the continental ice sheet extending south from Canada. The ice cap occurred here, in part, because the magmatic activity beneath Yellowstone had pushed up the area to a higher elevation with colder temperatures and more precipitation than the surrounding land.

Scientific understanding of glacier dates, sequence, and extent continues to evolve; the information here is considered current by Yellowstone's geologists as of January 2010.

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 Plateau 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)*.

Above: The Beartooth Mountains northeast of Yellowstone are actually an uplifted block of Precambrian rock.

Left: Mt. Everts, near Mammoth, exposes sedimentary rock, which erodes easily and often tumbles or slides 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,

In Yellowstone, many petrified trees can be seen (above). 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?

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; Titanothere (type of rhinocerus) tooth and mandible found on Mt. Hornaday in 1999.

Remember: Collecting any natural resources, including rocks and fossils, is illegal in Yellowstone National Park.

Staff reviewers: Hank Heasler, Geologist; Cheryl Jaworowski, Geologist

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Yellowstone Science, free from the Yellowstone Center for Resources, in the Yellowstone Research Library, or online at www.nps.gov/yell. Recent articles covered historic sites and park history.

Yellowstone Today, distributed at entrance gates and visitor centers.

Site Bulletins, published as needed, provide more detailed information on park topics such as geology & wildlife. Free; available upon request from visitor centers.

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For More Information

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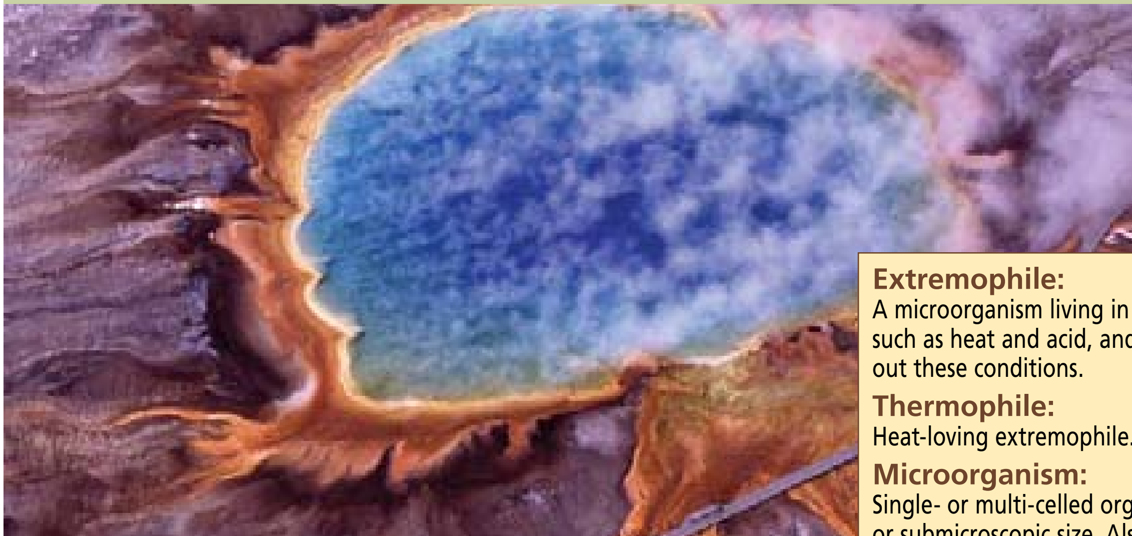
The Complete Yellowstone

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. 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 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 steaming alkaline 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.

Extremophile:
A microorganism living in extreme conditions such as heat and acid, and cannot survive without these conditions.

Thermophile:
Heat-loving extremophile.

Microorganism:
Single- or multi-celled organism of microscopic or submicroscopic 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 72)* —predated cyanobacteria and other photosynthesizers. Archaea can live in the hottest, most acidic conditions in Yellowstone; their relatives are considered among the very earliest life forms on Earth.

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

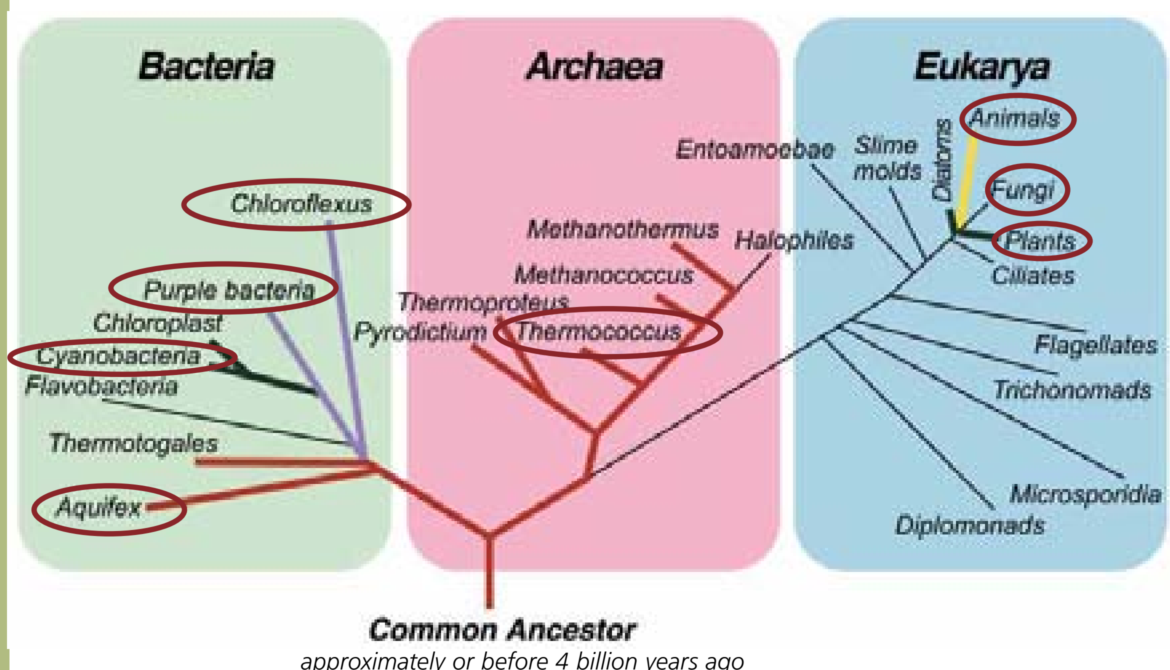
Regardless of scientific advances, visitors and explorers in Yellowstone can still relate to something else Weed said about Yellowstone, more than a century ago:

> *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.

4

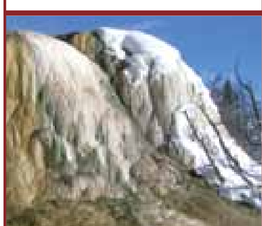
Thermophilic Bacteria

Bacteria (bacterium)
single-celled microorganisms varying in shape, metabolism, and ability to move

The word "bacteria" is often associated with disease, but only a few kinds of bacteria cause problems for humans. The other thousands of bacteria, 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 bind thermophilic mats, 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 76.)*

	Name	pH & T	Description	Where found
	Cyanobacteria: *Calothrix* *Oscillatoria* *Leptolyngbya* *Spirulina* *Synechococcus*	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: *Aquifex* *Chloroflexus* *Thermus*	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 *Thermus* sp. at Norris, especially at Cistern Spring
	Sulfur-oxidizing bacteria: *Aquificales* sp.	60–86°C 140–187°F optimum >70°C >158°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

Note: The cyanobacteria genus Phormidium *is now* Leptolyngbya.

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 next page.)*

Name	pH & T	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
Sulfolobus acidocaldarium 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, esp. Congress Pool Roaring Mountain

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

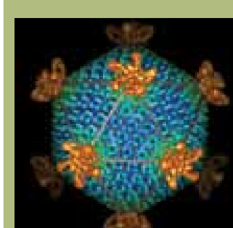
Like bacteria, the word "virus" often conjures up images of sickness and death. However, relatively few of the many types of viruses cause problems for humans. None of the thermophilic viruses in Yellowstone should cause problems for human health—our bodies are too cold, for one thing.

Unlike microorganisms in the three domains, viruses are not considered to be alive. (Yet they are still called "life forms.") 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 & T	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, *Sulfolobus*	Norris, Congress Pool

This virus parasitizes Sulfolobus.



4

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)**.

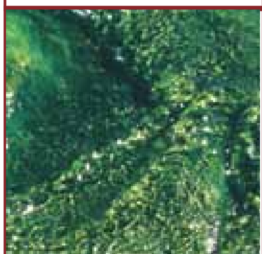
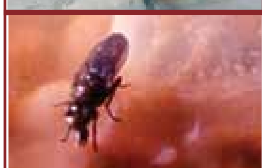
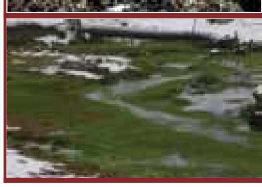
From the boardwalk crossing Porcelain Basin, you can also see larger eukarya, such as ephydrid flies. They live among the thermophilic mats and streamers, and eat, among other things, algae. The species that lives in the waters of Geyser Hill, in the Upper Geyser Basin, lays its eggs in pink-orange mounds, 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.

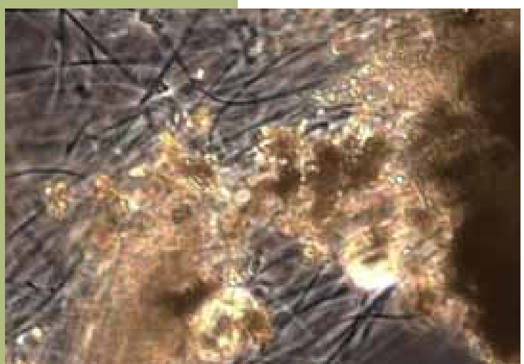
Some microscopic eukarya consume other thermophiles. A predatory protozoan, called *Vorticella,* thrives in the warm, acidic waters of Obsidian Creek, which flows north toward Mammoth Hot Springs, where it consumes thermophilic bacteria.

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 thermophilic fungi thrive in Yellowstone. *Curvularia protuberata* lives in the roots of hot springs panic grass **(bottom photo left)**. This association helps both can survive higher temperatures than when alone. In addition, researchers have recently discovered a virus inside the fungus that is also essential to the grass's ability to grow on hot ground.

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 & T	Description	Where found
	Algae *Cyanidium caldarium* *Zygogonium*	pH 0.5–3 <56°C/133°F pH 2–3 35°C/96°F)	color: bright green metabolism: photosynthetic form: coating on top of formations; mats color: dark brown or purple metabolism: photosynthetic form: filaments and mats	Roaring Mountain Norris, both basins Norris, especially Porcelain Basin
	Protozoa *Naegleria* (amoeba) *Vorticella* (ciliate)	warm alkaline	predator; can infect humans when ingested through nose consumer; single-celled ciliate (feathery appendages swirl water, bringing prey)	Huckleberry Hot Springs Boiling River Obsidian Creek
	Euglenids *Mutablis*	pH 1–2 <43°C/109°F	single-celled photosynthetic moves by waving one or two strands called flagella	
	Fungi *Curvularia protuberata*	≤65°C/149°F with panic grass <55°C/131°F without	grows in roots of hot springs panic grass *(Dichanthelium lanuginosum),* enabling both to survive high temperatures; the plant also produces sugars that the fungus feeds on	
	Ephydrid fly *Ephydra sp.*	>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 Mammoth Hot Springs
	Ross's bentgrass *Agrostis rossiae*	38°C/100°F	one of Yellowstone's three endemic plant species (see p. 86); may bloom in winter; dries out in summer's hot air temperatures	banks of Firehole River near Shoshone Lake
	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



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

Photosynthetic activity of cyanobacteria such as *Lyptolyngbya* form columns or pedestals **(bottom photo).** 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.

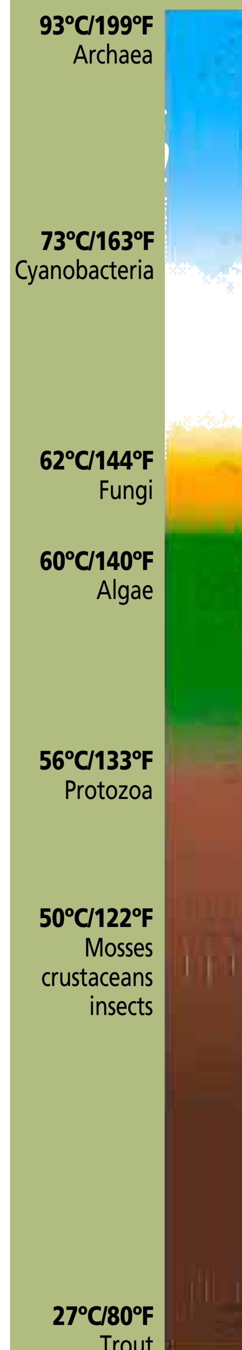
Mats can be as thin as tissue paper or as thick as lasagna. Multiple layers of microorganisms comprise inch-thick mats. Dozens of types of microbes from all three domains can exist in these layers. Each microbial layer is a community, and each layer interacts with the other layers, forming a complex 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 edges 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 thermophile thrives by oxidizing the abundant iron in the water, forming the orange community.

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

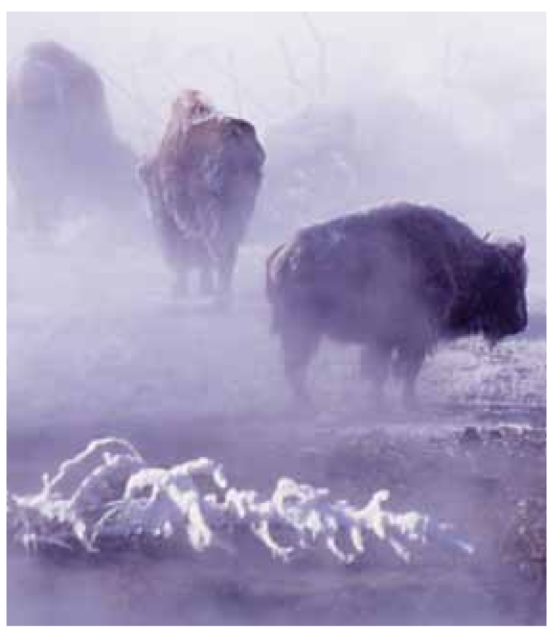
Thermophile community inhabitants are controlled, in part, by water temperature and pH. The chart at right provides general guidelines for what lives in which temperature.



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 this water. 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 concentration at the Chocolate Pots, where the iron is one hundred times more concentrated 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 74–75. 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 processes. Biologists continue to discover more about the individuals involved in thermophilic communities, and ecologists continue to follow the threads of these intricate webs.



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

Characteristics	Thermophiles by Temp.	Thermophiles by Color
• pH 7–11 (alkaline) • underlain by rhyolitic rock • water rich in silica, which forms sinter and geyserite deposits	• >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, Lyptolyngbya,* and *Calothrix* (cyanobacteria) plus *Roseiflexus* (filamentous green bacterium) form mats that line cooler hot springs and runoff channels	• 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

Characteristics	Thermophiles by Temp.	Thermophiles by Color
• pH 0–5 (acidic) • 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, *Zygogonium*, 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

Characteristics	Thermophiles by Temp.	Thermophiles by Color
• 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 time. This evidence does not prove life developed on Mars, but it brings the possibility one step closer to reality.

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

To Mars—and Beyond?

The hydrothermal features of Yellowstone and their associated thermophilic communities are studied by scientists 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.

What's the Connection?

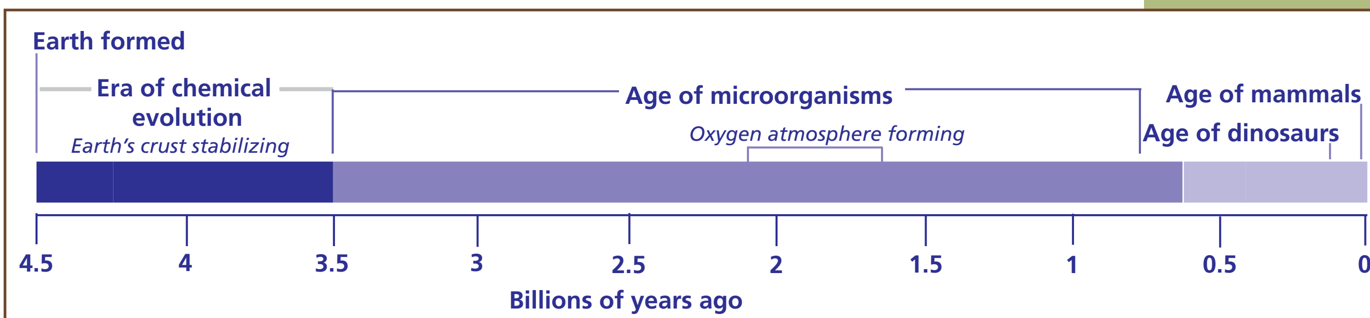
- Yellowstone's hydrothermal features contain modern examples of Earth's earliest life forms, both chemo- and photosynthetic, and thus provide a window into Earth's ancient past.
- Yellowstone hydrothermal communities reveal the extremes life can endure, providing clues to environments that might harbor 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 8, "Bioprospecting."

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 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.



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For More Information

www.nps.gov/yell

www.greateryellowstone-science.org/index.html

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.

Site Bulletins, published as needed, provide more detailed information on park topics such as geology. Free; available upon request from visitor centers.

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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.

VEGETATION

5

Arrowleaf balsamroot

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: whitebark pine, Engelmann spruce, subalpine 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.
- Three endemics—Ross' bentgrass, Yellowstone sand verbena, Yellowstone sulfur wild buckwheat *(see p. 86)*.
- More than 210 exotics.

Management

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

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. Today, the roughly 1,150 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 three endemics occur, Yellowstone sand verbena *(Abronia ammophila)*, Ross' bentgrass *(Agrostis rossiae)*, and Yellowstone sulfur wild buckwheat *(Eriogonum umbellatum var. cladophorum)*.

Major Types

Montane Forests

Forests cover roughly 80 percent of the park. Miles and miles of lodgepole pine forest characterize the park, especially within the Yellowstone Caldera. Extensive areas of forest dominated by subalpine fir and Engelmann spruce are also present, 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 and in non-rhyolitic soil, subalpine fir and Engelmann spruce can replace the lodgepole pine, leading to a canopy dominated by these species. In rhyolitic soils, which are poor in nutrients needed by fir and spruce, lodgepole pine remains dominant. 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. Wind and dessication cause distorted forms known as krumholtz where most of the 'tree' is protected below 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.

5

Major Vegetation Types

Finding Wetlands

Here are a few wetlands locations near roads:

Northeast Entrance Road, beginning east of Yellowstone Picnic Area: listen for frogs in spring, look for sandhill cranes throughout the Lamar Valley

Firehole Lake Road: listen for frogs and look for elephant's head flowers where the road begins

Dunraven Pass area: look for abundant wildflowers in high elevation wetlands near the road

Norris Geyser Basin, Back Basin: near Puff 'n' Stuff Geyser, look for dragonflies

All thermal areas: look for ephydrid flies, thermophiles, and other life forms (see Chapter 4)

Some of 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

This vegetation type occurs in northern range, Hayden and Pelican valleys, and Gardner's Hole. Mountain big sagebrush *(Artemisia tridentata var. vaseyana)* dominates, along with several other kinds 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.

Wetlands

Yellowstone's wetlands include lakes, rivers, ponds, streams, seeps, marshes, fens, wet meadows, forested wetlands, and hydrothermal pools. They occupy over 357 square miles of Yellowstone: 44 percent are lakes and ponds larger than 20 acres or having water deeper than 6.6 feet at low water; 4 percent are rivers and streams; 52 percent are shallow water systems that dry up most years. Approximately 38 percent of park's plant species—including half of the rare plants—are associated with wetlands and 11 percent grow only in wetlands. Wetlands provide essential habitat for Yellowstone's rare plants *(see page 86)*, thermal species *(Chapter 4)*, reptiles and amphibians *(Chapter 7)*, and for numerous insects, birds and fish.

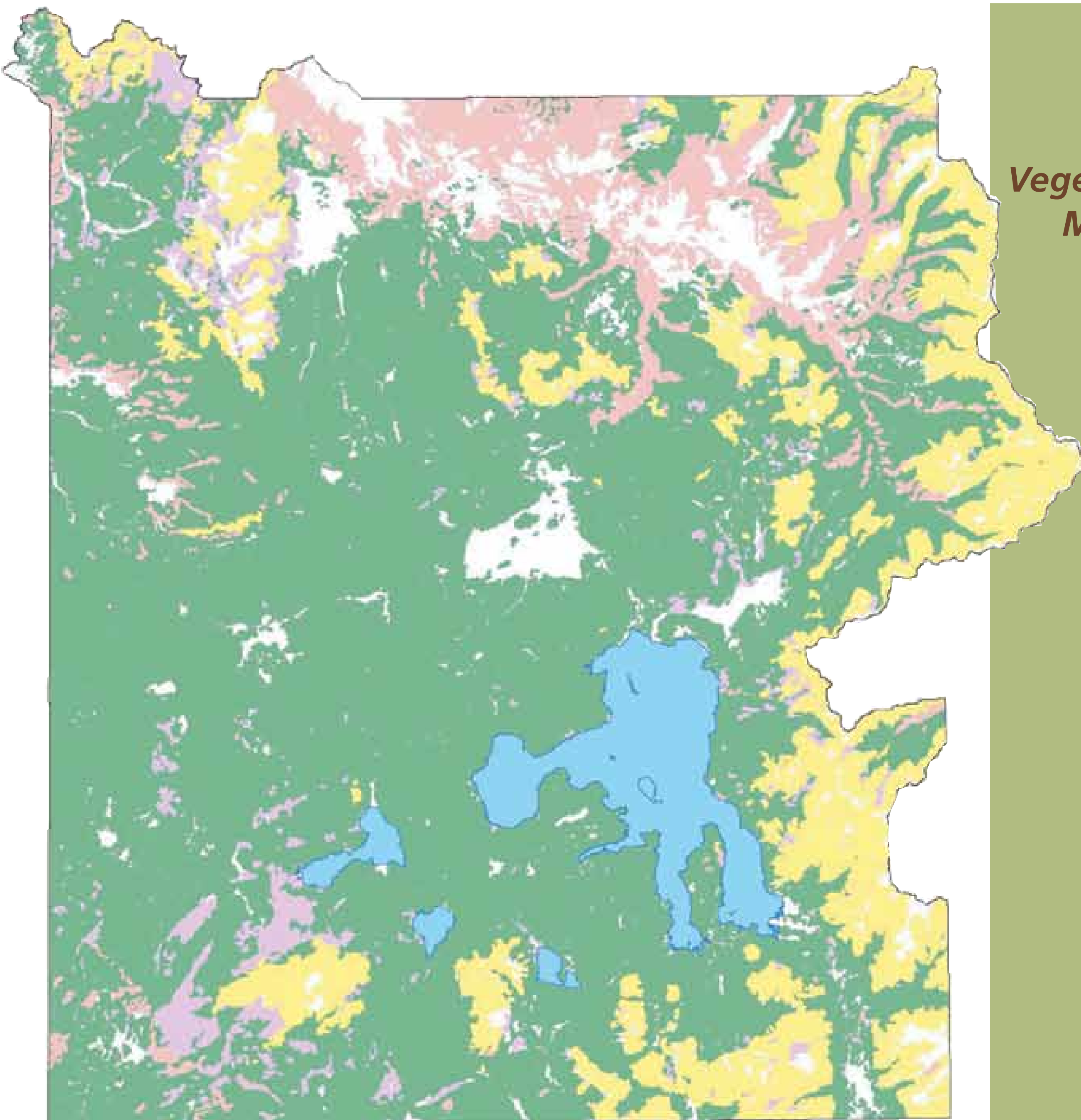
Hydrothermal Communities

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.

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 kill 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 changing climate *(see Chapter 8, "Climate Change")*.

Fringed gentian, considered the park's official flower, grows in wetlands.



Lodgepole pine forests

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

Douglas-fir forests

- Associated with the Lamar, Yellowstone, and Madison river drainages below 7,600 feet.
- Often less than 20 inches 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 above 8,400 feet.
- Major understory component of lodgepole-dominated forests from 7,000 to 8,400 feet.
- 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, sedge, and woody species.
- Riparian—typically streamside vegetation includes cottonwoods, willows, and various deciduous shrubs.

5

Trees

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 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 leaf petioles quake and shiver in the breeze
- Trunks often rough and black due, in part, to browsing by elk and other animals
- Reproduces by cloning (most often), and by seeds (related to fire)

LODGEPOLE 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.

Insects and Fungus Threaten the Trees of Yellowstone

The conifer trees of Yellowstone face six major insect and fungal threats. The fungus is an exotic species, but the insects are native to this ecosystem. They have been present and active in cycles, probably for centuries. A scientist studying lake cores from the park has found some of their insect remains in the cores, indicating their presence even millions of years ago. However, in the last ten years, all five insects have been extremely active, which may be due to the effects of climate change. *(See Chapter 8, "Climate Change.")*

The beetles damage trees in similar ways: their larvae and adults consume the inner bark. If the tree is girdled, it dies.

Mountain pine beetle *(Dendroctonus ponderosae)* Affects whitebark, lodgepole, and limber pine. The tree defends itself by increasing resin (pitch) production, which can "pitch out" the insect from the tree and seal the entrance to others. Look for globs of resin, often mixed with wood borings, on the bark. Adults emerge in mid-summer.

Spruce beetle *(D. rufipennis)* Affects Englemann spruce, rarely lodgepole pine. Larvae feed for two years. Look for reddish dust on the bark and at the base of the tree in early summer.

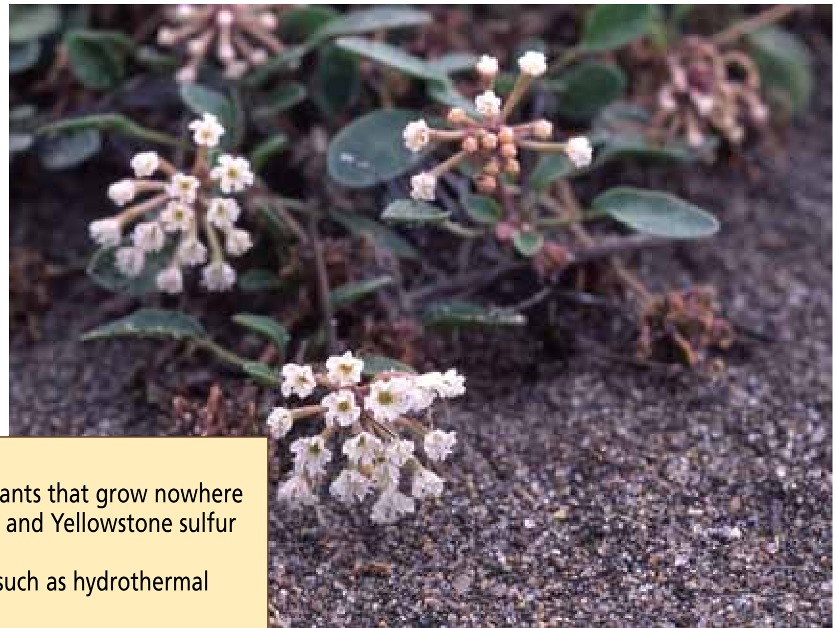
Douglas-fir beetle *(D. pseudotsugae)* Affects Douglas-fir. Larvae also consume outer bark.

Western balsam bark beetle *(Dryocoetes confusus)* Affects subalpine fir.

Western spruce budworm *(Choristoneura occidentalis)* Affects Douglas-fir, true firs, spruce. Larvae defoliate trees and can destroy cones and seeds. Look for clumps of chewed needles on branch tips.

Blister rust is a disease caused by a fungus, *Cronartium ribicola.* Affects whitebark and limber pines. The disease impacts the tree's ability to transport nutrients and produce cones, and generally kills the tree. Look for cankers (lesions) on the bark.

Endemics



Only Here

- Yellowstone is home to three endemic species—plants that grow nowhere else—Ross's bentgrass, Yellowstone sand verbena, and Yellowstone sulfur wild buckwheat.
- 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.

Wildflowers

Wildflowers such as lupine and arnica often grow under the forest canopy, but the most conspicuous wildflower displays occur in 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 balsamroot, white from phlox, reds and oranges from paintbrush, and blue from penstemon and lupine. Goldenrod and gentians indicate the coming of autumn.

Ross's Bentgrass (Agrostis rossiae)

Ross's bentgrass grows only in the geyser basins along the Firehole River and at 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 about 100°F. As a result, this grass is one of the first plants to green up in warm pockets of geyserite—sometimes as early as January.

Ross's bentgrass rarely grows taller than six inches and more typically only 2–3 inches. Another diagnostic characteristic of Ross's bentgrass is that the inflorescence (flower) never completely opens up. Flowers may be present in February and March, but the plants typically 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 sun's heat from above and the thermal heat from below. Ross's bentgrass is already dead and hard to find by July.

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 probably includes traveling on the muddy hooves of bison and elk who inhabit thermal areas during the winter. Exotic species, such as cheat grass, pose the only known threat; as they spread in thermal areas, they eventually may outcompete Ross's bentgrass.

Yellowstone Sand Verbena
(Abronia ammophila)

Yellowstone sand verbena *(photo above)* occurs along the shore of Yellowstone Lake. Taxonomists debate the relationship of this population of sand verbena to other sand verbenas. It may be distinct at the subspecific level, and is certainly reproductively isolated from the closest sand verbena populations in the Bighorn Basin of Wyoming.

Sand verbenas are a member of the four o'clock family. Very few members of the family grow this far north. Little is known about the life history of Yellowstone sand verbena. 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 this species survive. The flowers are white and the foliage is sticky, and bloom from mid-June until a killing frost.

Yellowstone Sulfur Wild Buckwheat
(Eriogonum umbellatum var. cladophorum)

Several varieties of sulfur buckwheat live in the park, but this variety grows along edges of thermally influenced sites from Madison Junction to the Upper Geyser Basin. It differs from the more common varieties by the densely hairy upper surface of the leaves, and by the bright yellow of its flowers.

5

Managing Invasive Plants

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 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.

Exotic Species

- More than 210 exotic plant species in the park.
- Resource managers target the most invasive species for control or removal.
- Species include (common names):
  Dalmation toadflax
  Spotted knapweed
  Canada thistle
  Ox-eye daisy
  Houndstongue
  Leafy spurge

Dalmation toadflax *Linaria dalmatica*

- Northern portions of the park, especially around Mammoth.
- Highly invasive, replacing native plants.

Spotted knapweed *Centaurea maculosa*

- Along roadsides and in the vicinity of Mammoth.
- Aggressive species that, once established, forms a monoculture, which displaces 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.
- Can become dominant in meadows, is unpalatable to elk and other wildlife.
- Control efforts have substantially curtailed infestation; monitoring and evaluation continue.

Hounds tongue *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.
- 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 Caribou-Targhee National Forest.
- Becomes a monoculture, forcing out native vegetation.
- Extremely hard to control because of deep underground stems (up to 30 feet) and dense vegetation.

Dalmatian toadflax

5

Restoring Native Plants

Restoration

Restoring an Invaded Land

In 1932, President Hoover added over 7,000 acres of land to Yellowstone National Park to provide low-elevation winter wildlife habitat near Gardiner, MT. *(See Chapter 1.)* The addition included 700 acres of irrigated agricultural fields.

Park managers stopped irrigating the fields and planted an exotic perennial grass, crested wheatgrass *(Agropyron cristatum),* that they hoped would tolerate the arid conditions and provide wildlife forage. It thrived for many decades, but was never suitable forage. Eventually another, more aggressive, non-native plant—an annual mustard, desert alyssum *(Alyssum desertorum)*—moved in. Alyssum germinates very early and uses up most of the soil moisture before other species even get started. It also exudes a chemical that inhibits soil bacteria needed by native plants.

Park managers are restoring native vegetation to this area, following recommendations of arid land restoration specialists. In 2008 and 2009, they fenced four pilot plots totaling 50 acres, where they are controlling non-native plants with herbicides and growing cover crops to increase soil organic matter and moisture-holding capacity and restore soil microbial communities. After 2 to 3 years, they will seed the plots with native species.

Managers expect the fencing to remain for 10 to 15 years while the native plants become established. The fencing prevents elk and other ungulates from grazing on the young plants.

Restoration of this area will proceed in multi-year phases to allow native plants to become established under natural conditions, to provide time for managers to monitor and refine their methods, and to provide winter wildlife habitat.

Some of these restoration plots are adjacent to the Old Yellowstone Trail, an unpaved road that parallels the Yellowstone River west of Gardiner, MT.

Staff reviewers: Mary Hektner, Supervisory Vegetation Specialist; Jennifer Whipple, Botanist; Roy Renkin, Vegetation Management Specialist

For More Information

www.nps.gov/yell

www.greateryellowstonescience.org/index.html

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

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Fire

6

Role of Fire in Yellowstone

- Fires have always occurred periodically in the Yellowstone ecosystem.
- Lightning starts many fires each year that go out on their own.
- Vegetation in this ecosystem is adapted to fire.

Factors Affecting Size & Severity

- Type of vegetation where the fire begins.
- In a forested area, the interval since the last stand-replacing fire.
- Fuel moisture in the dead and down logs.
- Length of drought.
- Temperatures and humidity.
- Wind.

A serotinous cone from a lodgepole pine, opened by fire.

Extensive, on-going research is revealing Yellowstone's long and complicated fire history. By measuring the amount and age of charcoal in lake sediments, scientists now have proof that large fires have been occurring in Yellowstone since forests became established following the last glacial retreat 14,000 years ago. By examining fire scars on old Douglas-fir trees in the northern range, they see indications that fire occurs in the sagebrush/steppe on average every 25 to 30 years. And their study of tree-rings show different intervals for lodgepole pine forests, depending on soil: 150 years or more on andesitic soils; 300 years on rhyolitic soils. In addition, records kept from 1931 show that lightning started an average of 22 fires each year until the 1990s, when fire average began increasing. This may be due, in part, to climate change. *(See Chapter 8.)*

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 the grasslands of Yellowstone, such as the Lamar and Hayden valleys. Trees such as Douglas-fir seeds require conditions that exist only in rare microhabitats in these grasslands. If a seed reaches such a microhabitat during a favorable year, a seedling may develop. 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 surface fires. In the past, in areas like the park's northern range, frequent surface fire kept most young trees from becoming part of the overstory. The widely scattered, large, fire-scarred trees in some of the dense Douglas-fir stands in the northern range are probably remnants of these communities.

Lodgepole pines produce two types of cones, one of which opens

Moisture Content

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

- *<13%: lightning will likely start fires that can spread rapidly*
- *13 to 20%: fires may burn actively and possibly spread rapidly*
- *21–24%: fires may start but few will spread*
- *>24%: few fires start*

and releases seeds after being heated to at least 113°F. These fire-dependent cones—called serotinous *(photo, previous page)*—ensure seedlings become established after a fire. Lodgepole seedlings 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, insects, 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.

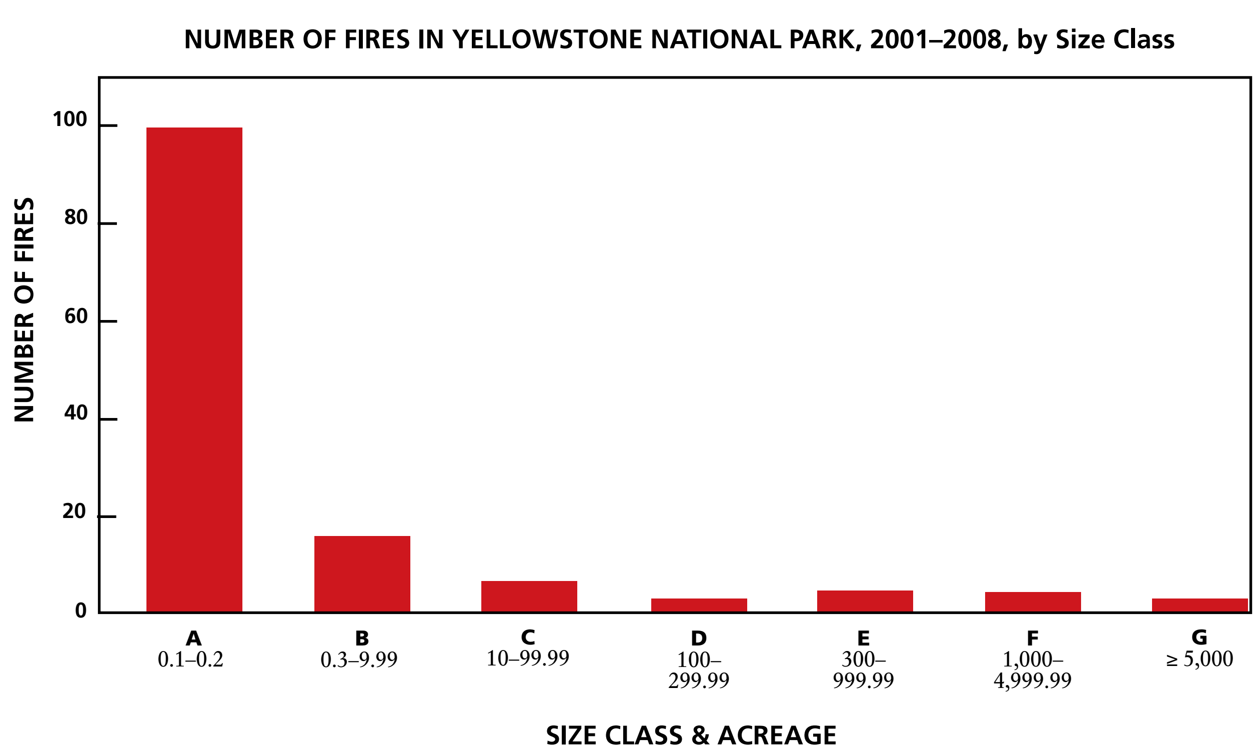
Fire suppression alters these natural conditions. Landscape diversity diminishes, and plant community structure and composition change. Diseases and insect infestations spread over greater areas, litter and deadfall accumulate, and minerals remain locked up or are more slowly released.

Fire Behavior

The moisture content of dead and down lodgepole pines and the year's weather trends are the main factors determining the severity of a given fire season. While fires can occur no matter the fuel moisture, many times conditions are too wet for fires to burn. In fact, 85 percent of all lightning-caused fires burn less than one acre. However, when fuel moisture falls below 13 percent *(see at left)*, fires that begin in older forests (>200-yr old) can grow quickly. If extreme drought continues, all forest types and ages are more likely to burn.

Fire managers may be able to predict a fire's behavior when they know where the fire is burning (older forest, grassland, etc.) and the fuel moisture content. However, predicting fire is much more difficult during extreme drought, such as was experienced in 1988 and in the 2000s.

Ongoing research in Yellowstone is also showing that forests experiencing stand-replacing fires can then affect fire behavior



Some fires burn with extreme fire behavior and rapid rates of spread. These large, fast moving fires send plumes of smoke thousands of feet into the air and receive much of the public's attention. These large fires (>100 acres) occur less than 11 percent of the time. Seventy-two percent of fires that occur in this park are less than 0.2 acres and another 12 percent range from 0.3 to 9.9 acres. These smaller, less intense fires play a role in this ecosystem by helping to thin out smaller trees and brush and boost the decay process that provides nutrients to the soil.

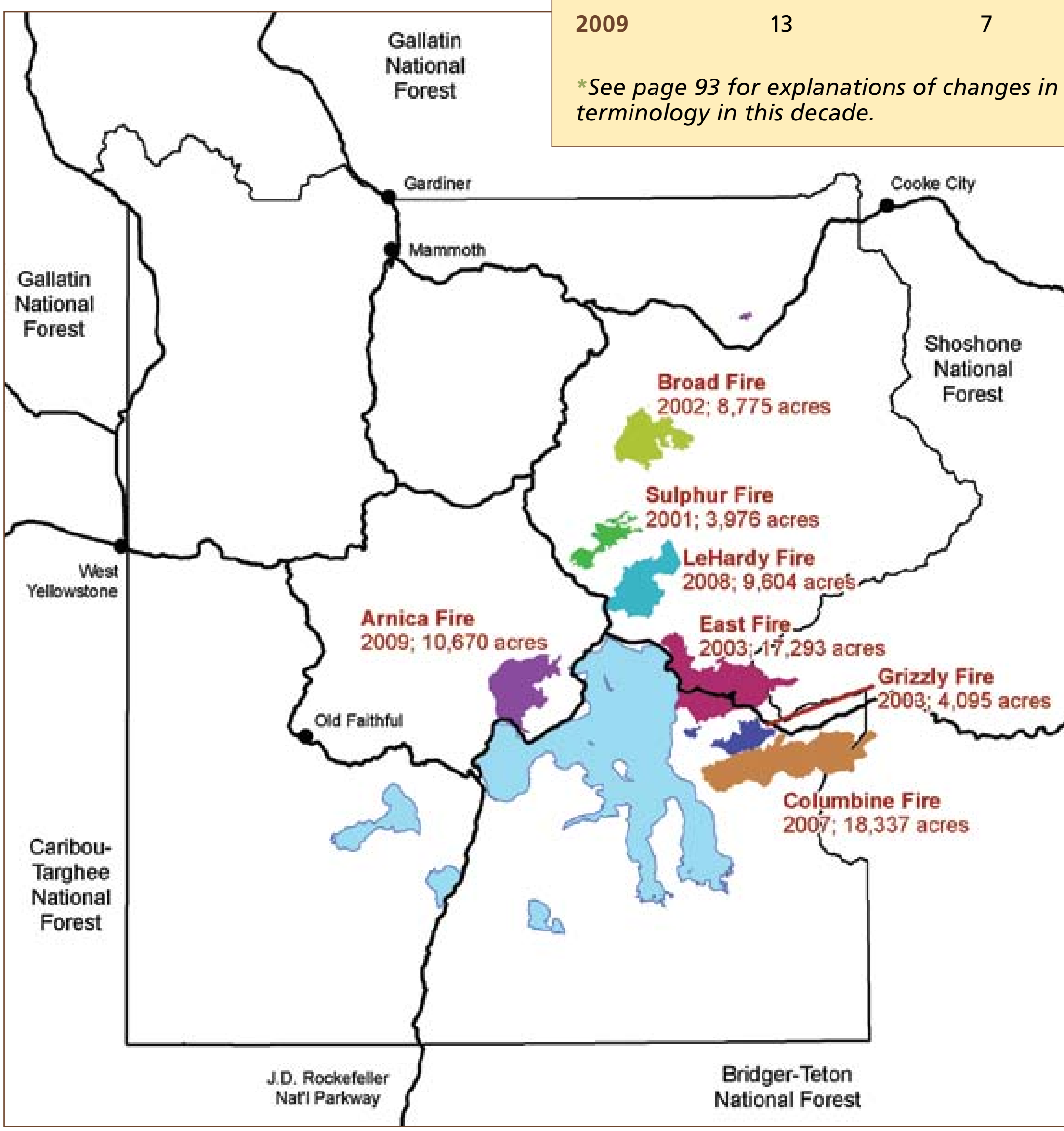
for up to 200 years. As a fire encounters the previously burned forest, its intensity and rate of spread decrease. In some cases, the fire moves entirely around the burned area. Thus, fire managers have another tool for predicting fire behavior: They can compare maps of previous stand-replacing fires with a current fire's location to predict its intensity and spread.

Major Fire Years in Yellowstone Since 2000

Year	*Managed Fires	Suppressed Fires	Acres Affected
2000	2	31	7,209
2001	16	21	7,987
2002	8	38	12,755
2003	7	71	28,849
2006	8	6	4,247
2007	9	18	24,601
2008	1	7	10,381
2009	13	7	10,898

**See page 93 for explanations of changes in fire management and terminology in this decade.*

Fires Visible from Park Roads



Compare the fire perimeters on this map with those of the 1988 fires (p. 98). So far, the large fires of the 21st century are burning in areas largely unaffected by the 1988 fires. Ongoing research is showing that areas of stand-replacing fires can affect future fire behavior for up to 200 years.

6

Managing Fire

History

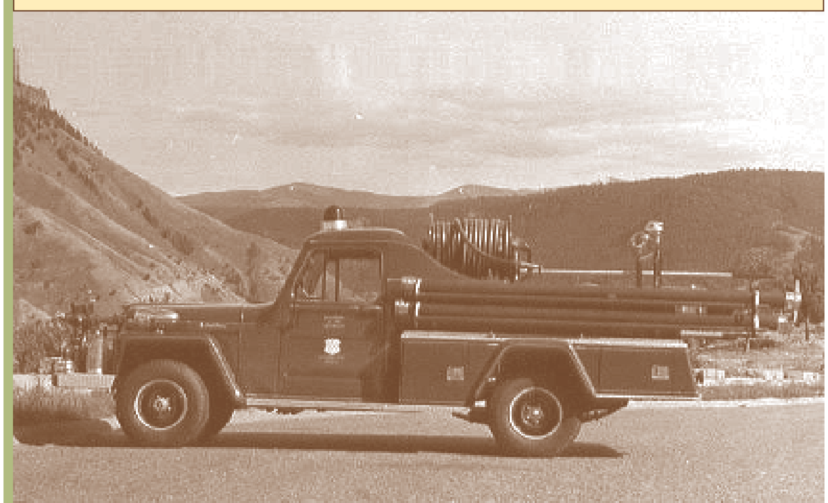
- For the first 100 years of the park's existence, managers believed fires had to be extinguished to preserve park resources.
- Scientific research revealed:

—fires have occurred in Yellowstone for as long as there has been vegetation to burn
—fire plays a role in creating the vegetation patterns of 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, unsuppressed 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 94.)
- The fires of 1988 brought about management changes, as did subsequent major fire seasons in this region.

Current Fire Management Policy

Yellowstone National Park follows guidelines of the 2003 Federal Wildland Fire Policy, which allows firefighters to manage fires for multiple objectives.



This old fire truck was pressed into use during the 1988 fires. Fire management policy, like the equipment, has been updated many times since that fiery year.

Fire suppression in Yellowstone National Park 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 the effect of their efforts on overall fire frequency or extent of fires cannot be fully determined. Their efforts are detectable on the northern range, where fire suppression allowed more trees to become established.

Post World War II

Reliable and consistent fire suppression began when modern airborne firefighting techniques became available after World War Two. Fire suppression continued until 1972. In that year, Yellowstone and several other national parks initiated programs allowing some natural fires to run their courses. Two backcountry areas in the park totaling 340,000 acres were designated as locations where natural fires could burn.

In 1976, the park's program expanded to 1,700,000 acres. 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.

In the years following, Yellowstone's fire management plan was revised and updated to meet National Park Service guidelines as research provided new information about fire behavior in the park. By 1985, cooperative agreements were in place within the greater Yellowstone area to allow natural fires to burn across the public land boundaries. Yellowstone's fire managers began revising the park's fire management plan. The new plan permitted some lightning-caused fires to burn under natural conditions; provided for suppressing fires that threatened human life, property, special natural features and historic and cultural sites; and recommended prescribed burns when and where necessary and practical to reduce hazardous fuels. It was in the final stages of approval in spring 1988.

Late 20th Century Reviews

Yellowstone's "new" fire policy was suspended during the summer of 1988. *(See following pages.)* After the fires of that summer, a national policy review team examined the national fire policy again, and concluded that natural fire policies in national parks and wilderness areas were basically sound. It also recommended improvements that were incorporated into the National Park Service's fire policy of June 1990 and into Yellowstone National Park's fire management plan of 1992.

Other major reviews occurred after the fire seasons of 1994 and 2000.

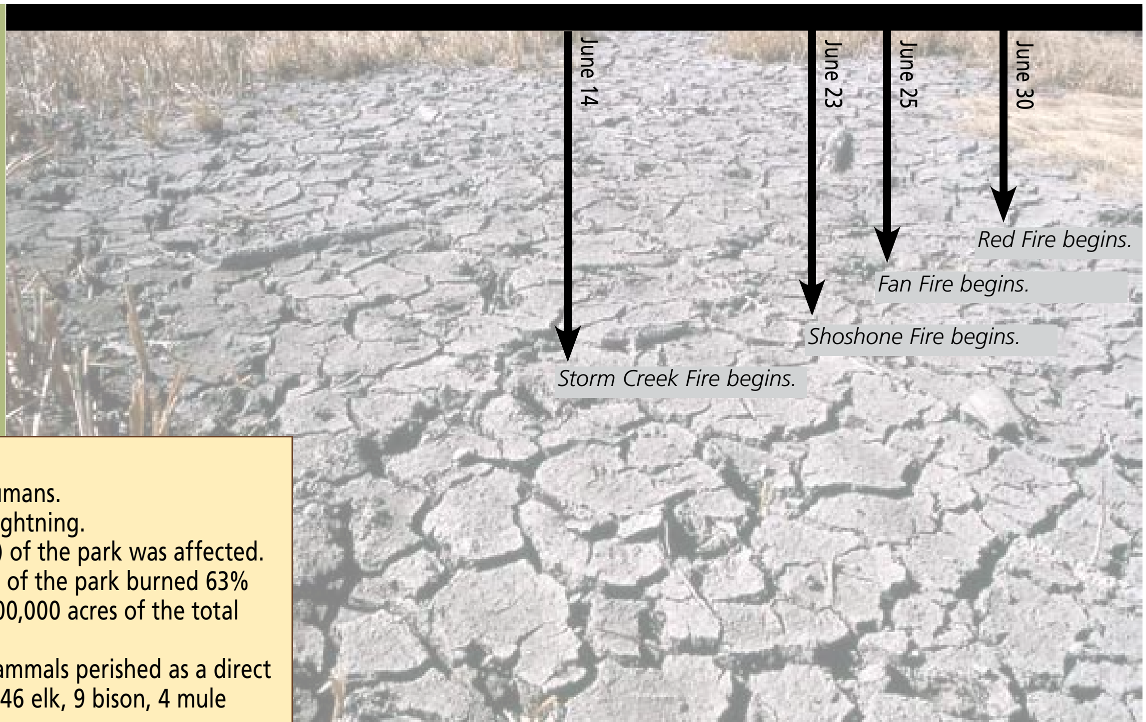
Fire Management Today in the Greater Yellowstone Ecosystem

Today, Yellowstone National Park operates under the 2003 Federal Wildland Fire Policy, which continues to evolve with experience and new knowledge. For example, current guidelines allow firefighters to manage a natural fire for multiple objectives. In the past, fires were required to be categorized as "suppression" or "fire-use for resource benefit." Now, firefighters can suppress one flank of a fire to protect structures and people while allowing another flank to burn to achieve natural fire benefits.

The LeHardy fire of 2008 was an example of managing a fire for multiple objectives. It was suppressed on its west and south flanks to protect power lines, the Fishing Bridge area, and to protect people using the roads. It was monitored, but not suppressed, as it moved north away from developed areas. Backcountry ranger cabins and research equipment in its path were wrapped in a material similar to a fire shelter to protect them from the heat.

A similar strategy was used in the 2009 Arnica Fire, which burned in 300-year-old lodgepole pine but threatened visitor travel, power lines, and Lake Village.

Wildland fire is a great example of interagency cooperation and coordination. Federal agencies, state and local governments, and private contractors all play a role in managing fire here the park. For example, the NPS relies on Forest Service smokejumpers to monitor or fight the park's remote fires. In return, the NPS sends its helicopter or engine to the Silver Gate or Cooke City areas, which are located on or adjacent to the Gallatin and Shoshone national forests. In 2009, the park's wildland engine was staffed by both NPS and Forest Service firefighters. Programmable radios ensure communication between NPS and Forest Service dispatch, which provides for firefighter safety. The NPS is also working with its partners to develop Community Wildfire Protection Plans that help in the pre-planning and preparing for a wildland fire that may threaten homes.



Statistics

- 9 fires caused by humans.
- 42 fires caused by lightning.
- 36% (793,880 acres) of the park was affected.
- 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 involved in these efforts.

Fighting the Fires

- Until July 15, park managers followed the policy to let naturally-caused fires burn.
- Beginning July 15, park managers suspended the natural fire policy and began suppressing new natural fires.
- After July 21, park managers began fighting all fires, including natural fires that had been allowed to burn.
- The 1988 fires comprised the largest fire-fighting effort in the United States at that time.
- Effort saved human life and property, but had little impact on the fires themselves.
- Rain and snow in September finally stopped the advance of the fires.

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)*. They allowed 18 lightning-caused fires to burn after evaluating them, 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 expected. By late July, after almost two months of little rain, the moisture content of grasses and small branches reached levels as low as 2 or 3 percent, and downed trees were as low as 7 percent (kiln-dried lumber is 12 percent). *(See page 90.)* In addition, 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 except those started adjacent to existing fires and that were clearly going to burn into existing fires. Even so, within a week the fire acreage in the park doubled to about 17,000 acres. After July 21, all fires—including those started naturally—were fully suppressed as staffing would allow. (Human-caused fires had been suppressed from the beginning.) On July 27, during a visit to Yellowstone, the Secretary of the Interior reaffirmed that all fires would be fought, regardless of their origin.

THE YEAR THE RAINS FAILED

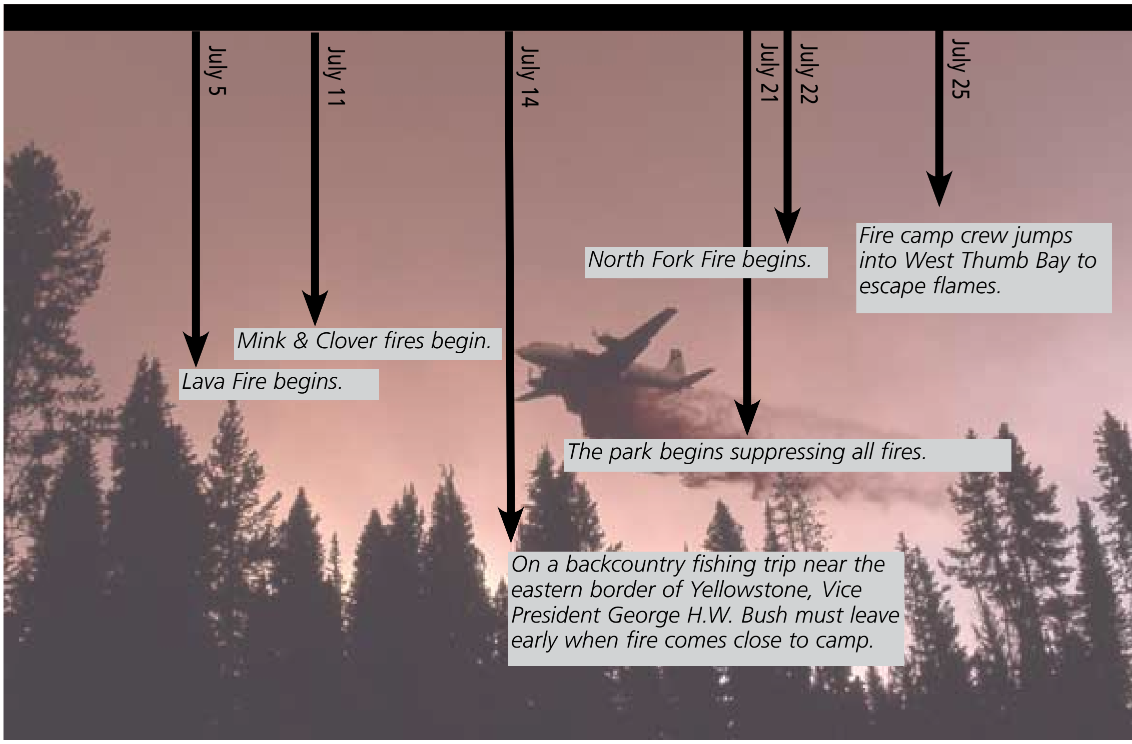
Percent of Normal Rainfall Mammoth Hot Springs

	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

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 this unprecedented series of wildfires. The extreme weather conditions and heavy, dry fuel accumulations presented even the most skilled professional firefighters with conditions rarely observed.

Accepted firefighting techniques were often ineffective because fires spread long



distances by "spotting," a phenomenon in which wind carries embers across unburned forest to start spot fires ahead of the main fire. In the severe conditions of 1988, fires were spotting up to a mile and a half ahead—jumping bulldozer lines, roads, rivers, even the Grand Canyon of the Yellowstone River.

Fires often moved two miles per hour, with common daily advances of five to ten miles. The fast movement, coupled with spotting, made direct 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. Typically, wildfires "lie down" at night as humidity increases and temperature decreases. But in 1988, the humidity remained low at night, and fire fighting was complicated by the danger of falling trees.

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 fires of 1988 received more national attention than any other event in the history of national parks up to that time. 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 oversimplified events and exaggerated 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 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 fires 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

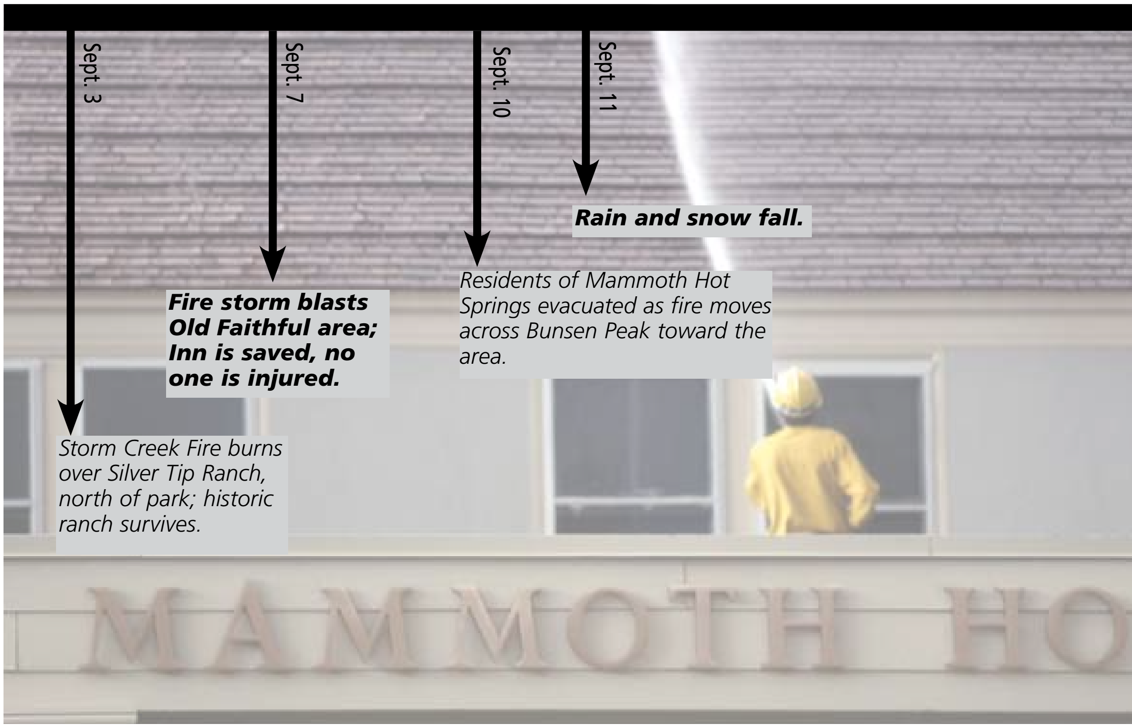
Absaroka–Beartooth Wilderness of the Custer National Forest northeast of Yellowstone; it eventually threatened the Cooke City–Silver Gate area, where it received extended national media coverage.

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 protecting 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.

Post-fire Response and Ecological Consequences

By late September, as the fires were diminishing, plans were already 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. Interpretive rangers developed programs to interpret the fires and their effects for visitors and for the general public. Other interpretive specialists developed indoor and outdoor exhibits, publications, and trails to help visitors learn about these historic fires. 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.

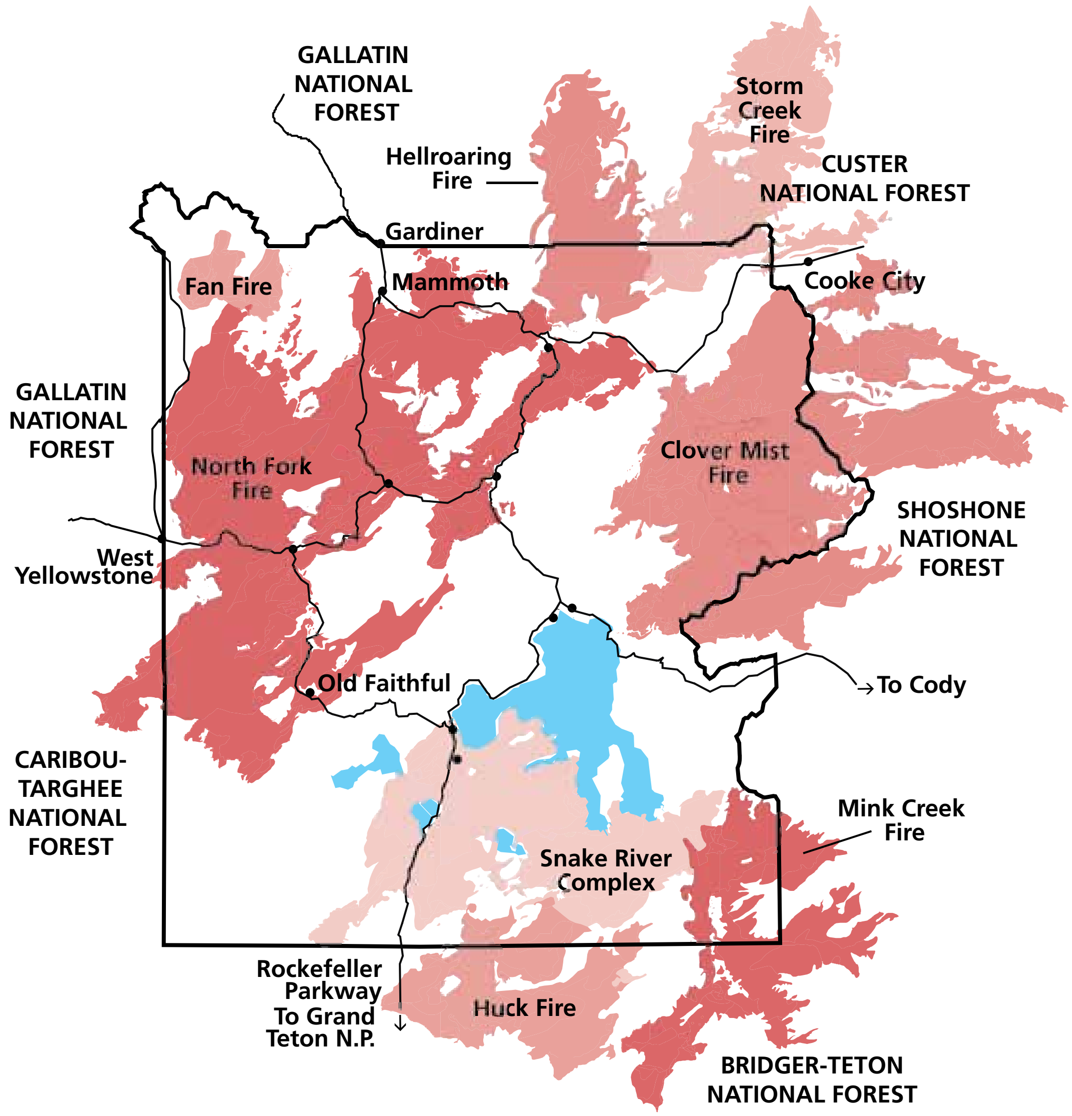
Scientists wanted to monitor the ecological processes following these major fires. The National Park Service cooperated with other agencies and independent researchers and institutions in developing comprehensive research directions for this unparalleled scientific opportunity. Observations began while 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, the fires killed many lodgepole pines and other trees, but did not kill most other plants; they merely burned the tops, leaving roots to regenerate. Temperatures high enough to kill deep roots 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, seeds, and other reproductive tissues had to wait until soil moisture was replenished the following spring.

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.

The fires of 1988 created a landscape of burns, partial burns, and unburned areas—called a mosaic. A mosaic provides natural firebreaks and sustains a greater variety of plant and animal species. Vegetation capable of sustaining another major fire will be rare for decades, except in extraordinary situations.

This map uses colors only to help you see fire boundaries. The colors do not indicate intensity, duration, or anything else.



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.*

6 After the 1988 Fires

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

Soils

Fertile soils with good water-holding capacity that have 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.

Trees

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 decades.

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 (which require fire to open), 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 24 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.

What Did *NOT* Happen

Many predictions were made about the 1988 fires' long-term consequences for visitation, wildlife, and vegetation. However, the following have not 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 silted 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.*
- ✗ *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.*

What *DID* Change

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 program to reduce hazardous fuels around developed areas.*

The most recent research was presented September 2008 at the 9th Biennial Scientific Conference, "The '88 Fires: Yellowstone & Beyond."

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 50 years old before producing cones. The young trees may die before reproducing if the interval between fires is too short or if faster-growing conifers over-take them. By 1995, whitebark pine seed-lings had appeared in all 275 study plots, though density was not significantly differ-ent between burned and unburned sites.

About one-third of the aspen in the north-ern 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.

Other Vegetation

The regrowth of plant communities began as soon as the fire was gone and moisture was available, which in some sites was with-in days. In dry soils, the seeds had to wait until moisture was replenished the follow-ing spring. New seedlings grew even in the few areas where the soil had burned intense-ly 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 out-side the park.) Even without the fires, sever-al 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 subse-quent 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 trans-mitters 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

The 1988 fires presented an unprecedented opportunity to study the landscape-scale ecological effects of an infrequent natural disturbance—a large, severe fire in this case—in an ecological system minimally affected by humans.

Monica Turner, 9th Biennial Scientific Conference, "The '88 Fires: Yellowstone & Beyond"

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, because of their capacity to have multiple litters with many young per year, rodents quickly repopulated burned areas.

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.

Yellowstone's park photographer established "photo points," or specific locations, to be photographed in 1988 and in subsequent years. This set shows a pond along the road between Canyon and Norris junctions, as it appeared in 1988 (above) and 1989 (below).

Aquatic Resources

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

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 were observed in nutrient enrichment, plankton production, or fish growth afterward. No apparent streambank erosion or other changes occured that affected cutthroat trout spawning habitat, nor did the number of spawning streams decline. 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 first years after a major fire, new vistas appear while the lush growth of new, young trees emerges from the burned ground. Today, more than twenty years after the 1988 fires, those young trees are renewed forests, once again filling in vistas. 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.

6

For More Information

www.nps.gov/yell

www.greateryellowstone-science.org/index.html

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.

Site Bulletins, published as needed, provide more detailed information on park topics such as history and geology. Free; available upon request from visitor centers.

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www.fire.nps.gov

www.iawfonline.org

www.nifc.gov

WILDLIFE

MAMMALS

- Yellowstone is home to the largest concentration of mammals in the lower 48 states.
- 67 different mammals live here, including many small mammals.
- Several hundred grizzly bears live in the greater Yellowstone area.
- Black bears are common.
- Gray wolves were restored in 1995; >100 live in the park now.
- Wolverine and lynx, which require 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 in Park
Family Ursidae		
*Black Bear *(Ursus americanus)*	forests, meadows	common
*Grizzly Bear *(Ursus arctos horribilis)*	forests, meadows	±150 in the park ±600 in Greater Yellowstone Ecosystem
Family Canidae		
*Coyote *(Canis latrans)*	forests, meadows, grasslands	common
*Gray Wolf *(Canis lupus)*	forests, meadows	±120 in the park
*Fox *(Vulpes vulpes)*	meadows	common
Family Felidae		
*Bobcat *(Lynx rufus)*	forests, rocky areas	may be widespread
*Cougar *(Puma concolor)*	mountains, rocky areas	14–23
*Lynx *(Lynx canadensis)*	subalpine forests	few
Family Procyonidae		
Raccoon *(Procyon lotor)*	rivers, cottonwoods	rare
Family Mustelidae		
Badger *(Taxidea taxus)*	sagebrush	common
Fisher *(Martes pennanti)*	forests	rare, if present
**Marten *(Martes martes)*	coniferous forests	common
Mink *(Mustela vison)*	riparian forests	occasional
**River Otter *(Lutra canadensis)*	rivers, lakes, ponds	common
Striped Skunk *(Mephitus mephitus)*	riparian to forest	rare
**Long-tailed Weasel *(Mustela frenata)*	willows to spruce/fir forests	common
**Short-tailed Weasel (ermine) *(Mustela erminea)*	willows to spruce/fir forests	common
**Wolverine *(Gulo gulo)*	alpine, coniferous forests	rare

**indicates a species described in the species accounts that begin on page 113, following "Small Mammals."*

***indicates a species described on pages 106–112 under "Small Mammals."*

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

ORDER Artiodactyla

Family Cervidae

*Elk (Wapiti) *(Cervus elaphus)*	meadows, forests	10,000–20,000 in summer
*Moose *(Alces alces shirasi)*	riparian, forests	<200
*Mule Deer *(Odocoileus hemionus)*	forests, grasslands, shrub lands	2,300–2,500
*White-tailed Deer *(O. virginianus)*	forests, grasslands, shrub lands	occasional

Family Bovidae

*Bison *(Bison bison)*	meadows, grasslands	±3,300
*Bighorn Sheep *(Ovis canadensis)*	cliffs, mountain slopes	250–275
Mountain Goat (non-native) *(Oreamnus americanus)*	alpine meadows, rocky slopes	175–225

Family Antilocapridae

*Pronghorn *(Antilocapra americanus)*	sagebrush, grasslands	±200

ORDER Chiroptera

Family Vespertilionidae

Big Brown Bat *(Eptesicus fuscus)*	roost in buildings, other sheltered areas	common
Fringe-tailed bat *(Myotis thysanodes)*	roost in cliffs, large snags	uncommon
Hoary Bat *(Lasiurus cinereus)*	roost in trees	uncommon
Little Brown Bat *(M. lucifugus)*	roost in caves, buildings, trees	common
Long-eared Bat *(M. evotis)*	roost in cliffs, buildings	uncommon
Long-legged Bat *(M. volans)*	roost in tree cavities, cliffs, buildings	common
Silver-haired bat *(Lasionycteris noctivagans)*	roost in trees, including snags	common
Western small-footed Bat *(M. ciliolabrum)*	roost in rocky areas, caves	rare, if present
Townsend's Big-eared Bat *(Corynorhinus townsendii)*	roost in caves	uncommon
Yuma Bat *(M. yumanensis)*	roost in caves, buildings, trees	rare, if present

ORDER Lagomorpha

Family Leporidae

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

Family Ochotonidae

**Pika *(Ochotona princeps)*	rocky slopes	common

ORDER Insectivora

Family Soricidae

Dusky Shrew *(Sorex monticolus)*	moist meadows, forests	common

Masked Shrew *(S. cinereus)*	moist meadows, forests	common
Water Shrew *(S. palustris)*	moist meadows, forests	common
Preble's Shrew *(S. preblei)*	moist meadows, forests	rare, if present
Dwarf Shrew *(S. nanus)*	moist meadows, forests	rare
ORDER Rodentia		
Family Castoridae		
*Beaver *(Castor candensis)*	ponds, streams	750
Family Sciuridae		
**Least Chipmunk *(Tamius minimus)*	forests	common
Uinta Chipmunk *(T. umbrinus)*	forests	common
Yellow Pine Chipmunk *(T. amoenus)*	forests	common
**Yellow-bellied Marmot *(Marmota flaviventris)*	rocky slopes	common
**Golden-mantled Ground Squirrel *(Spermophilus lateralis)*	forests, rocky slopes	common
Northern Flying Squirrel *(Glaucomys sabrinus)*	forests	occasional
**Red Squirrel *(Tamiasciurus hudsonicus)*	forests	common
**Uinta Ground Squirrel *(Spermophilus armatus)*	sagebrush, meadows	common
Family Geomyidae		
**Northern Pocket Gopher *(Thomomys talpoides)*	sagebrush, meadows, forests	common
Family Cricetidae		
Deer Mouse *(Peromyscus maniculatus)*	grasslands	common
Western Jumping Mouse *(Zapus princeps)*	riparian	occasional
Muskrat *(Ondatra zibethicus)*	streams, lakes, ponds	common
Heather Vole *(Phenacomys intermedius)*	sagebrush to forests	occasional
Long-tailed Vole *(Microtus longicaudus)*	moist meadows	common
Meadow Vole *(M. pennsylvanicus)*	moist meadows	common
**Montane Vole *(M. montanus)*	moist meadows	common
Red-backed Vole *(Clethrionomys gapperi)*	dense forests	common
Water Vole *(M. richardsoni)*	riparian	occasional
Bushy-tailed Woodrat *(Neotoma cinerea)*	rocky slopes	common
Family Erethizontidae		
Porcupine *(Erethizon dorsatum)*	forests, sagebrush, willows	common

Small Mammals

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 150–154 for suggested titles.

Species accounts appear in alphabetical order by their common name.

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 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 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

Tamius 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, outermost stripe on the sides is dark; underside tends to be white and 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.
- Eat 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.

All drawings in this chapter © Zachary Zdinak

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 110.

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

- Breed 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 light to dark brown or black; irregular, buffy to bright orange throat patch.
- Smaller than a fisher; buffy or orange bib rather than white.

Compare to long-tailed weasel (above) and short-tailed weasel, page 110.

Habitat

- Found in conifer forests with 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.

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 breed from mid-February to November; up to 4 litters of 2–10 young per year.

PIKA

Ochotona princeps

Identification

- 7–8.4 in. 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.
- Breed 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 range restriction 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 cheek pouches to underground cache. Grizzly bears 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, terminal buds of conifer trees, fungi, some insects; sometimes steal young birds from nests.
- Preyed on by coyotes, grizzly bears, hawks.

Behavior

- Breed February through 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.

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; generally found near water.
- Eat crayfish and fish; also frogs, turtles, sometimes young muskrats or beavers.

Behavior

- Active year-round.
- Breed in late March through April; one litter of two young per year.
- Females and offspring remain 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.
- May move long distances between water bodies.

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 107.

Habitat

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

Behavior

- Breed 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 day length.

Habitat

- Found particularly in coniferous forests with dense understory of shrubs, riparian areas with many willows, or low areas in spruce-fir cover.
- Rarely venture from forest cover except to feed in forest openings.
- Eat plants; uses lodgepole pine in winter.
- Preyed upon by lynx, bobcats, coyotes, foxes, weasels, 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 their abundant tracks in 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.

The white-tailed jackrabbit (Lepus townsendii) *also lives in Yellowstone. In 2008, a scientist raised the alarm that these hares seemed to have disappeared from the park. Other scientists came forward with evidence of the jackrabbit's presence, and he quickly retracted his alarm.*

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

WOLVERINE

Gulo gulo

Identification

- 38–47 inches long, 13–31 pounds.
- Largest member of weasel family; compact and strongly built, broad head, short legs; black to dark brown with white on chest that may extend as bands onto sides; shaggy appearance due to long guard hairs.

Habitat

- Found in high-elevation conifer forests and alpine tundra; rarely seen.
- Eat burrowing rodents, birds, eggs, beavers, squirrels, marmots, mice, and vegetation (including whitebark pine nuts); chiefly a scavenger in winter, but has also been known to take large prey such as deer or elk.

Behavior

- Active year-round, intermittently throughout the day
- Breed April to October; 1 litter of 2–4 young each year.
- Den in deep snow, under log jams and uprooted trees in avalanche chutes.
- Mostly solitary except when breeding.

Research

From 2005–2009, researchers gathered information about this species in eastern Yellowstone National Park and the adjoining Shoshone and Gallatin national forests. Animals were live-trapped and fitted with GPS collars to track their movement. Wolverines were present in the southeast corner of Yellowstone and in the Gallatin National Forest, north of the park.

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.
- Breed 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.

Bear, Black

In Yellowstone, about 50 percent of black bears *(Ursus americanus)* are black in color, others are brown, blonde, and cinnamon. They stand about 3 feet high at the shoulder. Males weigh 210–315 pounds; females weigh 135–200 pounds. They have fair eyesight and an exceptional sense of smell.

Black bears eat almost anything, including grass, fruits, tree cambium, eggs, insects, fish, elk calves, 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, black bears spend most of their time feeding, in a pre-denning 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 less than some other species, and they can be easily roused from hibernation.

Males and females without cubs are solitary, except during the mating season, 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 January 2010 . . .

Number in Yellowstone

common

Where to see

Tower and Mammoth areas, most often.

Behavior & Size

- Males weigh 210–315 pounds, females weigh 135–200 pounds; adults stand about 3 feet at the shoulder.
- May live 15–30 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; twelve black bears have been radio-collared.

See "Bear Management" in Chapter 8.

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 suckle and sleep.

After emerging from the den, the cubs and their mother roam over her home territory. The bears 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, rather than reacting aggressively. However, any bear, particularly a female with cubs, may attack when surprised at close range. Black bears occasionally stalk and kill humans—although this is rare. Whether it's a grizzly or a black bear, always give these animals a wide berth.

7A

Bear, Grizzly

As of January 2010 . . .

Number in Yellowstone

±150 with home ranges wholly or partially in park; ±600 in Greater Yellowstone Ecosystem.

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 15–30 years.
- Home range: male, 813–2,075 square miles, female, 309–537 square miles.
- Agile; can run up to 35–40 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; 1–3 cubs.
- Considered true hibernators.

Status

The grizzly bear population in the Greater Yellowstone Ecosystem was returned to the federal threatened species list in 2009; this decision may be appealed.

Scientists and managers believe the grizzly population is doing well. Grizzlies are raising cubs in nearly all portions of the Greater Yellowstone area. They are also dispersing into new habitat.

Current Management

See "Bear Management" in Chapter 8.

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 silver-tipped or "grizzled" hairs on some animals' coats. However, the coloration of black and grizzly bears is so variable that it 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 grow larger and their claws grow longer, they have a harder time climbing. Stories that bears cannot swim or run downhill are also untrue. Grizzlies can swim, run up and downhill, and sprint up to 40 miles per hour.

Bears are generally solitary, although they may tolerate other bears when food is plentiful. 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 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 biscuitroots, 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.

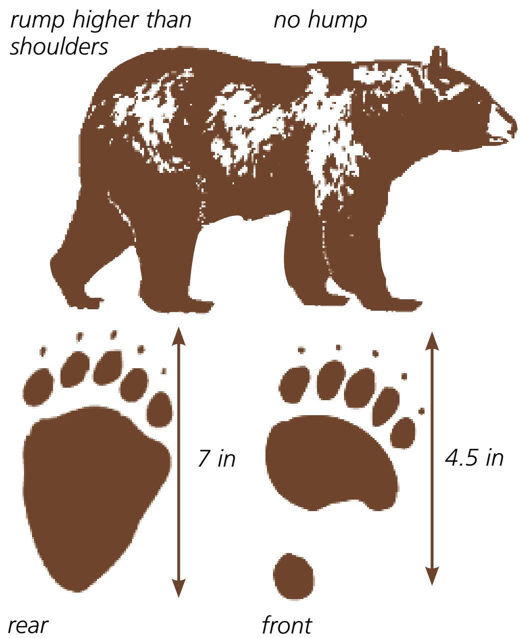
Grizzlies have a social hierarchy that determines which bears dominate the best habitats and food sources:

1. adult males
2. lone adult females, females with two-year-old cubs; females with yearlings
3. females with cubs of the year
4. subadults of either sex

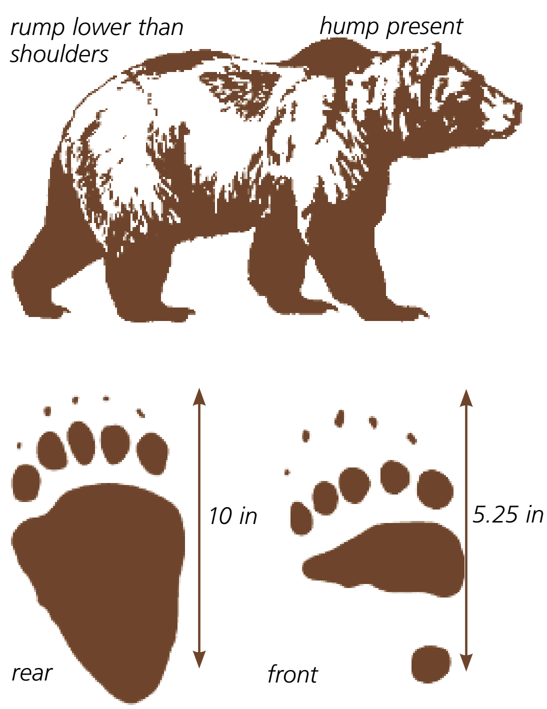
Subadult bears, who are just learning to live on their own away from mother's protection, are most likely to be living in poor-quality habitat or in areas nearer roads and developments. Thus, young adult bears are most vulnerable to danger from humans and other bears, and to being conditioned to human foods. Food-conditioned bears are removed from the wild population.

Like black bears, grizzlies spend most of their time feeding. 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. Grizzlies 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



Grizzly Bear



7A

Beaver

As of January 2010 . . .

Number in Yellowstone

Minimum estimate: 750 in 127 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 be seen occasionally in the Lamar, Gardner, and Madison rivers.

Behavior & Size

- Active at night.
- 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 Information

- Beavers are native to Yellowstone.
- Yellowstone's beavers escaped most of the trapping that occurred in the 1800s due to the region's inaccessibility.
- The most recent survey for beavers in Yellowstone was conducted in 2007.

Since 1989, park staff has periodically surveyed riparian habitat in Yellowstone to determine current presence and distribution of beaver *(Castor canadensis)*. These surveys confirmed that beavers 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.

Beavers, 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 beavers periodically live, such as Heart Lake, the lower Lamar River and Slough Creek area, Slide Lake, and the lower Gardner River. In these areas, beavers use willows for construction and for food. Where their preferred plants are few or absent, beavers may feed on submerged vegetation such as pond lilies.

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

Because beavers 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 campsites. Every year, beavers are seen along main park roadways. The nocturnal habits of beavers 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.

7A

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 January 2010 . . .

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 reports of large numbers of bighorn sheep in Yellowstone have led to speculation 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

Before a chlamydia (pinkeye) epidemic in 1982, almost 500 bighorn sheep lived on the northern range. Their population dropped 60% due to the epidemic, and it has been slow to recover. Researchers recently concluded that wolf reintroduction has not affected the bighorn sheep population. Their reasoning includes the fact that the population has been increasing by seven percent annually since 1998. They conclude that other, so far unknown, 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.

7A

Bison

As of January 2010 . . .

Number

approximately 3,300

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.
- 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.
- Two subpopulations: Northern Range and Hayden Valley.

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 the U.S. Army nearly caused 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 then, 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.

Current Issues

See "Bison Management," in Chapter 8.

For many years scientists considered Yellowstone's bison to be a subspecies known as the mountain bison. Today, most scientists 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, their life span averages 12–15 years; a few individuals live as long as 20 years. Both sexes have horns, those of the cow being slightly more curved and slender than the bull's.

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.*

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.

Wolves are the only large predator of adult bison. 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 get rid of insect pests. Birds such as the magpie "ride" a bison to feed on insects in its coat. The cowbird will also follow close behind a bison, feeding on insects disturbed by its steps.

Migration

Like most other ungulates of the greater Yellowstone area, bison will move from their summer ranges to lower winter ranges as snow accumulates and dense snowpacks develop. When and where they migrate depends on a complex relationship between abundance of bison, quality of summer forage, and winter snow pack. However, observations of bison movement patterns show that a large number of the central herd migrate north in winter. Bison remain along the west boundary well into birthing season. Research also shows that although bison travel on groomed roads, they select these routes because they follow stream courses that connect larger patches of habitat. *(See map at right.)*

History

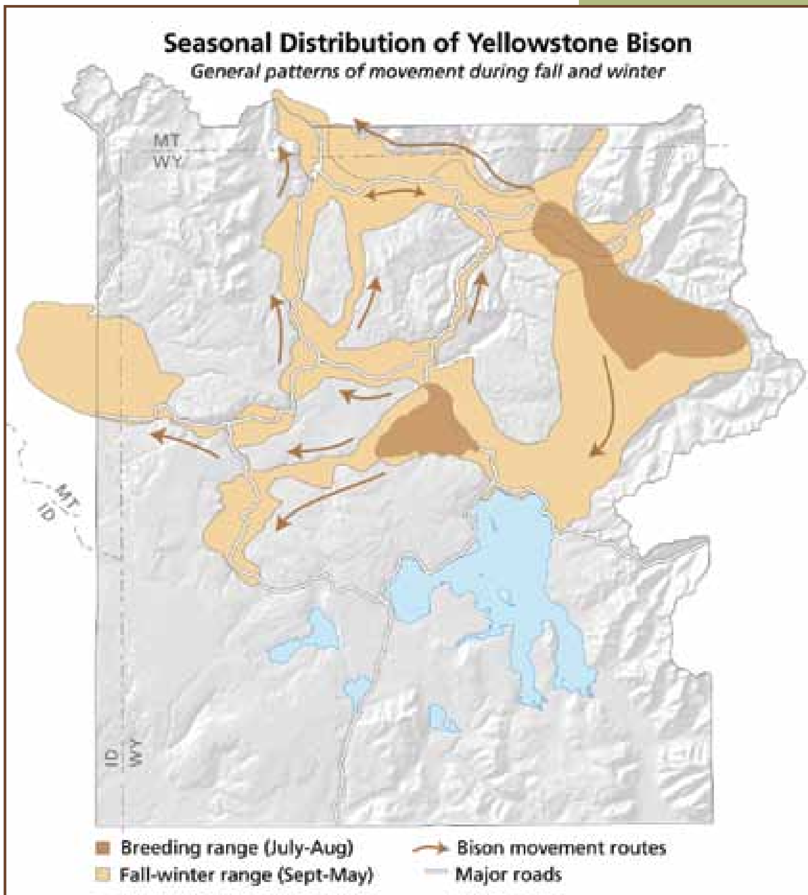
From 30 to 60 million bison may have roamed North America before the mid 1800s. Their historic range spread from the Pacific to the Appalachians, but their main habitat was the Great Plains where Plains tribes developed a culture that depended on bison. Almost all parts of the bison provided something for the Native American way of life—food, tools, shelter, or clothing; even the dung was burned for fuel. Hunting bison required skill and cooperation to herd and capture the animals. After tribes acquired horses in the 1600s, they could travel farther to find bison and hunt the animals more easily.

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 eliminated bison. Yellowstone was the only place in the contiguous 48 states where 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 and recovery of bison in Yellowstone is one of the great triumphs of American conservation. *(See Chapter 1.)*

Managing Bison

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 to manage these bison and increase their numbers. This herd grew to more than 1,000 animals; the park's small native bison herd in Pelican Valley also slowly increased. In the 1930s, the introduced bison were allowed to move freely and intermingle with the native bison. The park's bison popluation was close to 1,500 in 1954, and managers became concerned that bison would overgraze their habitat—so they began culling the animals. By March 1967, the herd was down to 400.

In 1968, managers stopped manipulating bison populations and allowed natural ecological processes to operate. As their population grew, bison began to move outside the park. Conflicts with humans began to occur. Bison can be a threat to human safety and can damage 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, bison generally are not welcome outside the park even though other ungulates that may also harbor the brucellosis organism are. Since the 1980s, this issue has grown steadily into one of the most heated and complex of Yellowstone's resource issues. *For more information about brucellosis and bison management, see Chapter 8, "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 generally widespread.

Where to see

- Rarely seen; most reports from rocky areas and near rivers.
- Typical habitat: rocky areas, conifer forests.

Behavior and Size

- Adult: 15–30 pounds; 31–34 inches long.
- Color ranges from red-brown fur with indistinct markings to light buff with dark spotting; short tail; ear tufts.
- Distinguish from lynx: has several black rings that do not fully circle the tail; no black tip on tail, shorter ear tufts, smaller track (2″).
- Solitary, active between sunset and sunrise.
- Eats rabbits, hares, voles, mice, red squirrels, wrens, sparrows, grouse; may take 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.

Behavior and Size

- Adult: 16–35 pounds, 26–33 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: black rings on tail are complete; 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, diurnal and nocturnal.
- Eats primarily snowshoe hares, especially in winter; also rodents, rabbits, birds, red squirrels, and other small mammals, particularly in summer.

Research

After a four-year research project to document the number and distribution of lynx in the park, completed in 2004, researchers confirmed lynx existed and reproduced in the central and eastern portions of the park.

In December 2007, Fred Paulsen, a Xanterra employee in Yellowstone, photographed this lynx along the Gibbon River.

7A

Cougar

The cougar *(Puma concolor),* also called the mountain lion, is among the largest cats in North America. (The jaguar, which occurs in New Mexico and Arizona, is larger.) Cougars live throughout the park in summer, but few people ever see them. 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 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's 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.

As of January 2010 . . .

Number in Yellowstone

14–23 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.

Interaction with humans

- Very few documented confrontations between cougars & humans have occurred in Yellowstone.
- If a big cat is close by: Stay in a 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.

In Yellowstone, most kittens are born June through September. Female cougars 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 trips and then returns to nurse her kittens. When the kittens are 8–10 weeks old, the female begins to hunt over 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.

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 areas, thus maintaining genetic variability

This cougar kitten was photographed by researchers under controlled research conditions.

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 and 4–5 days hunting for the next meal. 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, scavengers and competitors such as bears and wolves sometimes find it. 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 approximately 6 percent of their elk carcasses.

Management History

In the early 1900s, cougars were killed as part of predator control in the park. By 1925, very few individuals remained. However, cougar sightings in Yellowstone have increased dramatically since the mid 20th century.

In 1987, the first cougar ecology study 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.

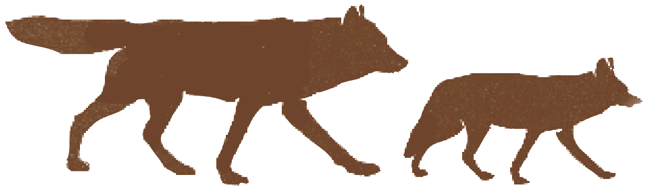
In 1998, the second phase of research began. Researchers collared 87 cougars, including 50 kittens in 22 litters. Between 1998 and 2005, researchers documented 473 known or probable cougar kills. Elk comprised 74 percent—52 percent calves, 36 percent cows, 9 percent bulls, 3 percent unknown sex or age. Cougars killed about one elk or deer every 9.4 days and spent almost 4 days at each kill. The study also documented that wolves detected and may have scavenged 22.5 percent of cougar-killed ungulates. This cougar monitoring study ended in 2006.

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.

Between 1998 and 2005, researchers documented 473 known or probable cougar kills, which included:

345 elk
64 mule deer
12 bighorn sheep
10 pronghorn
10 coyotes
7 marmots
5 porcupines
1 red fox
1 mountain goat
1 blue grouse
1 golden eagle

Cougars also killed six of their own kind, but few were eaten.



wolf *coyote*

Coyotes *(Canis latrans)* are intelligent and adaptable. Like wolves, they were perceived as threats to the survival of elk and other ungulates in the park's early days. Unlike wolves, however, coyotes successfully resisted extermination. Since then, research has shown coyotes eat mainly voles, mice, rabbits, other small animals, and carrion—and only the very young elk calves in the spring.

Often mistaken for a wolf, the coyote is about one-third the wolf's size with a slighter build. 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 after wolves were exterminated from the park. In Yellowstone, they live in packs or family groups of up to 7 animals, with an alpha male and female, and subordinate individuals (usually pups from previous litters). This social organization is characteristic of coyotes living in areas free from human hunting.

Coyotes, also known as 'song dogs', communicate with each other by a variety of long-range vocalizations. You may hear groups or lone animals howling, especially during dawn and dusk periods. Coyotes also use scent-marks (urine and feces) to communicate their location, breeding status, and territorial boundaries.

Until 1995, coyotes faced few predators in Yellowstone other than cougars, who will kill coyotes feeding on cougar kills. After wolves were restored, however, dozens of coyote pups and adults were been killed by wolves—primarily when feeding on other animals killed by wolves. On the northern range, wolves caused a 30–50 percent reduction in coyote population density through direct mortality and changes in coyote denning behaviors and success. Researchers see some evidence now that coyotes on the northern range have adapted to wolves and their population has recovered.

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 hit by a vehicle. Several instances of coyote aggression toward humans have occurred here, including a few attacks.

Park staff scare unwary coyotes from visitor-use areas with cracker-shell rounds, bear repellent spray, or other negative stimuli. Animals that continue to pose a threat to themselves or to humans are 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.

As of January 2010 . . .

Number in Yellowstone

Total unknown, but numerous. In the northern range, the coyote population decreased 30–50% after wolves were restored, but their population seems to have recovered.

Where to see

Meadows, fields, other grasslands, and foraging for small mammals along roadways.

Behavior & Size

- Weigh 25–35 pounds, 16–20 inches high at the shoulder.
- Average life span 6 years; up to 13 years in the park.
- Home range: 3–15 square miles.
- Primarily eat rodents, birds, insects, carrion, elk calves, some adult elk.
- 4–8 pups are born in April in dens; emerge in May.
- Killed by wolves, mountain lions.

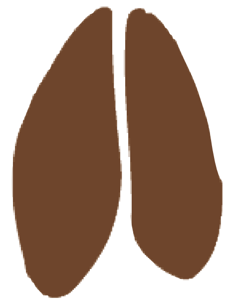
Management

- 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 partially 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.

7A

Deer

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 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 *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

As of January 2010 . . .

Number in Yellowstone

- Summer: 10,000–20,000 elk in 6 to 7 different herds.
- Winter: <5,000

Where to see

Summer: Gibbon Meadows, Elk Park, and Lamar Valley.

Autumn, during "rut" or mating season: northern range, including Mammoth Hot Springs; Madison River.

Winter: migrate south to the Jackson Hole Elk Refuge in Jackson, Wyoming, or north to the northern range and around Gardiner, Montana; <100 year-round 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 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.

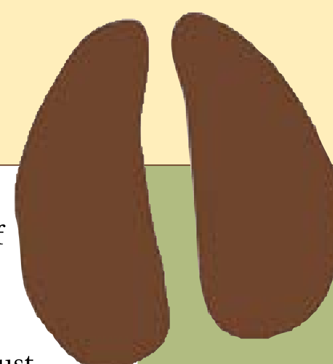
See article on the northern range, Chapter 8.

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 commonly referred to as "velvet." Blood flowing in the skin deposits calcium that makes the antler. Usually around early August, further hormonal changes signal the end of antler growth, and the bull begins scraping the velvet off, polishing and sharpening the antlers in the process.

The antler growing period is shortest for yearling bulls (about 90 days) and longest for healthy, mature bulls (about 140 days). Roughly 70 percent of the antler growth takes place in the last half of the period, when the antlers of a mature bull will grow ⅔ 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 bulls spend the winter with other bulls or with gender-mixed herds, retaining 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.

Elk

Antler Details

- *Are usually symmetrical.*
- *The average, healthy, mature bull has 6 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 10–20 inch spikes, sometimes forked.*
- *Two-year-old bulls usually have slender antlers with 4 to 5 points.*
- *Three-year-old bulls have thicker antlers.*
- *Four-year-old and older bulls typically have 6 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 can live 17–18 years; rare individuals may live 22 years.

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. One exception is the pronghorn, which sheds and regrows its horn sheath each year.

Habitat

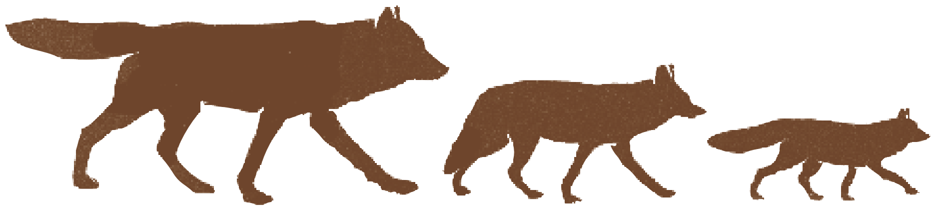
Climate is an important factor affecting the size and distribution of elk herds here. While nearly the entire park provides summer habitat for 10,000–20,000 elk, winter snowfalls force elk and other ungulates to leave most of the high elevation grasslands of the park. Less than 5,000 elk winter in the park.

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 (less than 100 animals) has been the focus of a research study since November 1991. Researchers are examining how environmental variability effects 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. 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.

For management history of elk, see Chapter 8, "Northern Range."



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 because they are nocturnal, usually forage alone, and travel along edges of meadows and forests. During winter, foxes may increase their activity around dawn and dusk, and even sometimes in broad daylight. In late April and May, when females are nursing kits at their dens, they are sometimes more visible during daylight hours, foraging busily to get enough food for their growing offspring.

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 of Yellowstone's animals.

A little known fact about red foxes is most of them in the lower 48 states, especially in

As of January 2010 . . .

Number in Yellowstone

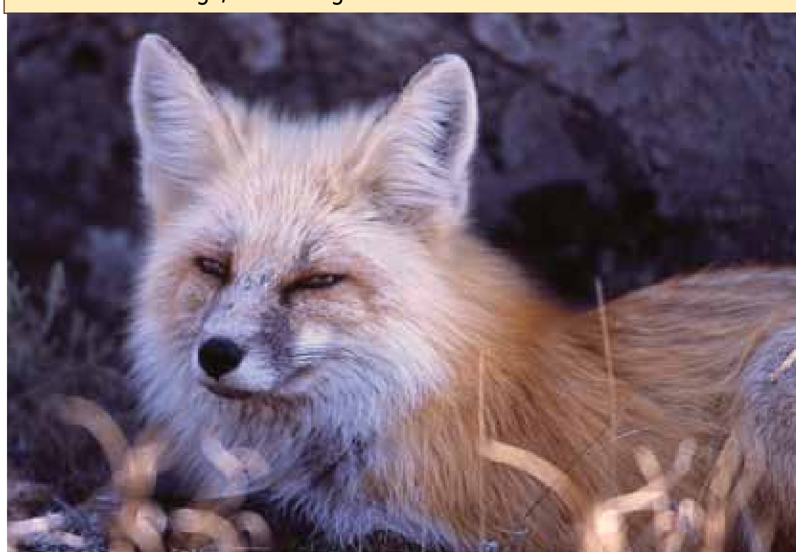
Total unknown, but not nearly as numerous as coyotes.

Where to see

- Lamar and Hayden valleys, Canyon Village area.
- Typical habitat: edges of sagebrush/grassland and within forests.

Behavior and Size

- Adult males weigh 11–12 pounds; females weigh average 10 pounds.
- Average 43 inches long.
- Average life span: 3–7 years; up to 11 years in Yellowstone.
- In northern range, home range averages 3.75 square miles, with males having slightly larger range than females.
- Several color phases; usually red fur with white-tipped tail, dark legs; slender, long snout.
- Barks; rarely howls or sings.
- Distinguish from coyote by size, color, and bushier tail.
- Solitary, in mated pairs, or with female from previous litter.
- Prey: voles, mice, rabbits, birds, amphibians, other small animals.
- Other food: carrion and some plants.
- Killed by coyotes, wolves, mountain lions.



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. necatar),* Cascade *(V. v. cascadensis),* and Rocky *(V. v. macroura)* mountains and are collectively called mountain foxes. (Yellowstone's fox is *V. v. macroura*.) Little is known about any of these subspecies.

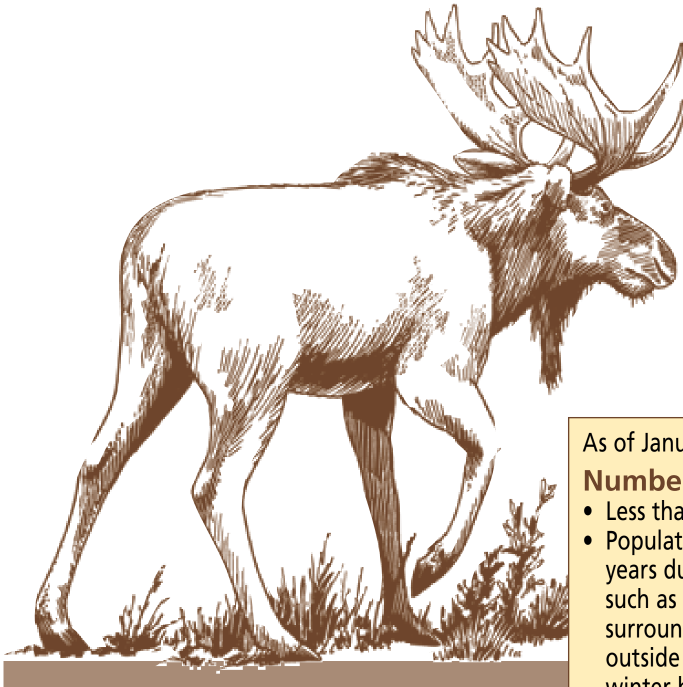
A research project conducted between 1994–1998 determined at least two subpopulations of foxes live in the Greater Yellowstone Ecosystem. At about 7,000 feet in elevation, there seemed to be a dividing line with no geographical barriers separating these foxes. The genetic difference between these foxes 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 higher elevations. This yellowish or cream color most often occurs above 7,000 feet in areas such as Cooke City and the Beartooth Plateau. Recent genetic analyses are beginning to shed light on this mysterious 'Yellow fox of the Yellowstone,' and new evidence is beginning to support the distinctiveness of this high elevation fox.

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.

Recent research shows that red fox are more nocturnal than coyotes, and strongly prefer forested habitats, while coyotes tend to use sagebrush and open meadow areas. In this way, potential competition between fox and coyotes is minimized. Fox don't seem to actively avoid coyotes during an average day, they just stick with forested habitat, sleep when coyotes are most active, and then forage opportunistically. Fox will visit carcasses (like wolf kills) for the occasional big meal, especially during winter, but this is more rare than the scavenging coyotes that park visitors can expect to see on many days, especially during winter.



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 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

As of January 2010 . . .

Number in Yellowstone

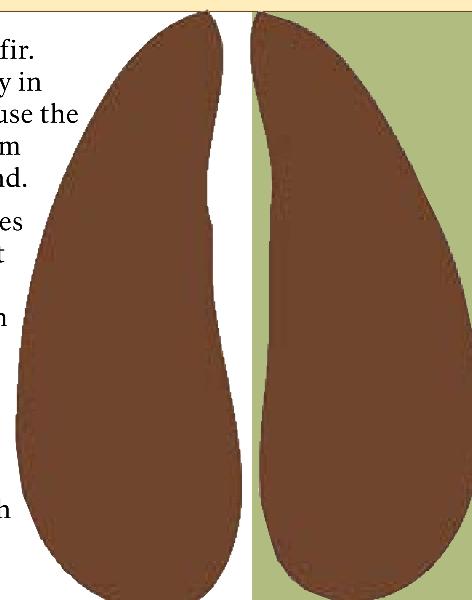
- Less than 200.
- Population has declined in last 40 years due to a number of factors such as loss of old growth forests surrounding the park, hunting outside the park, burning of winter habitat (spruce-fir forests) in 1988, and predators.

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 as high as 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 or June.
- Lives up to 20 years.



March. Shedding their heavy antlers helps them conserve energy and promotes easier 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 that 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 drives off any previous year's offspring that may have wintered with her and seeks 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 for 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. However, forest fire suppression probably was the most important factor in their population increase because 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 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.

Pronghorn

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 1804–1806 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 outrunning 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

As of January 2010 . . .

Number in Yellowstone

±200

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.
- During 1991–1995, the population dropped approximately 50%; 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.

they begin to 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 adapted well 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 winter 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 three-fourths 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.

7A

Wolf

As of January 2010 . . .

Number in Yellowstone area

- 400–450 wolves in the greater Yellowstone area.
- ±120 individuals live in the park.

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; can live up to 11 years in wild.
- Three color phases: gray, black, and white; gray is the most common; white is usually 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 from den 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 outside the park; the leading natural cause is wolves killing other wolves.

Current Management

See Chapter 8, "Wolf Restoration."

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, packs contain from 8 to 14 individuals, with some occasionally having twice that number. Pack size varies based on the size of its main prey. The pack is a complex social family, with leaders (the alpha male and alpha female) and subordinates, each having individual personality traits and roles in the pack. 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. They efficiently hunt large prey that other predators cannot usually kill. They also compete with coyotes (and, to a lesser extent, foxes) for smaller prey. In Yellowstone, 90 percent of their winter prey is elk; 25 percent of their summer prey is deer. They also can kill adult bison.

Many other animals benefit from wolf kills. For example, when wolves kill an elk, ravens arrive almost immediately. Coyotes arrive soon after, waiting nearby until the wolves are sated. Bears will attempt to chase the wolves away, and are usually successful. Many other animals—from magpies to foxes—consume the remains.

Changes in Their Prey

From 1995 to 2000, in early winter, elk calves comprised 50 percent of wolf prey and bull elk comprised 25 percent. That ratio reversed from 2001 to 2007. Scientists are examining why this happened and what it means. They know that bull elk are entering winter in worse condition than before. Therefore, bulls are easier to kill than before, and one bull provides much more meat than one calf or cow.

Wolves may be consuming as many pounds of meat each year, but working harder for that food. When such "food stress" occurs, it can lead to increased wolf mortality—which was seen in 2008. *(See below.)* Food stress may increase when a large number of older, unhealthy elk—those easiest to kill—died during the winter.

Population

From their confined beginnings in a few pens, the wolves have expanded their population and range, and now are found throughout the Greater Yellowstone Ecosystem. While their exact numbers are not known, scientists know that the wolf population fluctuates.

Disease periodically kills a number of pups. The first serious outbreak was 1999, then six years later in 2005. That year, distemper killed two-thirds of the pups. The next outbreak was just three years later, in 2008,

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.

when all but 22 of the pups died. This shortened interval concerns scientists. Infectious canine hepatitis, canine parvovirus, and sarcopitic mange also have been confirmed among adult wolves, but their effect on mortality is unknown.

Adult wolves kill each other in territory disputes. Such disputes happen each year, but increase when food is less abundant. This may have been why so many adult wolves died in fights during 2008. That year, scientists also found two wolves whose deaths were partially due to starvation.

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 eliminating 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 mid 20th century, wolves had been almost entirely eliminated from the 48 states.

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. 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 wildlife management policy changed to allow 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, 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

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. Most 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 or use bear pepper spray. Group up with other people, continue waving and yelling.
- Report the presence of wolves near developed areas or any wolf behaving strangely.

To date, eight wolves in Yellowstone National Park have become habituated to humans. Biologists successfully conducted aversive conditioning on some of them to discourage being close to humans, but two have had to be killed. In 2009, a wolf had to be killed because people had fed it, and it began to chase bicyclists at Old Faithful.

Never feed any animals!

See Chapter 2 for how wolves are affecting the ecosystem and Chapter 8, "Wolf Restoration," for more details about their management.

Birds

Records of bird sightings have been kept in Yellowstone since its establishment in 1872; these records document 322 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. Birds that stay in Yellowstone year-round include: the common raven, Canada goose, blue grouse, gray jay, red-breasted nuthatch, American dipper, and mountain chickadee. 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.

Additional information

As of January 2010 . . .

Number in Yellowstone

- 322 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.
- The peregrine falcon nests here. Formerly an endangered species, it was delisted in 1999.
- The bald eagle nests here. Formerly a threatened species, it was delisted in 2007.
- Species monitored: songbirds, American white pelicans, trumpeter swans, loons, ospreys, bald eagles, peregrine falcons, and colonial nesting birds.

Current Management

Yellowstone participates 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.

In addition, park biologists are:

- Surveying 3 breeding bird routes annually, which is part of an international effort to monitor bird population trends.
- Studying the relationship between songbirds and willows, which will establish a longterm database to help fill a gap in songbird knowledge.
- Surveying forest burns to determine how fire influences cavity-nesting birds in Yellowstone.

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:

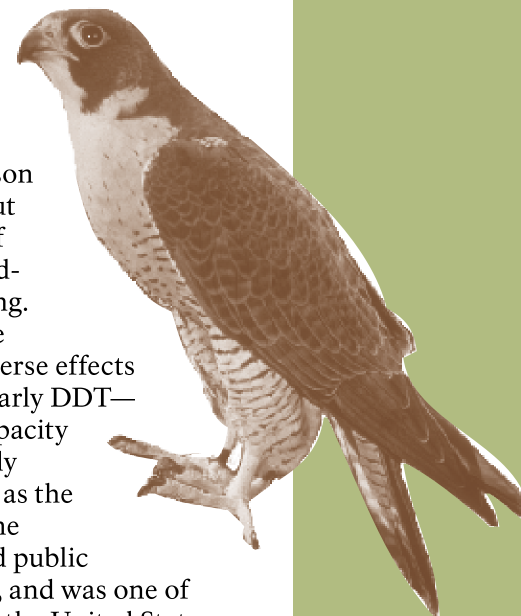
- Bald eagles are usually near water where they feed on fish and waterfowl.
- Golden eagles hunt in open country for rabbits and other small mammals.
- Exception: Both feed on carcasses in the winter, sometimes together.

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

- Removed from the threatened species list in August 2007.
- As of 1989, recovery objectives had been reached in the Greater Yellowstone Ecosystem.
- Some eagle territories are experiencing nest instability due to large numbers of trees that are falling as a result of the 1988 fires.
- In 2009, 15 pairs of eagles nested in the park; 6 of these pairs produced 8 young.
- Although the population is relatively stable parkwide, none of the nests in the Yellowstone Lake area succeeded.
- Bald eagles, like osprey, are among the fish-eating wildlife being monitored to find out if the declining cutthroat trout populaton is affecting them. *(See Chapter 8.)*



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.
- Up to 32 eyries have been documented in one year in Yellowstone, but not all are monitored each year.
- In 2009, 18 pairs of peregine falcons bred in Yellowstone National Park; 14 pairs produced 28 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 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.

Biologists in Yellowstone National Park will continue to monitor peregrine breeding to maintain the longterm data needed to assess the population of this sensitive species.

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. *(See previous page.)*
- Its populations rebounded during the latter part of the 20th century.
- In Yellowstone, the osprey population fluctuates, with 31 nests producing 25 young in 2007 and a high of 100 nests and 101 fledglings in 1994.
- Overall, osprey reproduction has increased each year since 2003.
- In 2009, osprey occupied 27 nests; 13 of these breeding pairs successfully fledged 28 young. However, none of the nests in the Yellowstone Lake area succeeded.
- Osprey in Yellowstone are being monitored, along with other fish-eating wildlife, to find out if they are affected by the declining population of cutthroat trout. *(See Chapter 8.)*

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 2007, no cygnets fledged.
- 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 of trumpeter swans is recovering from decades of habitat destruction, hunting, and poaching.
- Trumpeter swans are increasing in the Rocky Mountain region, stable in the Greater Yellowstone Ecosystem, but declining 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 swans.
- In 2009, only 2 pairs of trumpeter swans nested in Yellowstone National Park; neither successfully hatched eggs.
- Limiting factors in Yellowstone appear to be flooding of nests, predation by coyotes, competition with wintering swans, possibly effects of drought, and less immigration into the park from outside locations.
- 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.

Additional information

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.

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 has been eliminated. 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 more than one dozen adult trumpeter swans reside and nest in Paradise Valley. These swans have contributed to the park's population of trumpeter swans.

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 hunts. They wait in trees or on the ground, until wolves finish at a carcass. Other animals—such as coyotes, 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.

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.

7C

Fish

Yellowstone contains one of the most significant, near-pristine aquatic ecosystems found in the United States. More than 600 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 2,500 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, approximately 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 were substantially altered during the 20th 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. 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.

The U.S. Fish and Wildlife Service maintained an aquatic research and monitoring program in the park for approximately 30 years, ending in 1996. Since then, National Park Service fisheries managers have focused 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.

As of January 2010 . . .

Number in Yellowstone

- Native species: 11

—3 sport fish: cutthroat trout (two subspecies), Arctic grayling, mountain whitefish

—8 non-game fish: 4 minnows: longnose dace, speckled dace, redside shiner, Utah chub; 3 suckers: longnose sucker, mountain sucker, Utah sucker; mottled sculpin

- Non-native species: 5 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.
- By the late 1980s, native trout had recovered in some areas due to restrictions in fish harvest.
- In 2001, fishing regulations changed to require the release of all native fishes caught in park waters.
- Both subspecies of cutthroat trout are considered to be species at risk.
- Threats to the fisheries:
  1) Lake trout illegally introduced into Yellowstone Lake and its tributaries.
  2) Whirling disease now present in Yellowstone Lake, the Yellowstone and Firehole rivers, and Pelican Creek.
  3) New Zealand mud snails.
  4) Competition and hybridization with non-native rainbow trout (Slough Creek) and brook trout (Soda Butte Creek).

See Chapter 8, "Aquatic Invaders."

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. In the 1980s and 1990s, fisheries biologists monitored non-consumptive use of aquatic resources for about a decade at Fishing Bridge and LeHardys Rapids. In 1994, approximately 176,400 visitors watched fish at LeHardys Rapids, where spawning cutthroat can be observed jumping the rapids. At Fishing Bridge, approximately 167,000 people watched cutthroat trout in the waters below the bridge.

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 early November).
- 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).
- All native sport fish—cutthroat trout, 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.
- To protect fish, park waters may be temporarily closed to fishing when water levels are low and water temperatures are high.

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, redside shiner, and 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, redside shiner, 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 redside shiner.
- 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 persist, but native trout are threatened by hybridization with rainbow trout and competition with brook trout.

Volunteer Angler Report

Anglers contribute to the park's fisheries database by filling out the Volunteer Angler Report card that is issued with each fishing license. This information helps managers monitor the status of fisheries throughout the park.

Fish-watching numbers

Cutthroat Trout *Oncorhynchus clarkii*

In the greater Yellowstone ecosystem, cutthroat trout are considered a keystone species, upon which many other species depend. For example, they spawn in shallow water, where they become an important food resource for other Yellowstone wildlife, including the grizzly bear. They are at great risk from hybridization and competition with non-native trout, and predation by non-native lake trout.

Yellowstone Cutthroat Trout

Oncorhynchus clarkii bouvieri

- Includes two forms of the same subspecies:Yellowstone cutthroat (large spotted form)
  Snake River cutthroat (fine spotted form)
- Yellowstone cutthroat is native to the Yellowstone River, its tributaries, the Snake River, and the Falls River.
- Snake River cutthroat is native to Snake River drainage in and beyond Yellowstone and Grand Teton national parks.
- Require cold, clean water in streams or lakes.
- 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 historically a Pacific drainage species, it has (naturally) traveled across the Continental Divide into the Atlantic drainage. One possible such passage 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 watersheds and vice versa.

Management

Yellowstone Lake and Yellowstone River together contain the largest inland population of 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, which helped restore cutthroat trout population numbers and age structure. Whirling disease and illegally introduced lake trout in Yellowstone Lake now pose a serious threat to the cutthroat trout population.

See Chapter 8 for information about fisheries management.

Westslope Cutthroat Trout

Oncorhynchus clarkii lewisii

- Evolved independently of the Yellowstone and Snake River forms of the species, but shares their food and habitat requirements. *(See above.)*
- Originally throughout the Madison and Gallatin river drainages in Yellowstone National Park.
- Currently reduced to small headwater populations due to competition and interbreeding with non-native fish.
- Habitat loss and pollution negligible in the park.

Management

This subspecies is at risk through interbreeding with non-native rainbow trout and transplanted Yellowstone cutthroat trout. DNA analysis initially identified a genetically pure population in North Fork Fan Creek, but more detailed analysis showed that this population is now hybridizing with rainbow trout. The only known genetically pure populations in Yellowstone have been found in a tributary of Grayling Creek and in the Oxbow/Geode Creek complex. An intensive effort is underway to restore westslope cutthroat trout to Specimen Creek, a tributary to the Gallatin River

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 8 for details.

Arctic Grayling

Thymallus arcticus montanus

- Used to share similar habitat with westslope cutthroat trout and whitefish (with which it is sometimes confused).
- Displaced by non-native species.
- Native, river-dwelling form (fluvial) extinct in the park.
- Because of stocking in the 1920s, grayling live in Grebe, Wolf, and Cascade lakes.
- In these lakes, grayling spawn in June.
- Like trout, grayling eat mostly insects.

Management

Current efforts on behalf of the grayling include habitat surveys in the upper reaches of Grayling Creek to determine if a restoration project is possible in that location. Yellowstone National Park, Gallatin National Forest, and Montana Fish, Wildlife and Parks are working together on this project.

Mountain Whitefish

Prosopium williamsoni

- Slender silver fish, sometimes 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 along the bottom, eating aquatic insect larvae.
- Compete with trout for the same food.
- The whitefish has persisted in its native waters, 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 large cutthroat trout.
- Habitat distinguishes species:

  Mountain sucker *Catostomus platyrhynchus:* cold, fast, rocky streams and some lakes.

  Longnose sucker *C. catostomus:* 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*

- Lives in shallow, cold water throughout Yellowstone except in the Yellowstone River above Lower Falls and in Yellowstone Lake.
- 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 atratria:* 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:* 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.

  Speckled dace *Rhinichthys osculus:* Lives in the Snake River drainage.

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 are widespread in the park and often abundant at breeding or wintering sites.

To monitor amphibians in Yellowstone, researchers are collecting data on the number of wetlands that are occupied by breeding populations of each amphibian species. If occupancy (the proportion of suitable wetlands occupied) decreases, that species has probably declined. To implement monitoring, researchers randomly selected watershed units, known as catchments, from within the four main drainage basins of Yellowstone *(see map)*. Field crews search potential amphibian habitat within the catchments in June and July to document the presence or absence of amphibians. Researchers study the results to determine occupancy trends and factors that may be driving them.

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 overwinter, they can be adversely affected by disturbance or loss of key sites.

As of January 2010 . . .

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, boreal chorus frog, Columbia spotted frog, tiger salamander.

Current Research

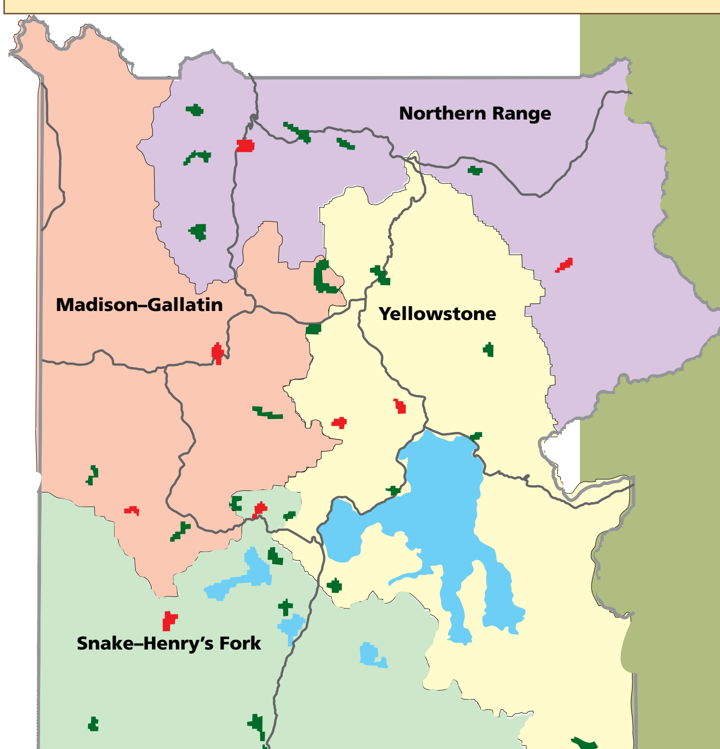
2000: Researchers begin inventorying reptiles and amphibians.

2004: NPS Greater Yellowstone Network selects amphibian occurrence as a Vital Sign for monitoring ecosystem health.

2006: Long-term, Vital Sign amphibian monitoring begins in Yellowstone.

Status

- Spotted and chorus frogs are widely distributed with many breeding sites in the park.
- Tiger salamanders are common and abundant in some portions of the Yellowstone, such as the northern range and Hayden Valley.
- Boreal toads are abundant in some local areas.
- None of the parks reptiles or amphibians are federally listed as threatened or endangered.
- Scientists are concerned about the boreal toad, which has declined sharply in other parts of the West.
- In 2008, a scientist reported drastically declined amphibian populations in the northern range, but the study is in question.



Amphibian Monitoring Sites

■ Monitored every year ■ Monitored every 5 years

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 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 area, 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.

BULL SNAKE *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 150–154 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 & 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

- Can be 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 & Behavior

- 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.
- 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.

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.

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.

Toad or Frog?

Toads can easily be distinguished from frogs by their warty bodies, thick waists, and prominent glands behind their eyes.

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 juveniles 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, resemble 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.

www.nps.gov/yell

www.greateryellowstone-science.org/index.html

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.

Site Bulletins, published as needed, provide more detailed information on park topics such as wildlife and geology. Free; available upon request from visitor centers.

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Aquatic Invaders

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) stocked 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 widely introduced—brook, brown, lake, and rainbow. Rainbow trout hybridize with native cutthroat trout, thus diluting genetic diversity. All four compete with and prey upon native fish.

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.

The Issue

Aquatic invaders can irreversibly damage the park's 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 6 invasive aquatic species exist in Yellowstone's waters:
  1 mollusk
  4 fish
  1 exotic disease-causing microorganism (whirling)
- Park staff continues to educate visitors about preventing the spread of aquatic invasive species.

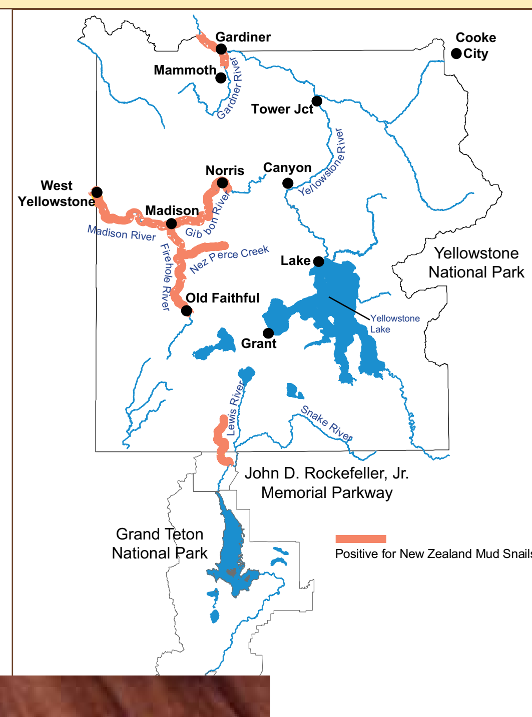
Clean, Inspect, Dry!

Read and follow the instructions provided in the fishing regulations, which include:

- Remove all plants, animals, mud, sand, and other debris from your boat and equipment.
- Do not dump water from other sources into Yellowstone waters.
- Drain your boat bilge area, live well, and other compartments away from park waters.
- Dry all equipment in the sun for 5 days or use high-pressure, hot (>140°F) water (available at car washes outside the park) to clean your boat, trailer, waders, and equipment.

Angler and boater introduction of aquatic invasive species remains a serious threat to Yellowstone's aquatic ecosystem because exotic aquatic species occur in waters 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 in the park. The park's efforts join those of other agencies around the country working to protect the nation's aquatic ecosystems.



Mud Snails

About one-quarter inch long *(photo below)*, 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 for fish. They also consume a majority of algae growth in park streams, which is a primary food for native aquatic invertebrates. Strategies for dealing with this invader are being developed.

8

Aquatic Invaders: Lake Trout

Lake Trout

Non-native lake trout in Yellowstone Lake threaten the survival of native Yellowstone cutthroat trout and species that depend on if.

History/Background

- During the time 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.
- Lake trout probably were introduced into Yellowstone Lake several decades ago.
- One mature lake trout can eat approximately 41 cutthroat trout per year.
- The cutthroat trout population in Yellowstone Lake could fall to 10% of historic highs.
- 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 the trout live in deep water, spawn in the lake, and are large.

Current Status

- Gill-netting by fisheries staff has removed almost 450,000 lake trout since the mid-1990s.
- Recreational anglers catch approximately 9,000 lake trout each year.
- In 2009, YNP contracted with a commercial gill-netting company to increase the catch of lake trout.

Outlook

With continued aggressive control efforts, fisheries managers expect to reduce lake trout numbers and lessen impacts to cutthroat trout.

About the photo: Erinn Hasselgren holds up the largest lake trout caught in Yellowstone Lake so far. Erinn is a volunteer with the Student Conservation Association, www.thesca.org

The lake trout is a large and aggressive predatory fish that can decimate cutthroat trout populations in Yellowstone Lake. If this happens, the impacts will reach far beyond the cutthroat trout population; it could be be an ecological disaster.

Hydroacoustic work (using sonar-based fish finders) confirmed lake trout concentrations 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 biologists 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 control efforts.

Controlling Lake Trout

Lake trout gill-netting begins as ice is leaving the lake and continues into October. Since the mid-1990s, almost 450,000 lake trout have been caught. Gill net operations also provide valuable data —numbers, age structure, maturity, and potential new spawning areas—leading to more effective control. For example, scientists have discovered lake trout spawning areas.

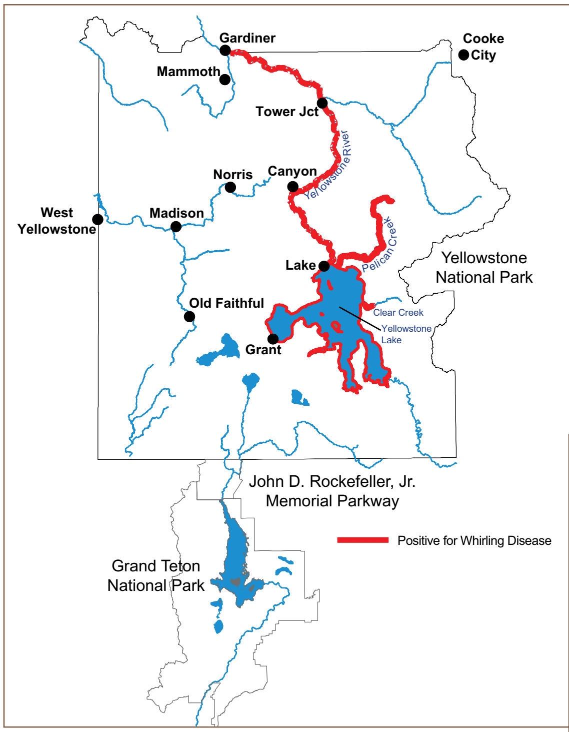
Anglers contribute to lake trout management—they are encouraged to fish for lake trout, and are required to kill all lake trout caught in Yellowstone Lake and its tributaries. They have the most success in catching lake trout 15–24 inches long, which are found in shallow, near-shore waters in June and early July. Anglers have taken approximately 30 percent of the lake trout removed from Yellowstone Lake.

Cutthroat trout comprise about 80 percent of a mature lake trout's diet. Biologists estimate 41 cutthroat trout are saved each year for every mature lake trout caught.

Increasing Suppression

In August 2008, a scientific review panel overwhelmingly agreed that the Yellowstone Lake cutthroat trout population is in serious trouble, but that suppression efforts could restore this population to healthy levels. They believe very little time remains to turn the situation around, and recommended park managers increase lake trout removal. To accomplish this, the park contracted with a commercial gill-netting company to increase the take of lake trout. In 2009, working cooperatively with NPS crews, they removed over 14,000 additional lake trout from Yellowstone Lake during June. In 2010, the park expects to expand commercial gill-netting and to test deep-water trap nets that have been successful in other large lakes.

Lake trout probably can't be eliminated from Yellowstone Lake. However, ongoing management of the problem can control lake trout population growth and maintain the cutthroat trout population, which is a critical ecological link between Yellowstone Lake and its surrounding landscape.



In 1998, whirling disease was detected in Yellowstone's cutthroat trout. This disease is caused by a non-native 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.

Studying the Disease

Yellowstone National Park's cutthroat trout spawning streams, which vary widely in thermal, hydrological, and geological characteristics, provide an exceptional opportunity to study whirling disease in native trout. Park staff have been working with Montana State University's Department of Ecology to measure how the infection rate might vary in different stream conditions. They are also investigating if certain fish-eating birds help to disperse the parasite. Research has shown that the parasite can pass through the gastrointestinal tract of some birds, such as great blue herons, and remain alive.

Whirling Disease

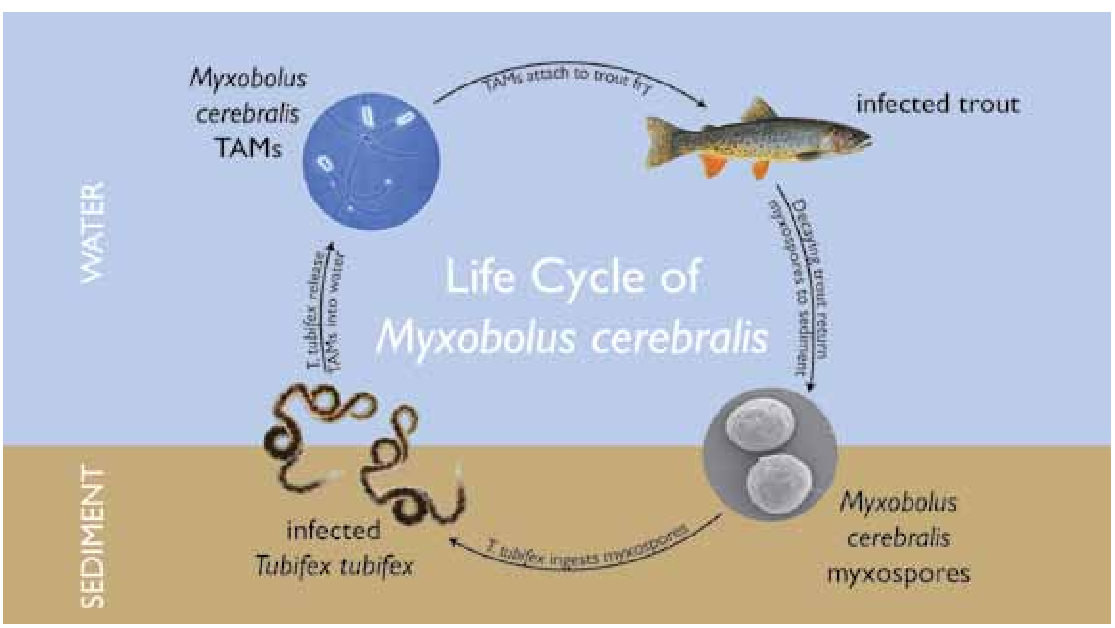
Whirling disease is caused by a parasite attacking the developing cartilage of young fish, resulting in skeletal deformities and sometimes whirling behavior. Affected fish cannot feed normally and are vulnerable to predation.

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, and in Yellowstone in 1998.
- It most likely came to the U.S. in frozen fish products.
- Whirling disease has been confirmed in 26 states and appears to be rapidly spreading throughout the western United States.
- Recent laboratory tests suggest cutthroat trout are 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.

Current Status

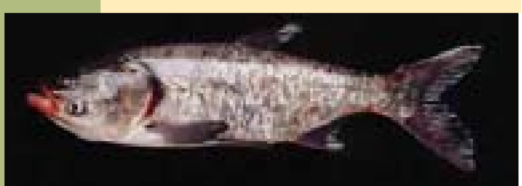
- Testing for whirling disease continues throughout the park.
- Pelican Creek's migratory cutthroat trout population is almost gone.



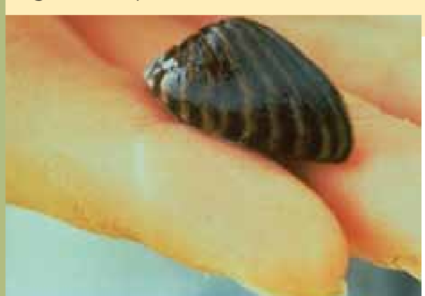
No effective treatment exists for wild trout infected with this disease or for the waters containing infected fish. Therefore, the park is emphasizing prevention by educating people participating in water-related activities—including anglers, boaters, or swimmers—to take steps to help prevent the spread of the disease. This includes thoroughly cleaning mud and aquatic vegetation from all equipment and inspecting footwear before moving to another drainage. *(See page 155 and instructions in the park's fishing regulations.)* Anglers should not transport fish between drainages and should clean fish in the body of water where they were caught.

Remember: CLEAN, INSPECT, DRY!

Round goby



Bighead carp



Zebra mussels (above) clog water intakes, crowd out bottom invertebrates, and reduce lake productivity.

Not shown: three zooplankton species that can displace native zooplankton that are important food for cutthroat trout. These 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. Their arrival might be avoided 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 any species to Yellowstone waters.
- To clean all of their gear properly. *(See page 155.)*

Eurasian water-milfoil

Eurasian water-milfoil *(below)* has spread to 46 of the 48 contiguous United States. In 2007, it was found in Montana. Wyoming and Maine are the only 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.

8

Issues: Bear Management

Bear Management

Feeding Bears

- Late 1880s: Bears begin gathering 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 begins 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 occurr annually in Yellowstone.

Changes in Management

- 1970: Yellowstone implements a new bear management program to restore bears to subsistence on natural foods and to reduce property damage and human injuries.
- Strictly enforcing regulations prohibiting the feeding of bears and requiring proper storage of human food and garbage.
- All garbage cans in the park convert to a bear-proof design.
- Garbage dumps close within and adjacent to the park.

Current Status

- 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 15 per year in the 2000s.
- 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 0.34 black bear and 0.2 grizzly bear per year in the 2000s.
- 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 0.6 grizzly bear per year in the 2000s.

For details about grizzly bear management, see the next page.

During its first century, Yellowstone National Park was known as the place to see and interact with bears. Hundreds of people gathered nightly to watch bears feed on garbage in the park's dumps. Enthusiastic visitors fed bears along the roads and behaved recklessly to take photographs.

Beginning in 1931, park managers recorded an average of 48 bear-inflicted human injuries and more than 100 incidents of property damage each year in Yellowstone.

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 and to re-establish bears in a natural state. The plan included expanding visitor education about bear behavior and the proper way to store food and other bear attractants; using bear-proof garbage cans; strictly prohibiting feeding of bears; and removing potentially dangerous bears, habituated bears, and bears that damaged property in search of food.

After 10 years of this 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 program that included eliminating open-pit garbage dumps inside the park. The long-term goal was to wean bears off human food and back to a natural diet of plant and animal foods.

Drs. John and Frank Craighead, who were brothers that had studied grizzly bear ecology since 1959, predicted bears would range more widely and come into more conflict with humans. This indeed occurred in the first three years when an annual average of 38 grizzly bears and 23 black bears were moved to backcountry areas, and an annual average of 12 grizzly bears and 6 black bears were removed from the population. After 1972, though, the number of bear-human conflicts decreased to an annual average of 10 each year. Bear removals also decreased.

In 1983, the park implemented a new grizzly bear management program that emphasized habitat protection in backcountry areas. The park established "bear management areas" that restricted recreational use where grizzly bears were known to concentrate. 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.

8

Bear Management: Grizzly

The Issue

The grizzly bear was listed as a threatened species in 1975, which required recovering the species to a self-sustaining population.

History

1993: A recovery plan is implemented with three specific recovery goals that have to be met for six straight years.

2000: The Draft Conservation Strategy for the Grizzly Bear in the Greater Yellowstone Ecosystem is completed.

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; will be implemented when the grizzly is removed from threatened species list.

2003: The recovery goals are met for the sixth year in a row.

2005: The USFWS proposes removing the grizzly bear from threatened species list.

2006: The Grizzly Bear Recovery Plan is modified to update methods of estimating population size and sustainable mortality.

2007: The grizzly bear population in the Greater Yellowstone Ecosystem is removed from the threatened species list and the Conservation Strategy is implemented.

2009: The population is returned to the threatened species list; management continues under the 2006 revision of the recovery plan.

Status & Management

On July 28, 1975, under the authority of the Endangered Species Act (ESA), the U.S. Fish and Wildlife Service (USFWS) listed the grizzly bear in the lower 48 states 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 goal of ESA listing is to recover a species to self-sustaining, viable populations that no longer need protection.

To achieve this goal, federal and state agencies:

- Stopped the grizzly hunting seasons in the Greater Yellowstone Ecosystem.
- Established the Yellowstone grizzly bear recovery area (Yellowstone National Park, John D. Rockefeller, Jr. Memorial Parkway, portions of Grand Teton National Park and national forests surrounding Yellowstone, Bureau of Land Management lands, and state and private lands in Idaho, Montana, and Wyoming).
- Began the Interagency Grizzly Bear Study Team (IGBST) to coordinate bear management among the federal agencies and state wildlife managers; the team monitors bear populations and studies grizzly bear food habits and behavior.
- Established the Interagency Grizzly Bear Committee (IGBC) to increase communication and cooperation among managers in all recovery areas, and to supervise public education programs, sanitation initiatives, and research studies.
- Developed and implemented a recovery plan and a conservation strategy.

On the List = The Grizzly Bear Recovery Plan

The Grizzly Bear Recovery Plan was established in 1993 and revised in 2006. It has four demographic and sustainable mortality goals, listed on the next page, for grizzly bears in the Greater Yellowstone Ecosystem (GYE). This plan guides management when the grizzly is on the threatened species list. When the grizzly is off that list, as it was recently, managers follow the Conservation Strategy, as described next.

Off the List = The Grizzly Conservation Strategy

Bear managers use the conservation strategy when the grizzly is off the threatened species list. It is the long-term guide for managing and monitoring the grizzly bear population and assuring sufficient habitat to maintain recovery. It emphasizes 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. It incorporates existing laws, regulations, policies, and goals.

Grizzly Bear Recovery Plan: New Population Monitoring Criteria

Population Objectives	Was the objective achieved? 05	06	07	08	09
1 Estimated percent of total mortality of independent aged females not to exceed 9%.	✔	✔	✔	✘	✔
2 Estimated percent of total mortality of independent aged males not to exceed 15%.	✘	✔	✔	✘	✔
3 Estimated percent mortality from human causes for dependent young not to exceed 9%.	✔	✔	✔	✔	✔
4 Demographic objective of 48 females producing cubs annually.	✔	✔	✔	✔	✔

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 grizzly bear population will be sustained at or above 500 bears in the 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.
- Managers will remove nuisance bears conservatively and within mortality limits outlined above, and with minimal removal of females; they will emphasize removing the human cause of conflict rather than removing a bear.
- Outside the PCA, states develop management plans, with input from affected groups and individuals, that define where grizzly bears are acceptable.

Current Status & Outlook

Scientists and managers believe the grizzly population has grown robustly since 1986. Grizzlies are raising cubs in nearly all portions of the recovery area, and cub survival is high. They are also dispersing into new habitat. Of the estimated 579 grizzlies estimated to live in the area, approximately 150 have home ranges wholly or partially in Yellowstone National Park. Other bears range south into the Wind River Range, north through the Gallatin Range, and east of the Absarokas onto the plains.

For these reasons, the Yellowstone grizzly population was removed from the threatened species list in 2007. This decision was challenged in several courts, and some cases are pending.

In 2009, U.S. District Judge Donald Molloy returned the grizzly to the federal threatened species list, saying the Conservation Strategy was not enforceable and insufficiently considered the impact of climate change on grizzly food sources. The USFWS is considering whether or not to appeal the decision. However, the Department of Justice makes the final decision on filing appeals.

Meanwhile, management of the bears in the GYE changes little whether it is listed on the threatened species list or not. Scientists will continue to monitor the long-term recovery goals for grizzly bears and strive to ensure the criteria are met.

8

Issues: Bioprospecting & Benefits-sharing

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* is discovered in a Yellowstone hot spring.

1985: An enzyme from *T. aquaticus,* which is synthetically reproduced, contributes to the DNA fingerprinting process that has earned hundreds of millions of dollars for the patent holder.

1997: The park signs 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 puts on hold implementation of this agreement until an environmental analysis (EA or EIS) is completed.

2006: Draft EIS released.

2009: Final EIS completed.

Current Status

- The final EIS is complete. Early in 2010, the NPS will decide whether or not to implement benefits-sharing.
- 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, "Life in Extreme Heat."

Yellowstone's extremophiles—especially 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 extremophiles. *(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.

Until the 1980s, 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 an extremophile, Taq polymerase can withstand the heat of the PCR process without breaking down like ordinary polymerase enzymes. Many laboratory versions of this enzyme are now

Dr. Thomas Brock

used and have allowed DNA studies to be practical and affordable.

Many other species of microbes have been found in Yellowstone's thermal areas since 1966. Each of these extremophiles produces enzymes that operate under conditions too harsh for most proteins, and a few of these enzymes are proving to be useful. Researchers estimate more than 99 percent of the extremophiles present in Yellowstone's hydrothermal features have yet to be identified.

Science

Genetic studies important to medical, agricultural, and environmental research use hundreds of enzymes developed from the study of microbes, like Taq polymerase. In addition, many industrial processes require the use of enzymes in biochemical reactions. Because some enzymes developed through study of extremophiles can withstand harsh manufacturing processes better than inorganic catalysts, they can improve efficiency—which saves energy. In some cases, using enzymes also contributes to reducing pollution.

Yellowstone's geology provides a wide variety of high-temperature physical and chemical habitats that support one of the planet's greatest concentrations of extremophilic biodiversity. Research on these extremophiles 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 proven useful in producing biofuels, treating agricultural and industrial waste, bioremediating chlorinated hydrocarbons, recovering oil, biobleaching paper pulp, improving animal feed, 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 logging 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

T. aquaticus as seen through a scanning electron microscope

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. Ten years later, annual sales of Taq polymerase reportedly were $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 the 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 have been 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 Corporation 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 had research sites around the world, was collecting DNA samples directly from nature and screening the genes for the ability to produce enzymes. In its labs, scientists spliced the most useful genes into microbial "livestock," and these microbes then produced the compound or enzyme. (Diversa has since merged with another company to form Verenium Corporation.) 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 the 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 the 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:
1) the CRADA was consistent with the NPS mission of resource conservation; 2) bioprospecting did not constitute a consumptive use; 3) 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.

Outlook

The NPS completed a Final Environmental Impact Statement in November 2009; it is available on the internet. *(See at left.)* In early 2010, the NPS is expected to decide whether benefits-sharing should be implemented in national parks nationwide.

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.

More information, including the 2000 court decision, is at www.nature.nps.gov/benefitssharing

The final EIS is at parkplanning.nps.gov: select "Washington Office" from the menu and follow the benefits-sharing links.

About Brucellosis

Brucellosis, caused by the bacterium *Brucella abortus*, can cause pregnant cattle, elk, and bison to abort their calves. It 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 when calves, as are bison calves and yearlings released after capture.

Although rare in the United States, humans can contract brucellosis by consuming unpasteurized, infected milk products or contacting infected birth tissue. It cannot be contracted by eating cooked meat from an infected animal. In humans, the disease is called undulant fever. Since the advent of milk pasteurization, people in developed countries 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. 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.

Park managers face numerous uncertainties about how to best manage and preserve bison while addressing the issue of brucellosis-infected wildlife in the greater Yellowstone area. 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

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 166–167)

- Bison probably contracted brucellosis from 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, is no longer a public health threat in the U.S.
- A vaccine used in cattle, RB51, is being used for Yellowstone bison.
- Bison have not been known to transmit brucellosis to cattle under natural conditions although transmission 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

- The bison management plan in effect since December 2000 has been revised.
- Bison are now tolerated outside the west boundary until May 15.
- A large herd of cattle on the north boundary has been removed, opening that area to a few bison in winter.
- A few tribes are conducting bison hunts north of Yellowstone according to their 1855 treaties with the United States.

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)

1985 *Montana receives brucellosis-free status; begins public hunts for bison.*

1989 *Almost 600 bison killed in public hunt.*

1990 *Montana ends hunt due to public outcry. NPS prepares EA enabling park staff to haze and shoot bison outside the park.*

1995 *Montana files lawsuit against NPS; settlement requires EIS preparation.*

1996 *Interim Bison Management Plan begins.*

1997 *Unusually severe winter. More than 1,000 bison shot or shipped to slaughter.*

1998 *94 bison died in management actions.*
Draft EIS released. Receives 67,500+ public comments.

1999 *No bison die in management actions.*
August: Almost 8,000 acres winter wildlife habitat acquired by federal government or put under easement.
December: Federal agencies withdraw from agreement with Montana to produce an EIS.

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. In addition, the majority of elk in the greater Yellowstone area have a brucellosis exposure rate up to 3 percent; but elk that use feed grounds in Wyoming outside of Yellowstone National Park show exposure rates up to 35 percent. This disease reservoir 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. Under current regulations, brucellosis infections in two cattle herds would downgrade a state's status and adversely affect the finances of ranchers. When one cow in a cattle herd becomes infected with brucellosis, the herd is quarantined and may be slaughtered to eliminate the infection. Federal and state indemnity funds partially compensate the livestock producer for this loss.

Montana's status

Montana first attained class-free status in 1985, and retained it until 2008. Cattle on two ranches had become infected and the state was downgraded to class-A status. There is a minimum one year time period before class-free status can be regained. Following a scientific review of the risk and extensive testing of cattle close to the infected herds, the U. S. Department of Agriculture re-classified Montana as brucellosis free in 2009.

Because of concern over losing brucellosis class-free status, livestock regulatory agencies recommend an aggressive strategy for managing wildlife to achieve the goal of brucellosis eradication in the greater Yellowstone area. 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 interspecies transmission risks. Keeping bison and livestock separated is a key part of the Interagency Bison Management Plan *(IBMP; described on page 168)*.

Vaccinating cattle and bison is another important component of the IBMP. RB51 is a brucellosis vaccine safe for bison calves, yearlings, and adult males. Unlike other brucellosis vaccines, animals vaccinated with RB51 will not test positive for brucellosis on the standard battery of diagnostic tests. Vaccination of some Yellowstone bison began in spring 2004; it is limited to calves and yearlings captured at the boundary and then released back into the park.

Developing a Long-term Management Plan

In 1985, the year that Montana first received brucellosis class-free status, the state began a public hunt along the north and west boundaries to keep bison out of the state. After 569 bison were killed in the winter of 1988–89, nationwide criticism over how the hunt was conducted caused the state to stop the hunt.

In 1989, the state of Montana, Yellowstone National Park, and Gallatin National Forest agreed to develop a long-term management plan to cooperatively manage bison. While they were preparing this plan, Montana needed an interim management plan to protect private property, provide for human safety, and protect the state's brucellosis class-free status. A 1990 management plan provided for limited NPS management of bison through hazing, monitoring, and shooting outside of park boundaries. In 1992, the partners added the federal Animal

2000
February: Federal judge orders state & federal agencies into mediation to work out differences.
August: Final EIS released.
December: Records of Decision signed by federal and state governments.

2002–2005
During years 2–5 of the Bison Management Plan, approximately 200 bison are shipped to slaughter or killed.

2005
FWP & APHIS open quarantine facility; several dozen bison calves taken from Yellowstone for project. DOL & APHIS begin vaccinating captured bison.
FWP begins bison hunt on November 15.

2006
Approximately 1,000 bison removed from Yellowstone through management actions, transfer to quarantine, or hunting.

2008
Approximately 2.000 bison removed, mostly by management actions, plus large number of deaths in winter.
August: State and federal agencies begin revising the management plan.
December: Revisions to plan announced; more bison will be tolerated outside both boundaries in winter.

Plant Health Inspection Service (APHIS) to to the planning process. Developing the long-term management plan was a difficult process because of a wide variety of agency perspectives and missions and would take many years to resolve these differences.

Lawsuit & Interim Management Plan

In January 1995, the state of Montana sued the NPS and APHIS because the federal agencies were asking the state to implement conflicting management actions. The NPS wanted more tolerance for bison on winter range outside the park; APHIS threatened the state with losing its brucellosis class-free status if bison from an infected population (i.e. Yellowstone) ranged free in Montana. In the settlement, APHIS agreed not to downgrade Montana's status if bison migrated from Yellowstone into Montana as long as certain actions were taken, including completing the long-term management plan. The partners also agreed on another interim management plan.

The 1996 interim plan called for the 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 would be monitored and not captured. The Montana Department of Livestock (which, in 1995, had been given the lead 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 pregnant females would be sent to slaughter. Other seronegative bison would be released on public land. The state could shoot any untested bison in the West Yellowstone area that couldn't be captured.

This plan began during the winter of 1996–97, the most severe winter since the 1940s. Hundreds 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. Bison management again became the focus of nationwide debate about how to conserve this population of bison and yet tackle the percieved threat of brucellosis transmission to livestock near the park.

The last public hearing on the draft EIS, held in Minneapolis, MN, was preceded by a rally organized by area tribes.

Ongoing Environmental Analysis

A draft EIS describing the impacts of seven alternatives for management of Yellowstone bison was released in 1998. The draft plan received more than 67,500 public comments.

While attempting to settle on the final management strategy, the agencies reached an impasse and the federal agencies withdrew from the agreement to produce a long-term management plan. The state once again sued. The judge's opinion noted that the federal agencies had the authority to complete a management plan without the state's concurrence, but recognized that the success of a long-term bison management plan required collaboration between the state and the federal agencies. The agencies subsequently agreed to use a court-appointed mediator to help find common ground in managing bison. The resulting *Final Environmental Impact Statement for the Interagency Bison Management Plan for the State of Montana and Yellowstone National Park* was released in August 2000.

Bison Management Objectives

- *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.*

After a public comment period and slight modifications to the plan, the federal government and the state of Montana released separate Records of Decision in December 2000 describing the negotiated settlement.

The Interagency Bison Management Plan (IBMP)

The Interagency Bison Management Plan (IBMP) identified two common goals: 1) maintain a wild, free-ranging bison population and 2) prevent transmission of brucellosis from bison to cattle surrounding Yellowstone National Park. Because so much uncertainty remained about how to achieve these goals, the IBMP uses adaptive management, which allows for modifying the plan as scientists and managers learn more about bison behavior and migration, and about brucellosis.

The IBMP allows progressively greater tolerance for bison outside Yellowstone in three phases:

Step One: Up to 100 sero-negative bison can occupy one management area outside the west boundary, November to mid-May.

Step Two: Up to 100 sero-negative bison can be outside the north boundary from November to mid-April once cattle no longer graze on the Royal Teton Ranch during the winter (initiated March 2008).

Step Three: Up to 100 untested bison can be in both of these defined management areas during winter.

During all steps, the Eagle Creek/Bear Creek area outside the north boundary provides habitat for an unlimited number of bison during all months of the year.

The IBMP also allows natural processes to occur throughout most of the bison conservation area (the interior ranges within Yellowstone National Park) and accounts for the migratory nature of bison. But as bison approach the park boundary, more intensive management actions would occur to keep bison from commingling with cattle.

The IBMP was in use without major changes until the end of winter in 2008, and remained in Step One. Managers had the authority each winter to capture and remove all bison, regardless of disease status, outside the west boundary or north boundary if the bison population was above 3,000. Removal meant capturing bison and sending most of them to slaughter.

Winter 2005–2006

At the start of winter in 2005, almost 5,000 bison lived in the park. Hundreds migrated to winter range along and outside the park's north boundary. More than 800 bison were captured and shipped to slaughter. Also, 87 calves were sent to quarantine *(see next page)*. Scientists believe that the loss of this many bison would not prevent the long-term conservation of the bison population.

Winter 2007–2008

In the autumn of 2007, more than 4,500 bison were counted in Yellowstone; by March 2008 less than 2,500 remained. Approximately 1,600 were sent to slaughter, 116 killed in the Montana state hunt, 112 calves sent to quarantine research, and several hundred killed by the winter. By March 2008, managers realized the bison population had dropped low enough that their long-term conservation was at risk. Management actions were put on hold, and the remaining bison were allowed outside the park with minimal hazing. As in 1997, bison management came under intense national scrutiny.

Revising the Plan

In March 2008, the Government Accounting Office (GAO) released an audit of the IBMP that recommended it be revised. GAO's recommendations included:

- Clearly define measurable objectives and refine, revise, or replace the plan and procedures as needed.
- Define specific scientific and management questions to be answered and incorporating the results into the IBMP.
- Make easily accessible to the public all documents reflecting decisions made and actions taken.
- Report annually to Congress on the progress and expenditures related to the plan.

Between August and December 2008, the agencies met seven times to begin implementing these and other changes. Their adjustments to the IBMP include:

- Establish www.ibmp.info to provide bison management documents to the public.
- Provide greater tolerance for untested bison on the Horse Butte peninsula, which is outside the park beyond West Yellowstone.
- Allow bison beyond the northern boundary in a limited area to learn how bison

may use this new winter range.
- Allow adult male bison outside the west boundary, with management based on minimizing private property damage and providing public safety.
- Work with private land owners to prevent or resolve wildlife conflicts.
- Consider fencing as a tool to help create separation between cattle and bison.

Other Recent Developments

Brucellosis near Yellowstone

Wyoming, Idaho, and Montana lost their brucellosis-free status in recent years. Elk—not bison—were the likely source. The states have increased efforts to keep elk and cattle separate through more aggressive disease testing, fencing, and culling. All three have regained their brucellosis-free status.

Vaccination

The NPS is undergoing an environmental study to evaluate vaccinating bison 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 remote field vaccination could succeed.

Bison hunting

The state of Montana reauthorized a winter bison hunt outside Yellowstone National Park beginning in 2005. The state hopes to use the hunt to manage bison numbers on low elevation winter range and increase public support for expanding bison habitat outside the park. In addition, the Nez Perce and Confederated Salish-Kootenai Tribes are hunting bison on public lands outside the park in accordance with their 1855 treaties with the United States.

Quarantine

Montana Fish, Wildlife and Parks and APHIS are conducting a bison quarantine feasibility study. Bison calves that would otherwise be sent to slaughter are being used to develop and test a protocol to certify disease-free bison. From the first group of 36 female bison, 22 calved successfully and cleared the quarantine protocol. They and their calves and a few males are expected to depart quarantine in early 2010. The remaining females were allowed to breed in 2008 and moved through the final steps of quarantine in 2009; they are expected to depart quarantine in the next year. If successful, quarantine could provide a way for Yellowstone bison to be a part of bison conservation in other places.

Genetics

Several studies have reported relatively high genetic variation in Yellowstone bison compared to other bison populations in North America. This population has made a significant contribution to the overall genetic diversity in publicly-owned bison populations because they were used as a source to supplement or establish many herds. In addition, Yellowstone bison are one of only three publicly managed bison populations with no evidence of cattle hybridization.

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 consume most of these materials.

Understanding bison movement

Like most other ungulates of the greater Yellowstone area, bison are migratory, as explained in Chapter 7, "Bison." Managers are studying their movements to understand when, how, and where they migrate both inside and outside of the park. This may help managers anticipate large herd movements, and to better understand how to keep bison apart from cattle once they leave Yellowstone.

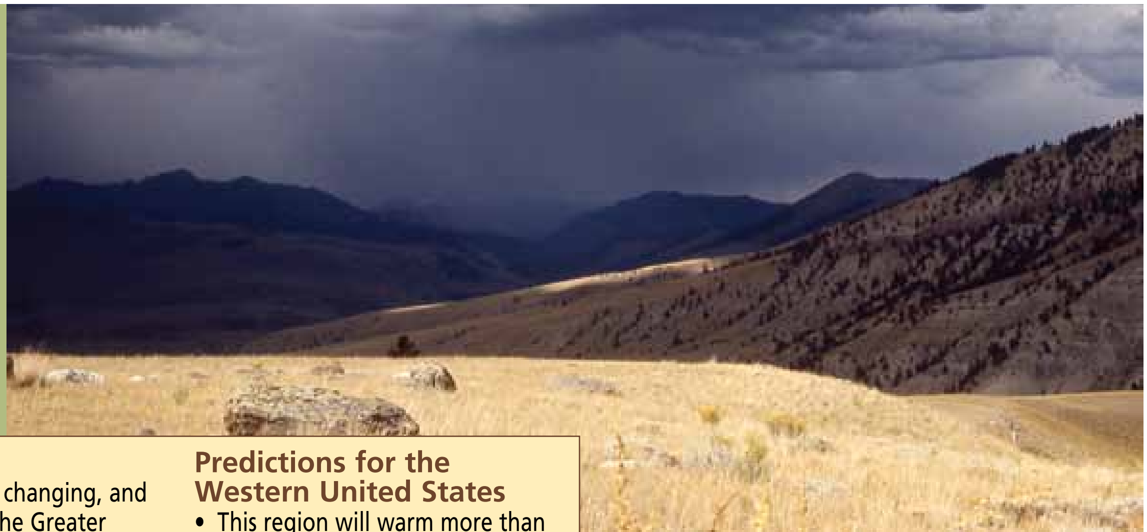
Outlook

Brucellosis is not a major factor in determining herd survival for either elk or bison, but will remain a cause of concern to the livestock industry. The U.S. Department of Agriculture has proposed revising the rules that define brucellosis-free status, eliminating the state-by-state designations and focusing on Yellowstone-area cattle populations. If accepted, this rule would become effective in 2010 and help ease concerns of cattle producers nationwide.

State and federal agencies will continue to work together using the Interagency Bison Management Plan as their primary tool to prevent bison to livestock transmission. Each agency plays a separate role in managing this population that now has approximately 80,000 acres of habitat in Montana outside Yellowstone National Park.

8

Issues: Climate Change



The Issue

The global climate is changing, and is already affecting the Greater Yellowstone Ecosystem.

History

1750: The Industrial Revolution is underway; manufacturing begins producing greenhouse gases such as carbon dioxide and methane.

1827: Jean-Baptiste Joseph Fourier, a scientist in France, describes Earth's atmosphere being like a glass box that traps heat—later termed the "greenhouse effect."

1896: Savre Arrehnius looks at the science, and perceives a simple cause and effect: increasing greenhouse gases in the atmosphere will cause global warming.

1958: Charles David Keeling begins measuring atmospheric carbon dioxide from Mauna Loa, Hawaii.

1957–58: International Geophysical Year

1963: Keeling warns of 10.8°F temperature rise in next century.

1965: First Global Climate Models (GCM) developed.

1969: Weather satellites begin providing weather & atmospheric data.

1978: Satellites begin measuring sea ice in both the Arctic and Antarctic.

1988: The Intergovernmental Panel on Climate Change (IPCC) is established.

1995–2006: 11 of these 12 years are the warmest years on record.

1997: The Kyoto Protocol sets mandatory targets for greenhouse gas emissions for most industrialized nations.

2007: IPCC begins its 4th report, "Warming of the climate system is unequivocal."

Predictions for the Western United States

- This region will warm more than the global average.
- Summer temperatures will increase 5–7°F in 50 years.
- Precipitation will stay the same or increase.
- Overall moisture available to the ecosystem will decrease because *evaporation* will increase as the region warms.
- Ecosystem changes will be affected by land forms, microclimates, and other local factors, and will occur in all directions—north, south, lower elevations, higher elevations.

What is already happening:

- Since the mid 1970s, the wildfire season increased by 11 weeks, with fires lasting an average of 5 weeks.
- Snowpack is decreasing and melting 2 to 4 weeks earlier.

Predictions for the Greater Yellowstone Ecosystem

- Alpine habitat will decrease, affecting almost all alpine flora and fauna.
- Grizzly bear alpine food sources (whitebark pine, army cutworm moths) will decrease.
- Wolverine may lose habitat and denning sites.
- Pika and lynx may lose their habitat in the park.
- Sagebrush-steppe conditions, such as on the northern range, will increase.

What is already happening:

- Growing season has increased by two weeks.
- Willows are growing 3 times the average recorded in the 1980s, in part due to the longer growing season.

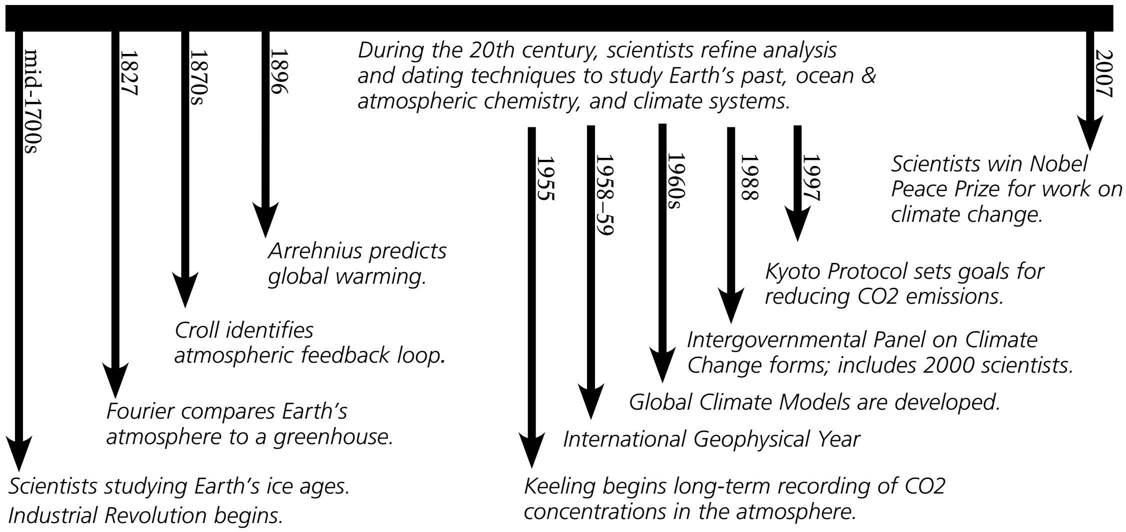
In recent years, natural events in Yellowstone associated with weather seemed to come two to three weeks early—including the peak snowmelt. Was this unusual weather or global climate change? To answer this question, you need to understand the difference between weather and climate (defined on the next page), and you need data spanning several decades, ideally centuries or even millennia. Scientists now have that data, which establish our global climate is changing rapidly and the change is unprecedented in the last several thousands of years. However, understanding global climate change dates to the 1700s.

Ironically, ice age investigations led directly to understanding global climate warming. In the 1700s, scientists began trying to understand how the ice ages had occurred. At the same time, the Industrial Revolution began, powered by fossil fuels.

Scientists studying the ice ages developed some of the first climate theories. For example, Jean-Baptiste Joseph Fourier compared Earth's atmosphere to a glass box, which allows heat in but not out—which later scientists called "the greenhouse effect." James Croll noted that ice and snow reflect heat back into the atmosphere—and if the amount of heat changed, winds would change, which would affect ocean currents, which could sustain cold temperatures—and thus create a feedback loop.

In 1896, a Swedish scientist connected climate with pollution. Savre Arrehnius wanted to know how carbon dioxide (CO_2) might have affected the ice ages. He calculated the amount of CO_2 emitted by industry, then doubled that amount and calculated it would raise global temperatures 9–11˚F.

During the first 50 years of the 20th century, scientists continued to research the ice ages, developing methods and data essential to



future understanding of climate change. For example, scientists began studying pollen found in sediment layers. Based on the types of vegetation represented, the scientists could assume climate conditions in the past would resemble climate conditions where such vegetation is found today. Similarly, they developed a method to measure ancient ocean temperatures by studying shells of plankton laid down over centuries in the sea bed. By 1955, scientists had ocean temperature records going back 300,000 years.

In the 1950s, scientific attention began focusing on Earth's systems. Roger Revelle found the oceans could not absorb all the CO_2 humans were emitting. Knowing that CO_2 emissions would increase as industrialization increased, he wanted to know where the CO_2 would go. Revelle hired Charles Keeling to gather baseline data on atmospheric CO_2 from a lab on Mauna Loa, Hawaii, far from industry. Keeling saw the opportunity to begin long-term CO_2 analysis, and so began the first data set confirming atmospheric CO_2 was rising far beyond that caused by any natural mechanisms. *(See chart next page.)*

Additional research begun during the 1957–58 International Geophysical Year produced equally interesting results, and the general public began to take notice. Newspapers began reporting evidence of climate change, such as thinning of the Arctic sea ice. During the 1960s, the first Global Climate Models (GCMs) were developed and weather satellites began gathering data about the atmosphere's chemical composition.

During the ensuing decades, scientists continued to refine instruments and models, and to gather data. To assemble and review this data, the United Nations established the Intergovernmental Panel on Climate Change (IPCC) in 1988, which is comprised of 2000 scientists. Based in part upon the IPCC's work, more than 60 countries convened in 1997 to draft the Kyoto Protocol, which set mandatory targets for greenhouse gas emissions for most industrialized nations. In 2007, the IPCC shared the Nobel Peace Prize with Al Gore, and published its fourth report, which begins with this conclusion: "Warming of the climate system is unequivocal."

Climate-Change Science

The IPCC, in its 2007 report, explains: "Projecting changes in climate due to greenhouse gases 50 years from now is very different and much more easily solved problem than forecasting weather patterns just weeks from now." Weather systems are chaotic and hard to measure and predict; longer-term changes, however, can be measured and predicted because we have the necessary instruments and understanding. However, when you average weather data, "the fact that the globe is warming emerges clearly."

Two basic physical factors are at work in climate change: water expands when heated; open water and bare ground absorb thermal energy, thus warming the sea, land, and air.

Evidence

Since the end of the last glaciations, 13,000 to 14,000 years ago, Earth's snow and ice cover has remained relatively consistent. These highly reflective surfaces bounce thermal radiation back into the atmosphere, and as long as this reflection remains steady, so do world temperatures. Satellite and military data during the past few decades show Arctic ice is thinning and melting; and much evidence shows annual snow cover is diminishing worldwide, but especially in the northern hemisphere. As snow and ice

The Terms of Climate Change

Weather: *the state of the atmosphere at a given time and place, and for the next few days to a month.*

Climate: *long-term meteorological conditions that prevail in a region, with a decade as the minimum span of averages.*

Global Climate Models (aka Global Circulation Models): *GCMs use established physical laws (such as water expands as it warms) and enormous amounts of data to show how variables (such as increases in carbon dioxide) will affect climate.*

Phenology: *relationship between periodic biological changes—like the budding of trees or arrival of migratory birds in the spring—and seasonal changes such as temperature.*

Climate changes in the past were caused, in part, by changes in the Sun's activity. Scientists have detected no such changes in the Sun during the past few decades.

coverage decreases, less thermal radiation is reflected, and more heat is absorbed by the increasing amounts of open water and bare land. This increased absorption increases surface and air temperatures.

Ocean temperature is measured every day from thousands of ships; this record combined with air temperature records provide the estimated global average temperature each month. As oceans warm, they expand and their levels rise. Data collected since the 1990s show oceans are rising 0.12 inches per year—50 percent due to water expanding from increased temperatures and 50 percent due to melting ice. This rate of change is unprecedented; the record shows global sea levels had been stable for thousands of years until the 20th century.

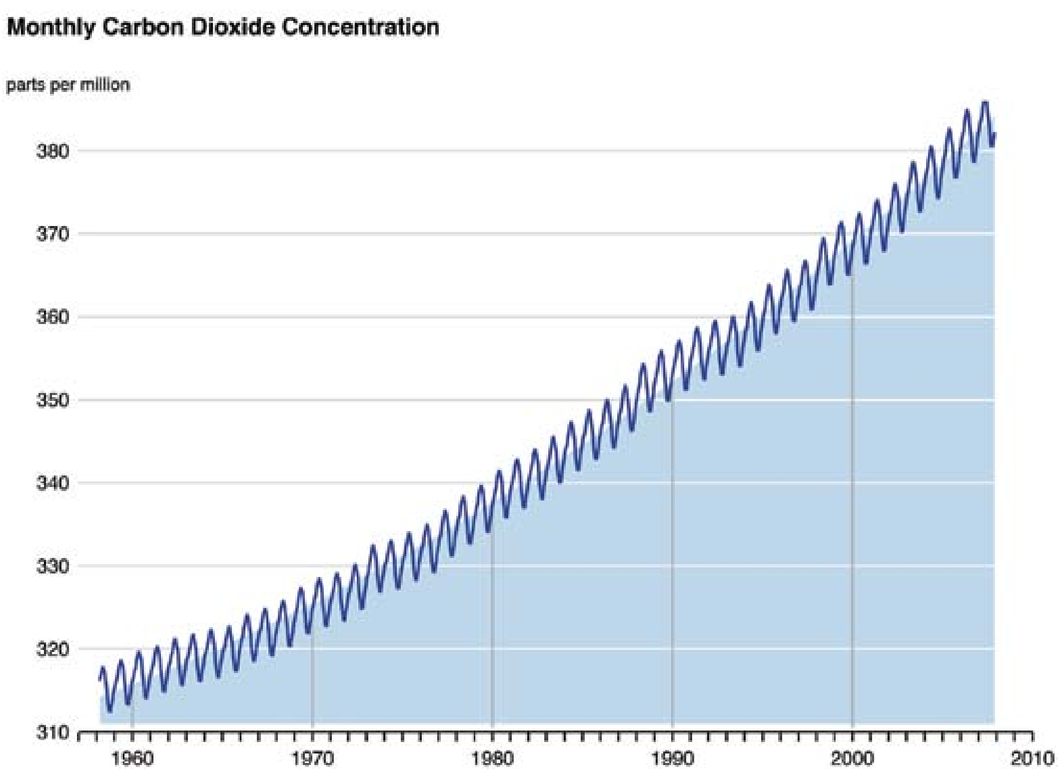
As scientists predicted in the 1800s, carbon dioxide build-up in the atmosphere is causing this extreme and rapid change in Earth's temperature. Ice core records show that after the last glacial period ended, CO_2 concentration gradually rose 80 ppm (parts per million) over 5,000 years. During the past 100 years alone, the concentration has risen 79 ppm—an unprecedented rate.

More than three-fourths of the CO_2 in the atmosphere comes from burning fossil fuels. Scientists know this because carbon atoms released during combustion are chemically distinguished from carbon released by natural causes, and thus can be measured.

Current Effects Around the World

- Since the 1950s, in most mid- to high-latitude regions, the number of very cold days and nights has decreased; the extremely hot days and nights have increased; and the length of the frost-free season has increased.
- In 2006, the average mean temperature in the United States was 55˚F—2.2˚F higher than the 20th century mean.
- The five hottest years on record were: 1998, 2002, 2003, 2004, and 2005.
- Temperatures in Alaska are rising almost twice as fast as elsewhere.
- Permafrost is melting across the Arctic regions, reducing habitat for birds, destroying buildings that used permafrost as a foundation, collapsing roads.
- Glaciers have decreased 95 percent.
- The area of melting Arctic sea ice is greater than two Montanas.
- The extent of regions affected by droughts has doubled since the 1970s.
- Since 1970, category 4 & 5 hurricanes have increased by about 75 percent.
- Since 1993, worldwide sea level has risen

The Mauna Loa Record, aka Keeling Curve (begun by Charles Keeling in 1958)



This version of the Keeling Curve by the CO_2 Program of the Scripps Institute of Oceanography, scrippsco2.ucsd.edu

1.7 inches—twice the rate of the previous 30 years.

Predictions

If we continue the current rates of CO_2 emissions, scientists predict the following:

Global

- Warming oceans will increase hurricane intensity.
- By 2030, CO_2 emissions will grow 40–110 percent.
- In this century, sea level will rise 15.8–27.6 inches.
- Increased ocean acidity (from increased CO_2) may stop growth of coral reefs.
- By 2100, global surface temperatures will be from 2.5 to 10.4˚F higher .
- Heat waves and heavy precipitation will become more frequent.
- Of the species whose sensitivity to climate change has been assessed, 20–30 percent will face greater risk of extinction.

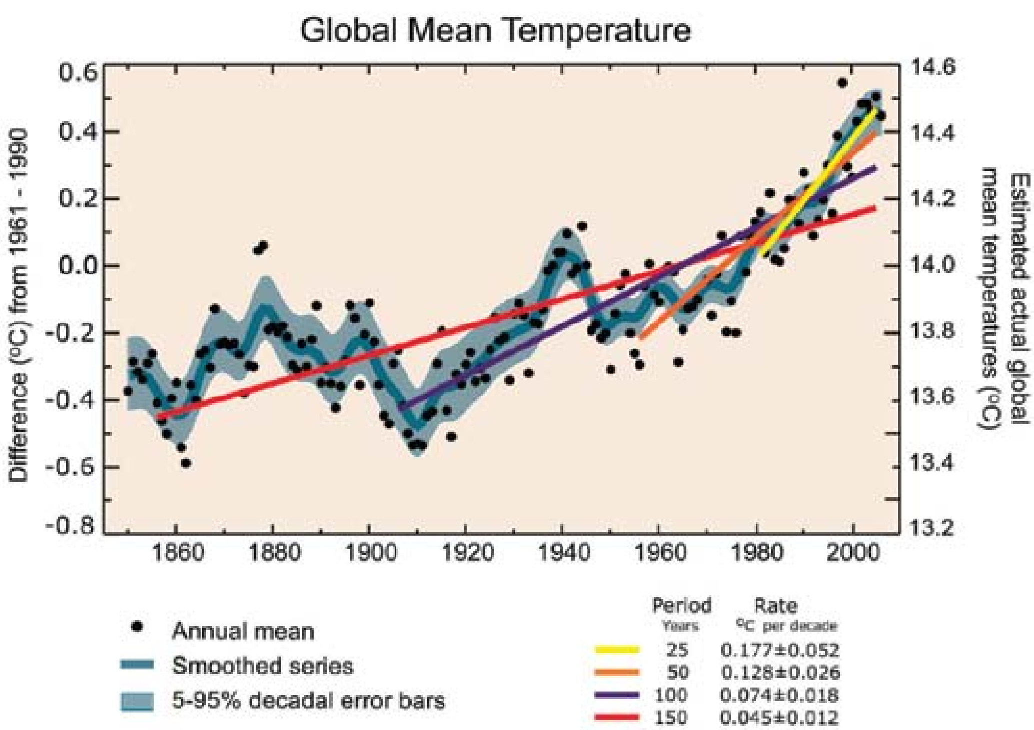
Western United States

Much of the western United States will likely become more arid according to the GCMs. Temperatures could increase 4–13˚F, with the increases higher in the mountains and greater during winter. The resulting smaller snowpacks will reduce surface and groundwater supplies, affecting all species in the region. As temperatures increase, evaporation rates increase. So even if precipitation remains the same or increases, less water will be available in the ecosystem.

Less water means wildfires will increase in frequency, intensity, and duration in most western regions. In the last 30 years, the wildfire season has increased more than two months, and individual fires last five times longer. In addition, the increasing levels of CO_2 may change the atmosphere's chemistry so that lightning—a prime cause of natural wildfire—will increase and thus, begin fires more frequently.

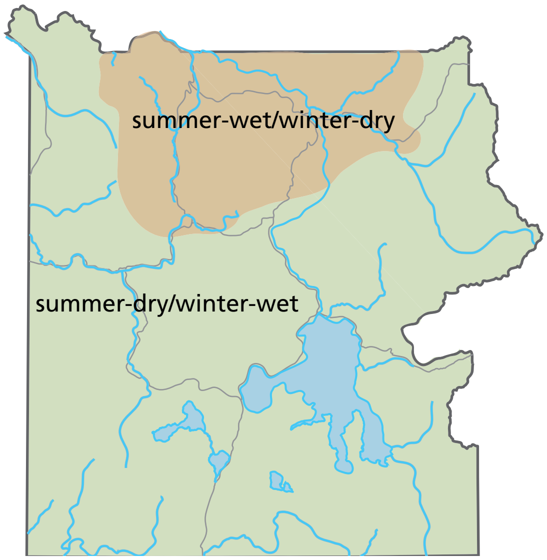
GCMs generally show changes by latitude—they cannot account for variations in topography, which are big variables in the western United States that affect regional climate, local weather, and ecosystems. Therefore, the GCMs cannot predict what changes will likely occur at different elevations and within small pockets of habitat.

In general, plants are especially vulnerable to rapid climate changes because they change locations by generations—at best. And even then, they face landscapes already fragmented by humans that will become even more fragmented by climate change.



IPCC published this graph in their 2007 report. An industrialization boom in the northern hemisphere after World War II contributed to cooler temperatures. Carbon dioxide and other greenhouse gases are the main cause of warming after the mid-1970s. The steeper slope in recent decades indicates accelerated warming.

This and other graphs available at www.ipcc.ch/graphics/gr-ar4-wg1.htm



The boundaries of Yellowstone's two climate regimes have remained stable for 14,000 years.

Plants adapted to live in cold environments, such as the Rocky Mountains, often require extremely cold temperatures. For example, young Douglas-fir must be exposed to cold for a certain length of time while they are dormant to promote maximum growth. They will face competition from trees and other plants that don't require such chilling periods.

Throughout the intermountain western United States, spring runoff is 20 days earlier than in the 20th century. Because of this change, scientists predict the following:

- By 2050, the Columbia River system—including the Snake River—will lose 35 percent of its snow pack.
- Coldwater fish habitat will be reduced 25–30 percent.
- Aquatic insects and other invertebrates living in streams will be reduced or wiped out.

Climate Change in Yellowstone

Yellowstone is not considered by many to be a "climate change" park that will have obvious changes in the next few decades. However, higher temperatures and changes in precipitation patterns can greatly change its ecosystems. The alpine zone, which begins at 9500 feet, will migrate higher, with important species like whitebark pine almost entirely lost to the ecosystem. Changes in snowpack and timing of spring runoff will disrupt native fish spawning and increase exotic aquatic species expansion. Changes in precipitation and temperature regimes will likely disrupt vegetation growth that in turn would seriously disrupt wildlife migrations, one of the key resources for which Yellowstone National Park is globally treasured.

Two climate regimes

Yellowstone National Park is bisected by two climate regimes that will influence how and what changes here. *(Map, left.)* These regimes—summer-wet/winter-dry and summer-dry/winter-wet—are remarkably stable, as shown by pollen records extracted from lake sediments throughout the region. By painstakingly examining and identifying pollen from these cores, scientists have determined that Yellowstone's climate regimes have retained approximately the same boundaries since the end of the last glaciation, 13,000 to 14,000 years ago. They remained steady even when temperatures increased 12,000 to 6,000 years ago. This temperature increase equals what we are experiencing now, but over millennia instead of decades.

The northern part of the park, roughly following the southern limit of the northern range *(see map)*, is in a summer-wet/winter-dry climate regime. Moisture comes in the summer via monsoon systems that move north from the gulfs of Mexico and California, wrapping around the Absarokas into the northern range; and winter storms come from the Pacific. Sagebrush-steppe and grasslands characterize the habitat within this regime. Global climate change may increase summer precipitation within this area, but this may be offset by more rapid evaporation, resulting in a net decrease in moisture available to the ecosystem.

The rest of the park is in a summer-dry/winter-wet regime, influenced by the Pacific sub-tropical high-pressure system in summer and westerly storms in winter. Higher winter moisture used to translate into high snowpack, which provided conditions suitable for forests and their inhabitants. With climate change comes warmer winters and more rain, which will alter the habitat over time.

Although the climate regime boundaries might not change, the vegetation within these regimes will change due to the speed of change and increasing disturbances such as fire and insect infestations.

Fire

The general prediction for wildfire in the western United States calls for more intense fires, similar to those of 1988. However, the charcoal in lake sediment cores is telling a different story in Yellowstone. These records extend back 17,000 years, and were taken from Cygnet Lake on the Central Plateau. Charcoal from 8,000 years ago, when temperature increases equal what we are now experiencing, shows more frequent but smaller fires than today. Fuels, along with fire weather, determine fire size and severity: the stand-replacing fires of today open up the forests where stands have been burned, limiting fuels for the next fire. As a result, areas with frequent fires also tend to have small fires. Whether this holds true for the future remains to be seen.

Insect infestations

In the past, insect infestations were cyclical, following changes in weather. For example, trees defend themselves from pine bark beetles by exuding sap that traps or prevents them from lodging in the tree. During a drought, a tree cannot produce enough sap to defend itself, and so insects infest it. Once the drought ends, the tree resumes defending itself and the infestation eventually diminishes. In 2000, insect infestations began increasing in Yellowstone. In 2007, all four pine bark beetles and the spruce budworm were attacking trees—a circumstance never seen before. Scientists suspect climate change at work. *(See also Chapter 5.)*

Wetlands

Wetlands in Yellowstone are few and far between *(see Chapter 5),* and include small lakes and kettle ponds, which are already drying up. Scientists don't know how much ground-water recharge they will need to recover. However, precipitation and snowpack will likely continue to decrease, which will continue to decrease surface and ground water—and thus the lakes and ponds may not recover.

As wetlands diminish, sedges, rushes, and other mesic (water-loving) plants will lose habitat. In their place, grasses and other xeric (dry-loving) plants will increase. Amphibians and birds will also lose habitat.

Willows, however, seem to be thriving. Their growth since 1995 has been three times the average recorded in the 1980s. In part, this is due to the changes in precipitation, snowmelt, and growing season. With a longer growing period to produce energy, willows can meet their essential needs earlier in the season and thus produce more defensive chemicals earlier. They also now have more water earlier in the year because snowmelt occurs sooner, and rain has increased in May and June. This moisture increase occurs at a time most beneficial to their growth.

Wildlife

Climate-change effects on large mammals are harder to determine than for other animals, and predictions are not easy to find. In general, scientists seem to think ungulates depending on grasslands will be able to find suitable habitat. Other species might not be so fortunate.

Grizzly bears will have less of their most valuable foods: whitebark pine nuts, army cutworm moths, & cutthroat trout.

Canada lynx will have less habitat and food as snow cover decreases in amount and duration.

Wolverines will have less deep snow for dens where they find shelter and give birth.

An ironic twist

Yellowstone's thermophilic plants may provide clues to help scientists predict how plants will respond to global climate change. These plants are adapted to unusually high levels of CO_2. Scientists are studying these "carbon-philic" species to understand how they withstand such high amounts of carbon dioxide, and what this could mean for other plants in the future.

Change in Other Western National Parks

Gates of the Arctic and Yukon–Charley:
Caribou ranges and population size may become less predictable, affecting the diet and culture of native Alaskans who rely on them.

Katmai:
Ocean warming may drive salmon out of southern Alaska; warmer rivers may increase parasites of salmon unusable.

North Cascades:
Seventy to 90% of the snowpack could disappear by the end of this century, threatening winter sports and water supplies.

Olympic:
Warmer winters and more extreme precipitation events could increase winter flood risk.

Yosemite:
Warming and drought have made wildfire season longer and more damaging, and increased insect damage.

Sequoia/Kings Canyon:
Warmer temperatures will worsen smog; increasing wildfires will contribute more smoke and airborne particulates.

This information reprinted from Unnatural Disaster: Global Warming and Our National Parks *by the National Parks & Conservation Association.*

Climate-Friendly Parks

In 2002, the Park Service began a Climate-Friendly Parks Program to help parks measure and reduce their greenhouse gas emissions, evaluate their vulnerability to climate change, monitor for climate change effects, and educate visitors. Learn more at www.nps.gov/climatefriendlyparks.

Action in Yellowstone

Park employees and residents are reducing their emissions contributions through landmark recycling efforts, using biodiesel and ethanol in vehicles, and other changes. In 2006 alone, park employees reduced the CO_2 emissions from vehicles by 575.4 tons by using alternative fuels. *(See "Sustainable Practices," in this chapter.)*

At the policy level, park scientists and resource managers have collaborated with other federal agency staff, scientists from the U.S. Geological Survey and from universities, to develop a science agenda that will build a foundation for understanding how the ecological system will change as the climate changes and how management can mitigate these effects. *(See Chapter 2.)*

Emissions Inventories

In addition, the National Park Service, Forest Service, and U.S. Fish & Wildlife Service have inventoried the amount of greenhouse gas (GHG) emissions they produce in the Greater Yellowstone Ecosystem. Yellowstone National Park's inventory revealed:

- Electricity use is responsible for more than 60 percent of the GHG emissions because of the emissions created in producing the electricity (coal mines, power plants, etc.)
- Heating & cooling park buildings contributes 27 percent to GHG emissions
- Cars, trucks, heavy equipment, and other vehicles directly emit almost 13 percent of Yellowstone's greenhouse gases

Yellowstone's emissions are higher than other units and agencies because its operation is the largest among them.

As a result of completing the comprehensive GHG emissions inventory, the agencies are developing an action plan to reduce GHG emissions in all their operations across the entire ecosystem.

Outlook

Data from thousands of years to the present and more than 2000 scientists agree: Earth's climate is warming 40 times faster than any other period in the planet's history. Vegetation cannot keep up with this rapid rate of change. Many animals will not be able to either. And the vast majority of humans, who live within three meters of sea level, will find their homes and livelihoods at risk in the coming decades.

Many scientists believe we have a chance to slow climate change—if we stop increasing CO_2 emissions by 2017. The technology for this change exists, as does the technology to produce climate-safe energy and power.

Yellowstone National Park is planning to reduce its GHG emissions approximately 43% by 2020.

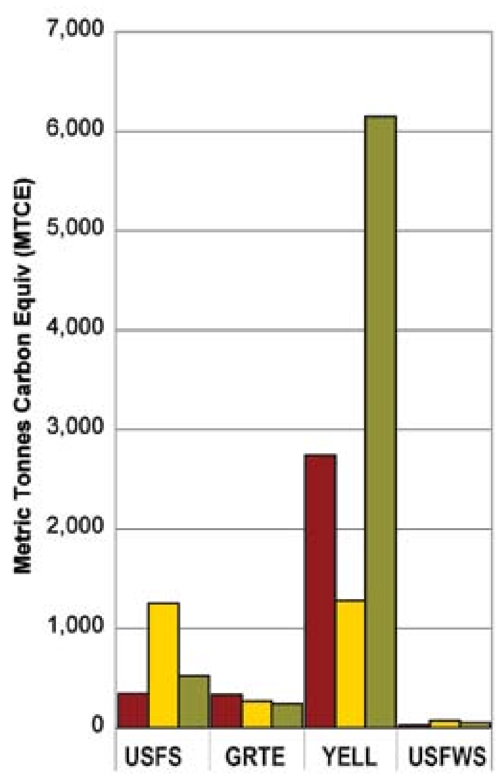
Greater Yellowstone Ecosystem Green House Gas Emissions

Purchased Electricity
Electricity purchased to power lights, computers, and other equipment. Emissions generated at the source of power, such as power plants.

Stationary Combustion
Energy-use on site, such as heating & cooling buildings. Emissions generated at the source of power.

Mobile Combustion
Emissions caused by motorized vehicles.

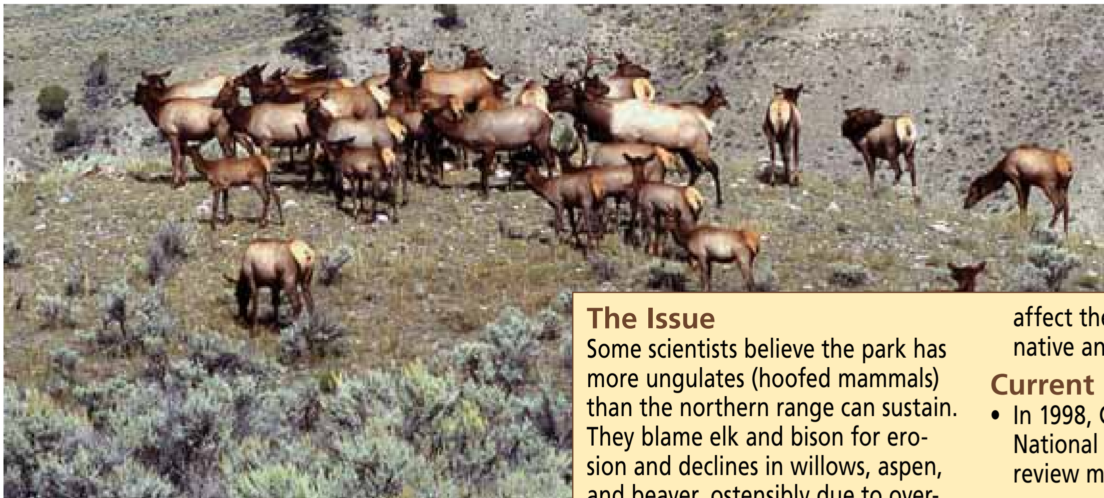
USFS 6 National Forests
GRTE Grand Teton National Park
YELL Yellowstone National Park
USFWS 2 national wildlife refuges



This chart adapted from a report by the National Renewable Energy Laboratory, Department of Energy.

8

Issues: Northern Range



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 are clear of snow, a result of wind and sun. Animals take advantage of this lack of snow, finding easy access to forage.

The Issue

Some scientists believe the park has more ungulates (hoofed mammals) than the northern range can sustain. They blame elk and bison for 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 the late 1960s 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 recent 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 60% since 1994.

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 over-grazing and overbrowsing, park managers removed ungulates—including elk, bison, and pronghorn—from the northern range by shooting or trapping from 1935 to the late 1960s. 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.

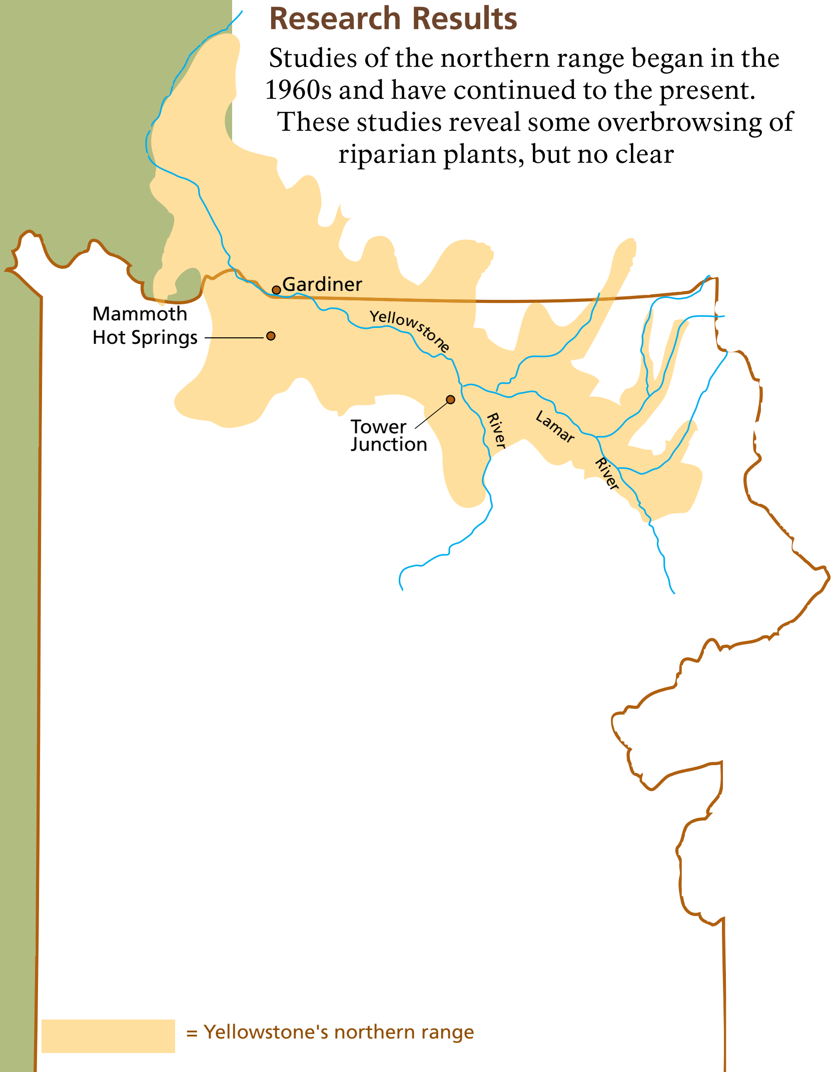
As the result of public pressure and changing NPS conservation philosophy, park managers ended elk removals in the late 1960s and let a combination of weather, predators, range conditions, and outside-the-park hunting and land uses influence elk abundance. Without any direct controls inside the park, 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 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 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 2008. 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 some hunters, outfitters, and state legislators: From 2002 to 2008, 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 the 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 establishment of sagebrush seedlings. 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.



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 background 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.

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.

Outlook

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.

See Chapter 2 for more about wolves affecting the ecosystem; and "Climate Change" in this chapter for its effects on this area.

8

Issues: Sustainable & Greening Practices

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 janitorial supplies and offers ethanol blended fuel to visitors.
- 2002: The park's diesel fleet converts to biodiesel; the Greater Yellowstone/Teton Clean Energy Coalition receives federal designation.
- 2003: Regional composting facility opens; park demonstrates the first fuel cell in a national park; park begins testing prototype alternatively fueled multi-season vehicles.
- 2004: Park employees begin using hybrid vehicles; Xanterra employee housing receives LEED designation.
- 2006: 70% of all garbage in the park is diverted away from a landfill through recycling & composting.
- 2007: Park completes a greenhouse gas inventory, leading to initiatives to reduce greenhouse gas emissions; interns begin gathering data for sustainability efforts; 75% of the park's waste stream is diverted from landfills.

2009 recycling in the park:

newspapers, magazines, office paper: 87 tons
aluminum & steel: 14 tons
glass: 178 tons
plastics: 41 tons
cardboard: 270 tons

In addition, annually in Yellowstone:

- 300 vehicles use more than 156,000 gallons of biodiesel fuel
- 350 vehicles use more than 193,000 gallons of ethanol blended fuel
- 1237 tons of food waste and other garbage are composted

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 biodiesel fuel. Since then, the park and various partners have addressed a variety of sustainable and greening issues to increase environmental conservation in the park and surrounding communities.

Meeting to "Green" Yellowstone

Yellowstone National Park, the states of Montana and Wyoming, the U.S. Department of Energy (DOE), and private groups hosted three-day conferences in October 1996 and May 1998. Participants developed a vision for sustaining the park's values and improving environmental quality. They considered 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. In 2003 and 2007, Yellowstone hosted additional greening conferences that highlighted environmental stewardship and successes in the region, and identified future initiatives.

Walking on Sustainability

Yellowstone has more than 15 miles of wood boardwalk, most of which are several decades old. As these walkways age, toxic chemicals from wood preservative leach into the ground and water. To reduce this pollutant, the park is replacing wood walkways with boards made of recycled plastic. This effort began in 1998 when Lever Brothers Company donated plastic lumber for the viewing platform around Old Faithful geyser. The lumber used the equivalent of three million plastic milk jugs. Now visitors receive an educational message about recycling while waiting for the world's most famous geyser eruption.

Today the park continues to replace old boardwalks with recycled plastic lumber, which decreases toxic chemicals in the park, lengthens the life of the walkways, and saves natural resources and money.

Driving Sustainability

Yellowstone National Park offers an opportunity to demonstrate alternative fuels in an environmentally sensitive and extremely cold area. Beginning in 1995, the National Park Service, the Montana Department of Environmental Quality (DEQ), DOE, and the University of Idaho began testing a biodiesel fuel made from canola oil and ethanol from potato waste. Dodge Truck

Inc. donated a new three-quarter ton 4x4 pickup to the project. The truck has been driven more than 200,000 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. The truck is still being used in the park.

The park also provides ample opportunity to test and use alternative fuels because its employees drive almost four million miles a year. 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 visitors at park service stations.

In 2004, the park's hybrid fleet began with four models donated by Toyota USA. They operate with electricity generated by the gasoline engine and its braking system. They conserve gas, reduce emissions, and run quietly when using electricity. The park now operates 17 hybrid vehicles.

In 2008, Michelin North America donated $50,000 worth of tires for the Yellowstone National Park fleet to test. These tires are designed to increase fuel efficiency and to last longer than other tires.

Building Sustainability

Yellowstone's buildings present opportunities for incorporating sustainable building materials and techniques as they are maintained, remodeled, or replaced. 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. *(See this and next page.)*
- 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.

"Green" Cleaning Products

In August 1998, the U.S. Environmental Protection Agency helped Yellowstone National Park assess its cleaning products. They found some products with slightly toxic ingredients and others with potentially significant health hazards. As a result, the park switched from more than 130 risky products to less than 10 safe products. 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 are testing and installing alternative renewable energy sources for various uses in the park. The Lamar Buffalo Ranch now meets 80 percent of its energy needs with a solar array. The Lewis Lake Contact Station and ranger residence also use solar energy, reducing the use of a polluting propane generator. Fuel cells, which convert hydrogen into power and don't need battery storage, have been tested as a source of electricity to the West Entrance Station. The park is also experimenting with producing biofuels from food waste. In 2007, it demonstrated a generator that produced electricity using 100 percent vegetable oil.

Recycling and Composting

In 1994, a study was done in Yellowstone National Park showing 60–75 percent of

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*
- *Landscaping with Yellowstone-produced compost*

Geothermal energy may seem like an obvious resource in the Yellowstone area—but its use could destroy the geysers and other hydrothermal features protected here. Other geysers in the world have been destroyed by geothermal energy development.

Greening the new Old Faithful Visitor Education Center

Features include:
- *a design that reduces heated space in winter*
- *water-conserving fixtures*
- *displays and programs about sustainable practices*
- *unobtrusive, down-directed exterior lighting*

The new Old Faithful Visitor Education Center, opening August 2010, is designed to achieve Gold level LEED certification (see previous page).

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 today transforms 60 percent of park's solid waste into valuable soil conditioner.

Another regional partnership that includes Yellowstone National Park is the Headwaters Cooperative Recycling Project, which is expanding recycling in the park and surrounding communities. For example, it has placed recycling bins for glass, plastic, paper, aluminum, and cardboard throughout the park.

In 2005, Yellowstone became the first national park to recycle small propane cylinders, such as those used for lanterns and some camp stoves. Now, more than 15,000 cylinders are 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—some 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 Energy Coalition

The Greater Yellowstone/Teton Clean Energy Coalition, which is part of the federal Clean Cities Coalition, promotes alternative, cleaner fuels. Its goals include:

- substantially reducing particulate matter entering the atmosphere
- educating and promoting the advancement of renewable fuels
- reducing dependency on fossil fuels
- setting an example of environmental stewardship

Projects 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 have made corporate commitments to an environmental management system (EMS) that meets international business standards for sustainability.

Ecologix: Xanterra Parks & Resorts

Xanterra, which provides lodging and other guest services in the park, calls its

EMS "Ecologix." It encourages employees to develop and implement sustainable practices such as:

- Replaced thousands of incandescent bulbs with efficient compact fluorescent lighting.
- Replaced two-stroke engines of rental boats and snowmobiles with cleaner burning and more efficient four-stroke engines.
- Recycle used motor oil, cooking oil, electronics, automotive batteries, antifreeze, and paint solvents.
- Use bleach-free paper products containing 100 percent post consumer content and soy-based inks for most printed materials.
- 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 foods including pork from pigs and beef from cattle raised without hormones or antibiotics in humane facilities.
- Offer a variety of environmentally-friendly products in its retail outlets as part of its "Sustain the Earth Campaign," including products made from recycled fabric, glass, paper, and wood.

In 2008, Xanterra began supplying guests in its lodging facilities with more sustainable toiletries, including products packaged in a corn-based biodegradable material, which annually diverts an average of 280,000 plastic bottles from the landfill.

Xanterra and the NPS collaborated on building two new employee housing units to LEED standards. *(See page 181.)* The homes are constructed to reduce energy consumption (such as using R38 walls, Energy Star appliances, double pane windows, solar panels) and water consumption (two-button low-flush toilets, efficient fixtures), and to use post-consumer content materials. The solar panels produce 5 million btu in electricity annually.

GreenPath: Delaware North

Delaware North Companies, which operates twelve general stores in the park, calls its EMS "Green Path." This EMS was the first in Yellowstone to attain ISO 14001 Registration, which means it exceeds strict environmental standards recognized internationally. Practices include:

- Purchase responsibly wherever possible. For example, using biodegradable dishware and cutlery in food service operations, which are then composted at a local facility.
- Conserve energy by bringing hybrids into its fleet of vehicles.
- Conserve water by installing low flow showerheads, kitchen sprayers, waterless urinals, and toilets.
- Eliminate the use of hazardous materials and waste where possible. For example, chemical film processing was replaced with digital photo processing, eliminating the use of many chemicals and the generation of hazardous waste.
- Operate an aggressive recycling program, annually collecting over 120 tons from over 22 different types of materials.
- Incorporate environmentally friendly materials and practices when remodeling the stores, while maintaining the integrity of historic structures.
- Partner with the NPS, other concessioners, nonprofit organizations, and others to improve environmental efforts in the greater Yellowstone area.
- Train seasonal associates to carry out the program and educate visitors at each store.

The YES! Initiative

In 2007, in concert with the Yellowstone Park Foundation, the park launched the "Yellowstone Environmental Stewardship (YES!) Initiative." YES! is a multi-year plan to elevate the park as a worldwide leader in operational environmental stewardship. This program enables Yellowstone to build upon its sustainability successes to further reduce the ecological footprint of its operations and decrease consumption of natural resources.

YES! intends to achieve the following goals by 2016:

- reduce greenhouse gas emissions by 30%
- reduce electricity consumption by 15%
- reduce fossil fuel consumption by 18%
- reduce water consumption by 15%
- divert 100% of solid waste from landfills

8 Issues: Wilderness

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 untrammeled 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

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 13% of backcountry users travel with boats and 17% travel with stock.
- During 2007: 16,360 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 does not yet have a wilderness plan to manage wilderness within the park.

Yellowstone National Park has always managed its backcountry to protect natural and cultural resources and to provide 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, the Secretary of the Interior 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 the 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 the 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 the 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 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
- 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 give significantly more weight than, economic efficiency and convenience. If wilderness resource or character impact is unavoidable, the only acceptable actions are those preserving wilderness character or having localized, short-term adverse impacts.

Wilderness Designation and Current Practices in Yellowstone

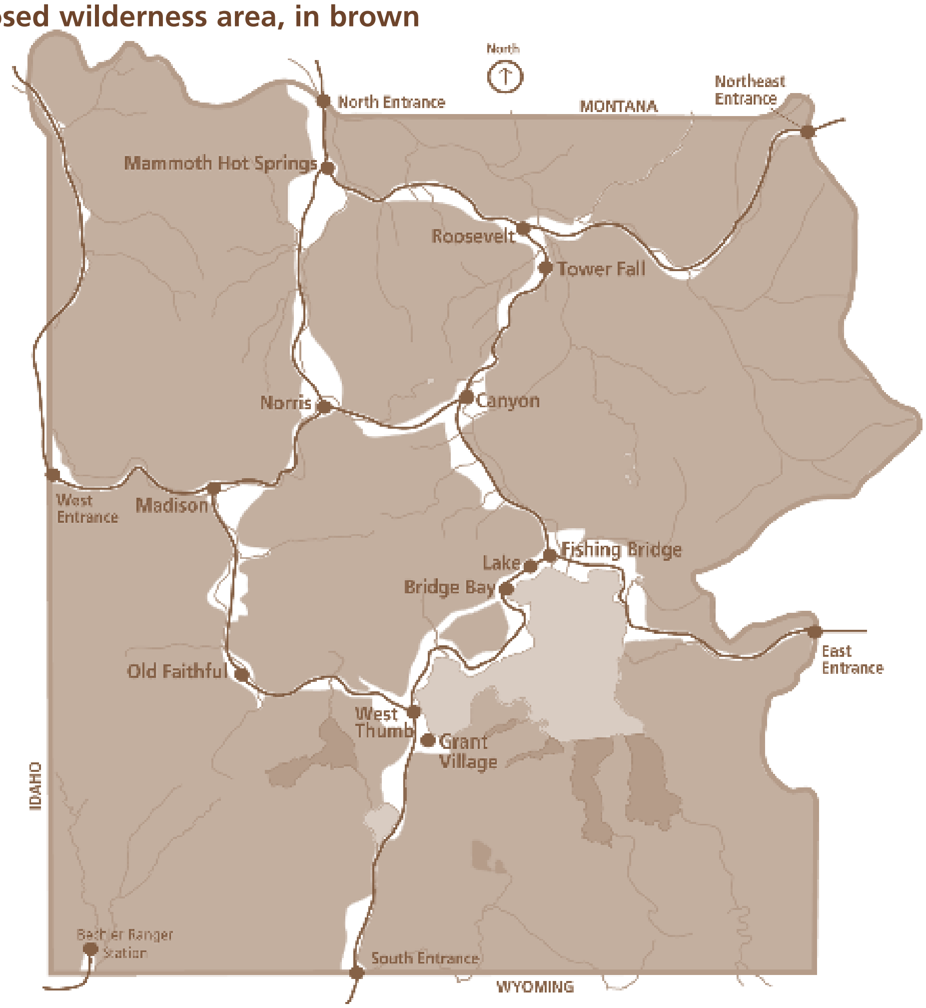
As managers develop a wilderness plan for Yellowstone, they must determine how current practices in the park will be handled within the proposed wilderness areas:

- 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 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.

Proposed wilderness area, in brown



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.

8

Issues: Winter Use

The Issue

We have debated appropriate winter use in Yellowstone for over 75 years.

Winter Use Goals

- Provide a high quality, safe and educational winter experience.
- 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.

History: *See also timeline*

1932: First request to park managers to plow roads year-round.

1949: First visitors using motorized oversnow vehicles (snowplanes).

1955: Snowcoaches enter the park.

1963: First snowmobiles (six, total) enter the park.

1967: Congressional hearing held on plowing park roads year-round.

1968: Yellowstone managers decide to formalize over-snow use instead of plowing.

1971: Managers begin grooming roads and Yellowstone Park Co. opens Old Faithful Snowlodge.

1990: NPS issues first winter-use environmental assessment (EA) for Yellowstone and Grand Teton.

1997: NPS is sued by groups who believe bison used groomed roads to leave the park, which led to their slaughter. NPS must develop a new winter-use environmental impact statement (EIS).

1999: Draft EIS released; ±46,000 public comments received.

2000: Final EIS released, banning snowmobiles and converting to snowcoach-only transportation.

2000, December: Snowmobile group files suit challenging the ban.

2001: NPS settles with snowmobilers' group by agreeing to prepare a supplemental EIS (SEIS).

2002: Draft SEIS released; ±357,000 comments received.

2003, December 11: Final rule published in *Federal Register* to allow 950 Best Available Technology (BAT), guided snowmobiles daily.

2003–2004: Federal court decisions void previous decisions. NPS writes a new EA, allowing 750 BAT, guided snowmobiles daily; 95,000 comments received.

2004–2007: Winter use proceeds per the 2004 EA.

2007: *Winter Use Plans EIS* released, which allows 540 BAT, guided snowmobiles in the park daily; 122,000 comments received; final rule published in December.

2008, September–December: Federal court decisions cancel the new winter plan.

2008, December 15: Winter season opens with a modified version of the winter plan followed in 2004–2007, allowing 720 BAT, guided snowmobiles daily.

2009, Interim winter-use plan for the next two winters allows 318 BAT, guided snowmobiles and 78 snowcoaches daily; a new EIS for long-term winter use in Yellowstone National Park is being drafted.

Updates: www.nps.gov/yell/planyourvisit/winteruse.htm

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), its interested observers, and park users have formally debated what Yellowstone should look and be like in winter.

Beginning in the early 1930s, communities around the park began asking the NPS to plow Yellowstone's roads year-round so tourist travel and associated spending in their communities would be stimulated. Each time, the NPS resisted, citing non-winterized buildings, harsh weather conditions, and roads too narrow for snow storage. Meanwhile, snowbound entrepreneurs in West Yellowstone began experimenting 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 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 dominant way to tour the park in winter.

Still, pressure to plow park roads persisted, and Yellowstone authorities knew that they could not accommodate both snowmobiles and automobiles. The matter culminated in a congressional hearing in Jackson, Wyoming, in 1967. By this time, park managers felt plowing would dramatically alter the look and feel of the park's winter wilderness. They thought snowmobiles offered a way to accommodate visitors while preserving a park-like atmosphere. Thus, an oversnow vehicle program was formalized. In 1971, park managers began grooming snowmobile routes to provide smoother, more comfortable touring, and also opened Old Faithful Snowlodge so visitors could stay overnight at the famous geyser.

Throughout the 1970s, 80s, and early 90s, visitation by snowmobile grew consistently. This brought unanticipated problems such as 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. The threshold of 143,000 visitors was exceeded in the winter of 1992–1993, eight years earlier than the plan predicted.

According to the 1990 plan, then, the NPS began an analysis of all types of winter recreation on all NPS and Forest Service (USFS) lands in the greater Yellowstone area. Park and forest staff used 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.

Unfortunately, the assessment did not change conditions in the parks. By the late 1990s, an average of 795 snowmobiles entered the park each day. All were two-stroke machines, which used a mix of oil and gas for combustion, resulting in high levels of pollution. Carbon monoxide pollution was especially severe, coming close to violating the Clean Air Act's standards at the West Entrance in one event. Particulate and some hydrocarbon levels were also high. Two-stroke machines were also loud, making it difficult to experience natural silence in the Firehole Valley on many days. Visitors traveling by snowmobile lacked the experience necessary to pass bison and other wildlife without causing harassment. Complaints about these conditions became common.

A Decade of Planning & Litigation

The winter of 1996–1997 was one of the three harshest winters of the 20th century, with abundant snow, cold temperatures, and a thick ice layer in the snowpack. Unable to access the forage under the ice, 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. *(See the section on bison management in this chapter.)* Concerned that groomed roads increased the number of bison leaving the park and being killed, the Fund for Animals and other groups filed suit in the U.S. District Court for the District of Columbia against the NPS in May 1997. The groups alleged that the NPS had failed to examine the environmental impacts of winter use. In 1999, Bluewater Network filed a legal petition with the NPS to ban snowmobiles from all national park units nationwide. These two actions inaugurated a decade of winter use planning and associated lawsuits, and catapulted the issue into one of the NPS's most visible and enduring environmental controversies.

The table on the next page summarizes the winter-use environmental documents produced by the NPS since 1998, along with the decisions, the number of comments

1992	Winter visitation exceeds threshold of 140,000 people per year, 8 years earlier than expected.
1993	NPS begins to evaluate winter recreation in the greater Yellowstone area.
1997	Fund for Animals files lawsuit; results in NPS agreeing to develop a new winter use plan and EIS.
1999	Draft EIS released. Bluewater Network and other organizations petition to prohibit trail grooming and snowmobile use in all national parks.
2000	Final EIS released and Record of decision signed. Snowmobile group sues to stop this winter plan.
2001	Snowmobilers lawsuit settled, which requires NPS to prepare SEIS.

Concerns Raised by the Public

overcrowding

visitor impacts on natural resources

noise & air pollution

availability of facilities and services

restricting snowmobiles, including requiring guides

restricting snowmobiles on side roads

importance of winter visitation to the local and regional economy

wildlife using groomed roads

displacing wildlife

health & human safety

received from the public, the associated litigation, and the legal outcomes. Each document was a product of its era, reflecting the state of scientific knowledge, technology, and sociopolitical climate. The first draft EIS (in 1999) proposed plowing the road from West Yellowstone to Old Faithful. Public comment did not favor plowing, and unmanaged snowmobile use was deemed to impair park resources. Therefore, park managers opted to ban snowmobiles and allow only snowcoaches in the final EIS. At the time, Best Available Technology (BAT) snowmobiles were not commercially available.

Since that EIS, environmental documents have proposed addressing the winter-use problems using a combination of new technologies, limits on vehicle numbers, mandatory guiding, and monitoring winter-use impacts on park resources. All documents proposed allowing a combination of snowmobiles and snowcoaches, with the snowmobile numbers decreasing from plan to plan and snowcoach numbers remaining consistent. By 2002, BAT snowmobiles were commercially available; these machines used new technologies to dramatically reduce emissions and somewhat reduce noise. Requiring visitors to tour with snowmobile guides or in commercially guided snowcoaches reduced the conflicts with wildlife. Resource monitoring allowed the NPS to gauge the effects of these actions

Year	Action: Decision	Number of Public Comments	Lawsuit Brought By	Legal Outcome
1998	EA: Do not close Hayden Valley to study bison use of groomed roads	2,742	Fund for Animals (FFA)	Upheld by U.S. District Court for the District of Columbia (D.C. Court)
2000	EIS: Ban Snowmobiles in favor of snowcoaches	46,000	State of Wyoming, International Snowmobile Manufacturer's Association (ISMA), and BlueRibbon Coalition (BRC)	Vacated by U.S. District Court for the District of Wyoming (Wyoming Court)
2003	SEIS: Allow 950 Snowmobiles (all Best Available Technology [BAT]; all guided)	357,000	Greater Yellowstone Coalition (GYC) and FFA	Vacated by D.C. Court
2004	EA: Allow 720 Snowmobiles (all BAT; all commercially guided) (valid only through 2006-2007)	95,000	ISMA, State of Wyoming, Wyoming Lodging and Restaurant Association, and FFA	Upheld by Wyoming Court; not ruled upon in D.C.; reinstated in 2008 and still being challenged
2007	EIS: Allow 540 Snowmobiles (all BAT; all commercially guided)	122,000	State of Wyoming, ISMA, GYC, and National Parks Conservation Association	Vacated by D.C. Court. Wyoming court would have upheld the EIS; the NPS reinstated 2004 rule to provide certainty for winter visitation in the winter of 2008-09.
2008	EA: Allow 318 snowmobiles (all BAT; all commercially guided)	27,000		Pending

2002
Draft SEIS released; >350,000 comments received.

2003
March: Record of decision signed.
Dec 11: Final rule published in Federal Register.
Dec 16: Federal judge directs YNP to begin phasing out snowmobiles.

2004
Feb: Another federal judge stops phase-out; requires temporary rules for rest of winter.
Aug: EA for temporary winter plan released.
Nov: Plan approved.

2007
March: Draft FEIS released; 122,000 comments.
Dec.: Final rule published in Federal Register.

2008
Courts stop new winter plan.
Dec. 15: Winter season opens using modified plan from 2004–2007.

2009
Dec. 15: Winter season opens under Interim Winter Use Plan
New winter use EIS process will begin in 2010.

and take further protective actions. These changes largely eliminated the problems of the past.

Each of the winter use plans was litigated. The Fund for Animals, the Greater Yellowstone Coalition, and other environmental groups consistently sue in the U.S. District Court for the District of Columbia. The International Snowmobile Manufacturer's Association, the State of Wyoming, the BlueRibbon Coalition, and others consistently file their lawsuits in the U.S. District Court for the District of Wyoming. Litigants have found some traction in each of their courts, with varying degrees of success on any given environmental document. Certainly, the litigation is one of the factors accounting for the ongoing nature of the winter use debate. In each decision against it, the NPS has responded by addressing the concerns of the courts.

Improving Conditions in the Parks

With the conversion to BAT snowmobiles, mandatory guiding, and limited numbers of snowmobiles, conditions in the park dramatically improved. The number of snowmobiles per day averaged 296 for the winters of 2006–07 and 2007–08, while the daily average of snowcoaches increased from 15 in the late 1990s to 35 for these two winters. (Peak use those winters was 557 snowmobiles and 60 snowcoaches.) In 2008–2009, with legal uncertainties and the economic downturn, use dropped to an average of 205 snowmobiles and 29 snowcoaches per day.

When measured in commercially-guided groups, snowmobile and snowcoach use levels are similar. In 2007–2008, for example, there was an average of 36 snowmobile groups per day and 9.3 people per group. Snowcoaches averaged 35 per day and 8.8 people per coach.

Overall, the number of oversnow visitors is lower than historic levels, though visitors entering the North Entrance by car have

increased from an average of 40,000 to over 50,000 each winter.

Levels of carbon monoxide and particulates fell dramatically with conversion to BAT snowmobiles and reduced vehicle numbers. Hydrocarbon and air toxic concentrations are also no longer a concern, with the possible exception of formaldehyde and benzene levels, which are being closely monitored. BAT snowmobiles and snowcoaches produce a similar amount of air pollution on a per passenger basis.

Noise levels also have fallen somewhat. Although snowmobiles and snowcoaches are commonly heard during certain periods of the day, their noise is absent during other times—even in developed areas like Old Faithful and along busy corridors like the West Entrance Road. Oversnow vehicles are audible 67 percent of the day at Old Faithful and 54 percent of the day at Madison Junction, on average. (NPS vehicles account for approximately one-fourth of this noise.) In a new long-term plan, the NPS hopes to implement BAT requirements for snowcoaches, which will reduce noise even more. Snowcoaches account for 94 percent of the

Situation & Outlook

loud oversnow vehicles. Guided snowmobile groups and snowcoaches contribute nearly equally to the percent of time oversnow vehicles are heard.

Making all visitors use a commercial guide has nearly eliminated wildlife harassment. Guides enforce proper touring behaviors, such as passing wildlife on or near roads without harassment and ensuring that wildlife do not obtain human food. Monitoring indicates that snowcoaches have a slightly higher probability of disturbing wildlife than do snowmobiles.

With commercial guiding has come a 50 percent reduction of law enforcement incidents, even when accounting for the drop in visitation. Arrests have virtually disappeared. Calls for medical assistance are the only statistic that has increased since the conversion to mandatory guiding.

The recent science on winter use indicates park resources are in very good condition. For each topic monitored, the NPS now understands that both snowmobiles and snowcoaches are contributing similarly to the measured impacts of winter use. The perception that snowmobiles are contributing to the vast majority of observed effects, and that those effects would greatly diminish with snowcoaches only, is not supported by the research. When managed, as they have been for the past five winters, both modes of transportation provide opportunities for visitors to enjoy the park. Each can offer different experiences for visitors, just as cross-country skiing, snowshoeing, and walking offer different opportunities for visitors to enjoy the park in the winter.

Visitor Survey Results

The University of Montana conducted a survey of winter visitors in 2007–2008:

- Almost 90% of those surveyed agreed that Yellowstone is a place for natural quiet and to hear natural sounds.
- 83% were somewhat or very satisfied with their experience of natural sounds.
- 71% indicated that they found the level of natural sound they desired for half or more of the time they desired it.
- 87% were “very satisfied” with their overall experience.
- The remaining 13% were “satisfied.”
- 71% considered the opportunity to view bison to be extremely important.
- 87% reported that this aspect of their Yellowstone winter experience was very satisfying.
- 99% who saw bison in winter were able to see them behaving naturally.
- 21% witnessed an encounter where the bison were hurried, took flight, or acted defensively.
- More than 72% largely considered the bison-human interactions they witnessed and the park setting as a whole as “very” appropriate and/or acceptable.

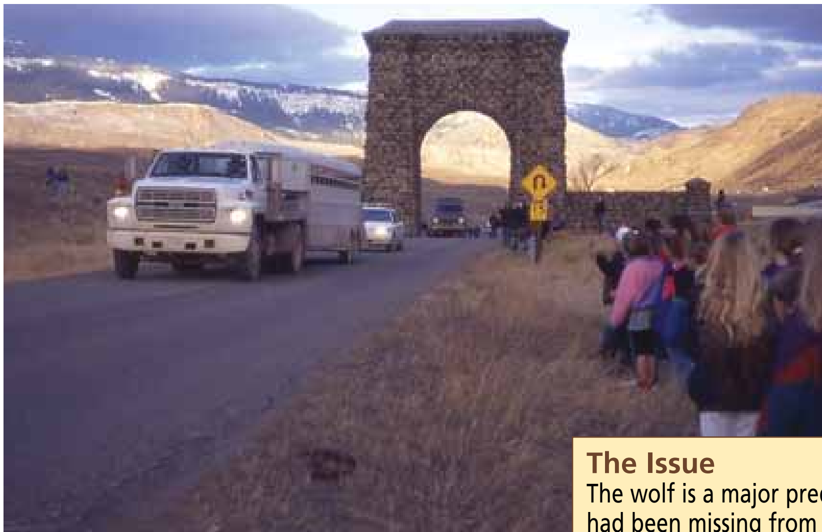
Current Situation & Outlook

As expected, litigation continues. In 2008, the Wyoming Court reinstated the 2004 rule, and Yellowstone operated under this rule for the winter of 2008–2009, which allowed up to 720 BAT, commercially guided snowmobiles and 78 snowcoaches per day. This reinstated rule has been challenged in both the U.S. District Court for the District of Columbia and the United States Tenth Circuit Court of Appeals. As of November 2009, both cases are pending.

In 2008 and 2009, the NPS proceeded to implement the Interim Winter Use Plan for Yellowstone National Park. The plan allows up to 318 commercially guided, BAT snowmobiles and up to 78 commercially guided snowcoaches a day in the park for the 2009–2010 and 2010–2011 winter seasons. It also continues to provide for motorized oversnow travel over Sylvan Pass and the East Entrance Road.

During the next two years, the NPS will prepare a new EIS and a new longterm plan for winter use in Yellowstone National Park, using the best available science and working with all stakeholders during the process.

Yellowstone is clearly cherished by much of the public, portions of whom have strong opinions about appropriate park policies. As the NPS looks to the future, the agency maintains its commitment to the winter use goals listed in the summary box. The park will be open for winter use and the agency welcomes all to visit and to participate in the discussions about future winter use management.



Welcoming the wolves on January 12, 1995.

8

Issues: Wolf Restoration

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 the 1970s 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 the 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.

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, are routinely killed in Yellowstone.
1926: The last wolf pack in Yellowstone is killed, although reports of single wolves continue.
1974: The gray wolf is listed as endangered; recovery is mandated under the Endangered Species Act.
1975: The long process to restore wolves in Yellowstone begins.
1991: Congress appropriates money for an EIS for wolf recovery.
1994: EIS completed for wolf reintroduction in Yellowstone and central Idaho. More than 160,000 public comments received—the largest number of public comments on any federal proposal at that time.
1995 and 1996: 31 gray wolves from western Canada relocated to Yellowstone.
1997: U.S. District Court judge orders the removal of the reintroduced wolves in Yellowstone, but stays his order, pending appeal.
2000: January, the decision is reversed.
1995–2003: Wolves prey on livestock outside Yellowstone much less than expected: 256 sheep, 41 cattle
2005: Wolf management transfers from the federal government to the states of Idaho and Montana.
2008: Wolf populations in Montana, Idaho, & Wyoming removed from the endangered species list, then returned to the list.

Current Status

- As of January 2010, 400–450 wolves live in the greater Yellowstone area.
- ±120 wolves live in Yellowstone National Park.
- The leading natural cause of mortality in Yellowstone National Park is wolves killing other wolves.
- Researchers are studying the impact of wolf restoration on cougars, coyotes, bears, and elk.
- Wolf populations in Montana & Idaho have been removed from the federal endangered species list.
- Wolf populations in Wyoming (including Yellowstone's) remain on the federal endangered species list. A legal challenge to this decision is in the courts.

1991–94 — *EIS process for wolf restoration in Yellowstone and central Idaho. More than 160,000 comments received.*

1995–96 — *31 wolves from Canada relocated to Yellowstone.*

2002 — *States begin process to remove wolves from the endangered species list.*

2005 — *Day-to-day wolf management transferred to Montana and Idaho. Population in park drops by 1/3 due mostly to disease killing 2/3 of the pups.*

2008 — *March: removed from endangered species list. July: returned to the list. Disease kills all but 22 of the year's pups.*

2009 — *Wolves removed from endangered species list in Montana & Idaho, but not Wyoming.*

Released from the cage into the pen.

One of the reintroduction pens remains standing. Park managers are discussing if it should be left as a historic site or taken down to return the site to its natural condition.

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 wanted isolation from each other.

Relocation & Release

In late 1994 and 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 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 how much wolves saw of 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 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 initially decreased the number of coyotes inside wolf territories, which may have benefited other smaller predators, rodents, and birds of prey.

So far, data suggests wolves are contributing to decreased numbers of elk calves surviving to adulthood and decreased survival of adult elk. 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 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. Results to date indicate the effects of wolf predation on elk population dynamics range from substantial to quite modest.

See Chapter 2 for more information on changes to the ecosystem.

Delisting

Delisting

The biological requirement for removing the wolf from the endangered species list has been achieved: Approximately 300 wolves and three years of 30 breeding pairs across the three recovery areas. The USFWS also has approved the wolf management plans of Idaho, Montana, and Wyoming. As a result, in 2008, the USFWS delisted the wolves in these three states, and in Yellowstone and Grand Teton national parks. Several environmental groups sued to stop the delisting. They argued that a genetically viable wolf population had not developed in the GYE beyond the national park, and that the Wyoming wolf management plan was flawed because it allowed wolves outside the GYE to be shot on sight as predators. A court decision required the wolf be listed again as an endangered species. In 2009, the USFWS again delisted the wolf populations in Montana and Idaho, but not in Wyoming. A legal challenge to this delisting is pending.

Outlook

The wolves' future is secure. Approximately 1600 wolves live in the three-state area—well above the minimum delisting requirements. Yellowstone National Park's wolf population declined in 2008 and 2009, likely a natural adjustment to the available food supply. The Yellowstone wolf population is not in danger.

8

For More Information

www.nps.gov/yell

www.greateryellowstonescience.org/index.html

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.

Site Bulletins, published as needed, provide more detailed information on park topics such as bioprospecting and wolf restoration. Free; available upon request from visitor centers.

Aquatic Invaders

Staff reviewer: Todd M. Koel, Supervisory Fishery Biologist

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Bioprospecting

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Bison Management

Staff reviewer: Rick Wallen, Bison Ecology & Management

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Sustainability

Staff reviewers: Jim Evanoff, Mary Murphy

www.nps.gov/yell

www.ypf.org

Wilderness

Staff reviewers: Ivan Kowski, Backcountry Program Manager; Dan Reinhart, Supervisory Resource Mgt. Specialist

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