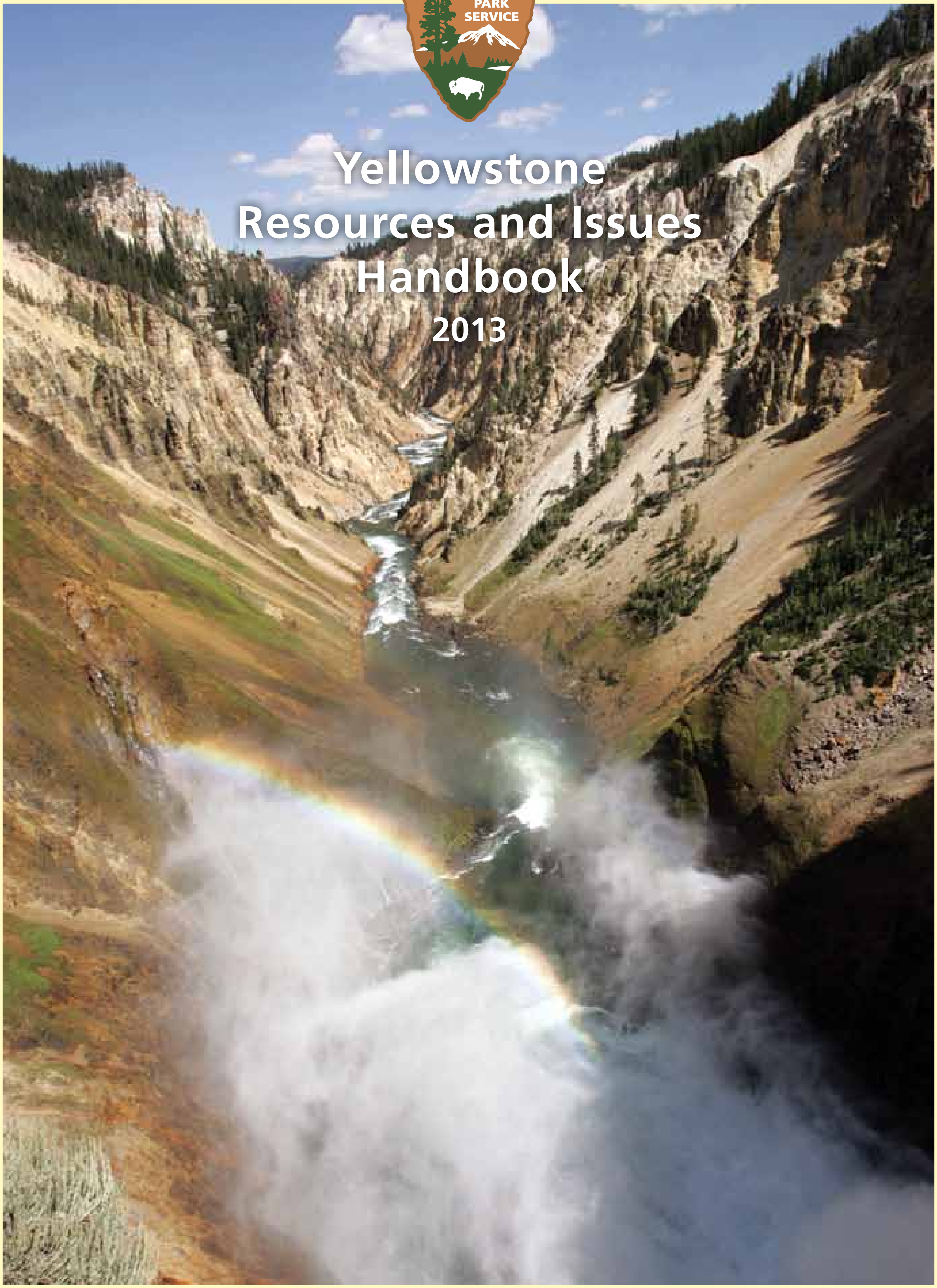

Yellowstone Resources and Issues Handbook

2013

U.S. Department of the Interior • National Park Service • Yellowstone National Park

Yellowstone Park and Protection Act

In 1872, the U.S. Congress established Yellowstone National Park. The Yellowstone National Park Protection Act states, "the headwaters of the Yellowstone River…is hereby reserved and withdrawn from settlement, occupancy, or sale…and dedicated and set apart as a public park or pleasuring-ground for the benefit and enjoyment of the people."

The Organic Act of the National Park Service

On August 25, 1916, President Woodrow Wilson signed the act creating the National Park Service, a federal bureau in the Department of the Interior. The Organic Act of the National Park Service states "the Service thus established shall promote and regulate the use of Federal areas known as national parks, monuments and reservations…by such means and measures as conform to the fundamental purpose of the said parks, monuments and reservations, which purpose is 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."

ON THE COVER

Grand Canyon of the Yellowstone as seen from Brink of the Lower Falls, August 2005.

NPS / JIM PEACO

Yellowstone Resources and Issues Handbook

2013

An annual compendium of information about Yellowstone National Park

U.S. Department of the Interior • National Park Service • Yellowstone National Park
Yellowstone National Park, Wyoming 82190

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Emily Yost, editor and designer
Tami Blackford, managing editor
Linda Young, executive editor

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www.yellowstoneassociation.org

Contents

Yellowstone National Park, the world's first national park, is named after the Yellowstone River.

Welcome

Yellowstone National Park is as wondrous as it is complex. The park has a rich history of human and ecological stories that continue to unfold. When Yellowstone was established as the world's first national park in 1872, it sparked an idea that influenced the creation of the National Park Service and the nearly 400 sites across the United States it protects today. Yellowstone National Park also forms the core of the Greater Yellowstone Ecosystem. At 28,000 square miles, it is one of the largest intact temperate-zone ecosystems on Earth. The park continues to influence preservation and science, and we are pleased to share its stories with you.

Many people have dedicated their lives and careers to studying Yellowstone and the park has a long history of study and public interest. This compendium is intended to help you understand the important concepts about its many resources and contains information about the park's history, natural and cultural resources, and issues. Each chapter is edited and carefully reviewed for accuracy and relevance.

In addition to the references listed for each topic covered in this handbook, here are some interdisciplinary sources. For updates and more detailed information, visit:

- www.nps.gov/yell
- www.greateryellowstonescience.org
- *Yellowstone Science*, free from the Yellowstone Center for Resources, in the Yellowstone Research Library, or online at www.nps.gov/yell.
- The park newspaper 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.
- Trail guides, available at all visitor centers and most viewpoints. A 50-cent donation is requested.

Park Facts

Yellowstone National Park was established on March 1, 1872.

Yellowstone is the world's first national park.

GEOGRAPHY

3,472 square miles (8,987 km^2)
2,221,766 acres or 899,139 hectares. *Note: No area figures have been scientifically verified. Efforts to confirm the park's total 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 feet (3,462 m; Eagle Peak)
Lowest Point: 5,282 feet (1,610 m; Reese Creek)
Larger than Rhode Island and Delaware combined
About 5% 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 daily, at Mammoth:
January: 9ºF (–13ºC)
July: 80ºF (27ºC)
Records:
High: 99ºF (37ºC), 2002 (Mammoth)
Low: –66ºF (–54ºC), 1933 (West Entrance, Riverside Station)

Yellowstone Lake

131.7 square miles of surface area (341.1 km^2)
141 miles of shoreline (227 km)
20 miles north to south (32 km)
14 miles east to west (22 km)
Average depth: 140 feet (47 m)
Maximum depth: 410 feet (125 m)

GEOLOGY

An active volcano
One of the world's largest calderas at 45 x 30 miles (72 x 48 km)
1,000–3,000 earthquakes annually
More than 10,000 hydrothermal features
More than 300 active geysers
About 290 waterfalls
Tallest waterfall near a road: Lower Falls of the Yellowstone River at 308 feet (94 m)

WILDLIFE

67 species of mammals, including:
7 species of native ungulates
2 species of bears
330 species of birds (150 nesting)
16 species of fish (5 nonnative)
More than 7 aquatic nuisance species (3 having significant detrimental effect)
4 species of amphibians
6 species of reptiles
2 threatened species: Canada lynx, grizzly bears (also: 1 proposed species, wolverines)

FLORA

7 species of conifers (more than 80% of forest is lodgepole pine)
1,150 species of native flowering species (3 endemic)
218 species of invasive plants
186 species of lichens

CULTURAL RESOURCES

26 associated Native American tribes
More than 1,700 archeological sites
More than 300 ethnographic resources (animals, plants, sites)
25 sites, landmarks, and districts on the National Register of Historic Places; many more eligible for listing
1 National Historic Trail
More than 900 historic buildings
More than 300,000 museum items, including 30 historic vehicles
Millions of archived documents
More than 20,000 books (many rare), manuscripts, periodicals

EMPLOYEES

National Park Service (July 2012)

Permanent (305 total)
Full time, year-round: 205
Subject to Furlough: 139
Part time: 6
Term (variable duration): 45
Seasonal: 439

Concessioners

About 3,200 people work for concessioners at summer peak

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
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 2011 (in millions)

Total: $66.4
Federal Funding
Congressional Annual Appropriations:
Operations and staff (base): $35.2
Wildland Fire: $1.5
Other Appropriations: $9
Other Funding
Donations and Grants: $1.3
Fees: $9.2
Reimbursable: $10.1

Distribution of Budget

Administration: 9% *Includes human resources, contracting, budget and finance, property management, telecommunications and information technology*
Facility Operations and Maintenance: 48% *Includes utilities, roads, trails, structures, historic preservation coordination, construction management*
Resource Protection: 25% *Includes research and monitoring of natural and cultural resources, invasive species management*
Visitor Services: 18% *Includes interpretation and education, law enforcement, emergency medical services, search and rescue, entrance station operations, structural fire activities, and park concessions management*

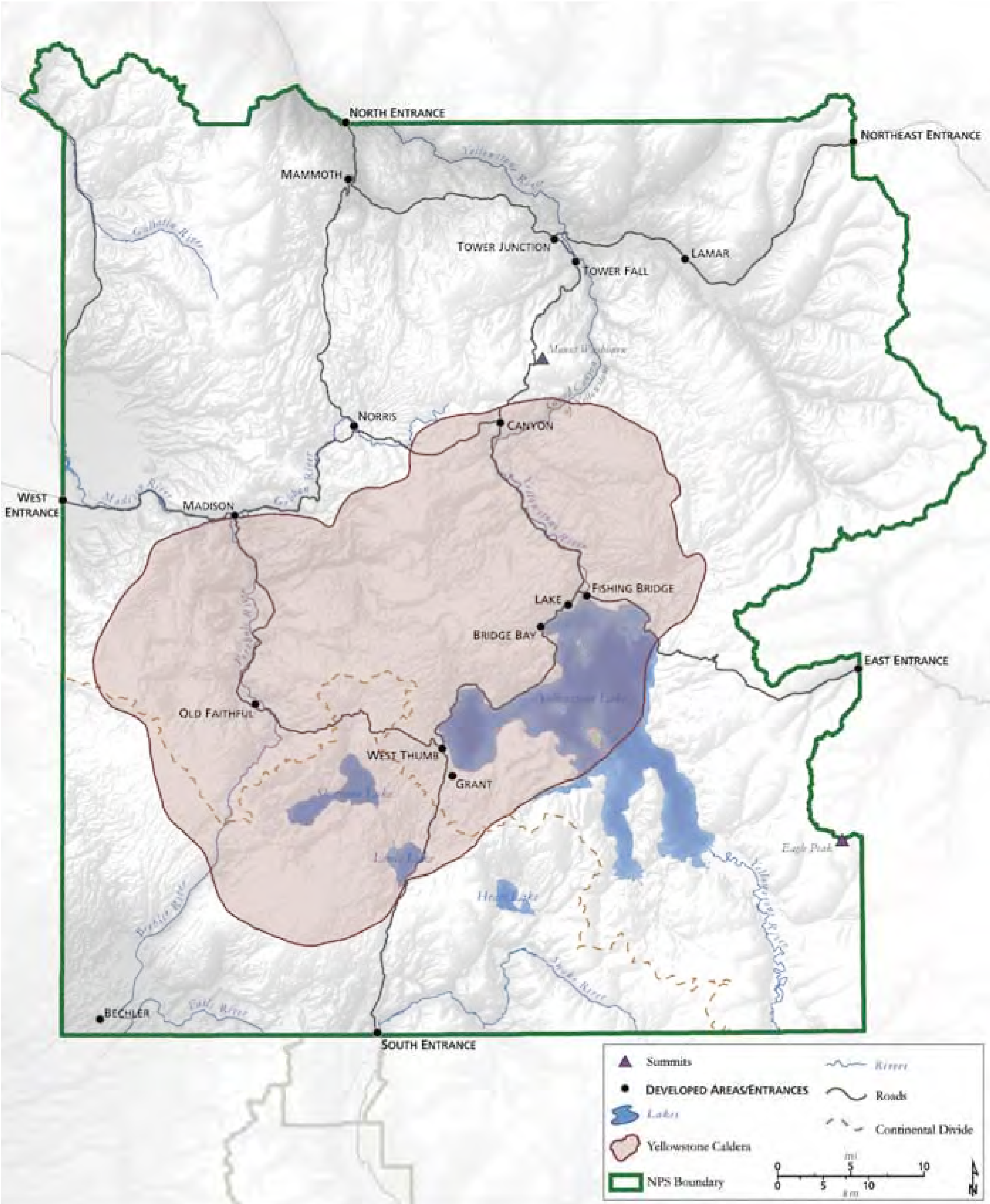
VISITATION

In 2012, park visitation topped the 3 million mark for the sixth straight year. It was the second highest visitation year on record. More than one-fourth of the park's total annual visitation was recorded during the month of July. The last time the park recorded fewer than 3 million annual recreational visits was in 2006, with 2.87 million visits.
Detailed park visitation information is available at https://irma.nps.gov/Stats/

Top 10 Visitation Years

1.	2010	3,640,184
2.	2012	3,447,727
3.	2011	3,394,321
4.	2009	3,295,187
5.	2007	3,151,343
6.	1992	3,144,405
7.	1999	3,131,381
8.	1995	3,125,285
9.	1998	3,120,830
10.	2008	3,066,570

Yellowstone National Park



Frequently Asked Questions

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, who live in what is now eastern Montana. 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."

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 (13 million acres) in the National Park System. Until 1994, 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.

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 US 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.*

To find out more, visit www.unesco.org/mab.

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.

Approximately 780 people work for the National Park Service in Yellowstone National Park during the peak summer season.

How many rangers work in Yellowstone?

Approximately 780 people work for the park during the peak summer season. Approximately 355 are permanent employees who stay year-round. Park rangers perform duties in 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?

Yellowstone is in the top five national parks for number of recreational visitors. Great Smoky Mountains National Park has the most—more than 9 million in 2012. The Grand Canyon (4.4 million) and Yosemite (3.8 million) also received more recreational visits than Yellowstone (3.4 million) last year. Visit the website https://irma.nps.gov/Stats/ to find out more details about how many visitors come to our national parks.

Can we swim in rivers and lakes?

Swimming is not recommended, and often prohibited by regulation because most lakes and streams are dangerously 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.

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 the Old Faithful area. Craig Pass is the highest crossing, at 8,262 feet.

Where does the Yellowstone River flow?

The river begins south of the the park on Younts Peak (Wyoming) 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?

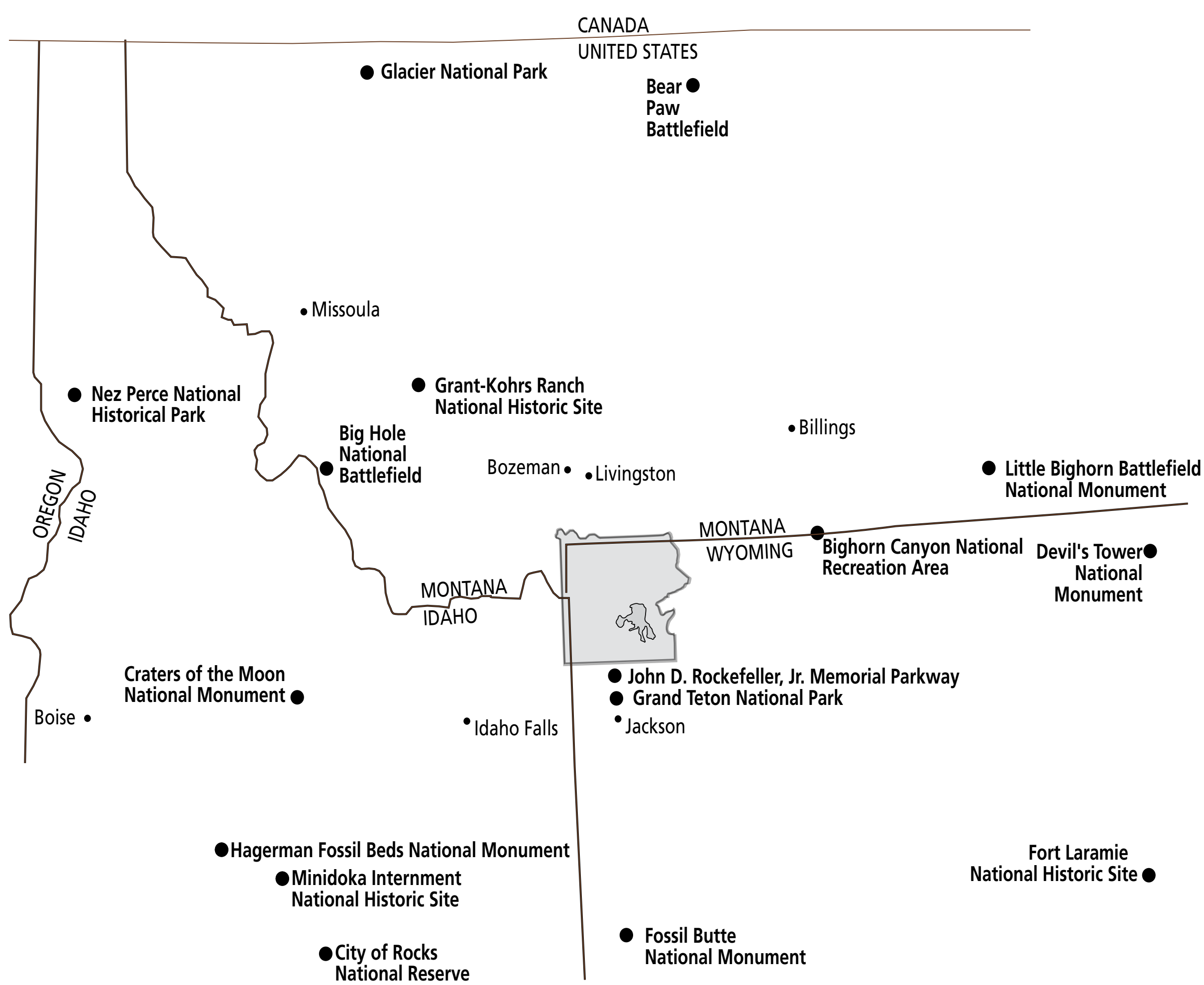
No, but its three tributaries begin in the Greater Yellowstone area. The Jefferson begins in the Centennial Mountains, west of the park. The Madison River forms inside the park at Madison Junction, where the Gibbon and Firehole rivers join. The Gallatin River also begins inside the park north of the 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. Only the northern part of the original volcano is still visible.



The National Park Service 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. Here are the sites near Yellowstone.

The Hayden Valley, shown here with the Yellowstone River and Washburn Range, is one of the best places in the park to view a wide variety of large mammals.

Canyon Village Area

Notable Places

- Grand Canyon of the Yellowstone River
- Mount Washburn
- Hayden Valley

How big is the Grand Canyon of the Yellowstone?

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

How did the canyon form?

Scientists continue to develop 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.

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 and hydration of minerals in the rock. Most of the yellows in the canyon result from iron and sulfur in the rock.

Where can I see the canyon and falls?

North Rim Drive: Accessible walkways at Brink of Lower Falls 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.

Visit Brink of Upper Falls from a viewing area just off the Grand Loop Road south of Canyon Junction, between the entrances to North and South Rim drives.

Where can I see both falls at once?

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 (or 240,000 liters) per second at peak runoff to 5,000 gallons (or 18,900 liters) per second in the late fall.

What causes the Lower Falls' green stripe?

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.

Is Artist Point the location where Thomas Moran painted his Grand Canyon of the Yellowstone?

No, it is thought that some sketches were made from Moran Point and that a compilation of canyon views were incorporated into the painting.

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. They nest here from late April until early September. Also look for ravens, bald eagles, and swallows. During July, a variety of butterflies feast on the abundant flowers in the meadows.

Hayden Valley, which begins approximately five 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. Large herds of bison may be seen in the spring, early summer, and during the rut in August. Coyotes can almost always be seen in the valley; wolves are sometimes seen.

Mount Washburn is another excellent place for viewing wildlife. Bighorn sheep and marmots can be seen on its slopes in the summer. Wolves and bears are sometimes seen. Elk and bison frequent the valley north of the mountain.

Fishing Bridge is a good place to watch trout, though fishing is now prohibited from the bridge. Overfishing of cutthroat trout here contributed to their decline in Yellowstone Lake.

Fishing Bridge and Lake

Historic Areas and Structures

- Fishing Bridge
- Fishing Bridge Visitor Center
- Lake Historic District
- Lake Fish Hatchery Historic District
- Lake Hotel
- Bridge Bay Marina Historic District
- East Entrance Historic Road

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.

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 LeHardy's Rapids to be the geologic northern boundary of the lake because the periodic rise and fall of that site appears to control lake outflow.

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. It's still a good place to watch trout.

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 happened to the old campground at Fishing Bridge?

The National Park Service campground was located where bears came to fish, and many 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.

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. In spring, you might be able to see trout leaping upstream at LeHardy's Rapids, three miles north of Fishing Bridge. Also look for white pelicans, bald eagles, osprey, and a variety of ducks and other water birds.

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.

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.

The Madison River is a good place to watch wildlife. Elk live along the river year-round and use meadows along the river during the spring for calving.

Madison and West Yellowstone Area

Historic Areas and Structures

- Madison Information Station

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 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 (0.3 m) over a remnant of the caldera rim.

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 west of Seven Mile Bridge in recent years. 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 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 centuries. Archeologists have found campfire remnants, obsidian flakes, and bone fragments dating back at least 10,000 years.

Mammoth Hot Springs is noted for its hot springs and history. Visitors can tour the Mammoth Terraces on foot and by car and take a self-guided or guided tour of historic Fort Yellowstone.

Mammoth Hot Springs Area

Historic Areas and Structures

- Mammoth Hot Springs Historic District
- Fort Yellowstone Historic Landmark District
- Obsidian Cliff National Historic Landmark
- US Post Office
- Administrative Headquarters
- Roosevelt Arch

Is Mammoth Hot Springs in the Yellowstone Caldera?

No, it lies to the north of it.

Where does the heat for the hot springs come from?

Scientists continue to study this question. One possibility is the volcano's magma chamber, similar to the heat source for other thermal areas closer to the 640,000-year-old caldera. There may also be basaltic magma bodies, related to the Yellowstone volcano, deep underground between Norris and Mammoth, which could be a contributing heat source.

Why are the dry springs so white?

Limestone, a naturally white rock, underlies this area. Water dissolves the mineral, which is deposited at the surface to form travertine. Colors in the hot springs come from thermophiles.

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, Bunsen Peak (south of Mammoth) is an intrusion of igneous material (magma) formed approximately 50 million years ago. 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 is still considered accurate.

What were these old buildings?

Many of the older buildings grouped together in Mammoth belong to Fort Yellowstone, built by the US Army from 1891 to 1913, when it managed the park. A self-guided trail goes 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 Boiling River north of Mammoth. It is open in daylight hours and 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. The majority of the Montana–Wyoming state line does not follow the parallel through the park.

What forms the canyon north of Mammoth?

The canyon is the face of Mount Everts, 7,841 feet high. It consists of layered sandstones and shales—sedimentary deposits from a shallow inland sea 70–140 million years ago. Its steep cliffs—eroded by glaciers, floods, and landslides—provide habitat for bighorn sheep. It was named for explorer Truman Everts, a member of the 1870 Washburn Expedition who became lost. 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 quarry obsidian, which they traded and used to make projectile points and other tools. Obsidian from this site has been found as far east as Ohio. The exhibit kiosk is also on the Register of National Historic Places. Built in 1931, it was one of the first wayside exhibit structures in the National Park System.

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. 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.

What is the purpose of the fenced areas north of the Blacktail Ponds?

Many park researchers have used the fenced areas on the northern range to study the long-term effects of grazing by fencing out large herbivores. Researchers can use existing data from the permanent plots or collect new data.

The Norris Geyser Basin, like other hydrothermal areas, changes over time. The basin periodically experiences wide-spread change lasting a few days to a few weeks.

Norris Area

Historic Areas and Structures

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

Is Norris Geyser Basin within the Yellowstone Caldera?

Norris is not in the Yellowstone Caldera, but it is close to the caldera rim, with its associated ring fractures and faults. 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.

When does Echinus Geyser erupt?

Once very predictable, Echinus's eruptions are now months to years apart, but could become frequent again.

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* glows 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.

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 may happen when surface water levels decrease, causing a decrease in pressure in deeper, underground thermal water. This may allow the deeper thermal waters to mix and flow to the ground surface.

How did Norris get its name?

The area is 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 located in the Norris Soldier Station, one of the only remaining soldier stations in the park.

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 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.

Are mudpots in this area?

Yes, at Artists' Paintpots, which is located 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 sometimes 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 the 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.

Visitors have long gathered near the Old Faithful Inn to watch Old Faithful Geyser erupt. Park staff use eruption data from a temperature logger to estimate the next interval of eruption.

Old Faithful Area

Notable Areas

- Upper, Midway, and Lower Geyser Basins

Historic Areas and Structures

- Nez Perce National Historic Trail
- Old Faithful Inn
- Old Faithful Lodge
- Old Faithful Historic District
- Both general stores
- Queen's Laundry, begun in 1881 but never finished, in Sentinel Meadows

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 2013, the usual interval is 88 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 203ºF (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. Sometimes the average interval decreases.

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

Old Faithful Geyser has been analyzed for years by mathematicians, statisticians, and dedicated observers. They have shown that 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 recharge in a short time. Longer eruptions mean more water and heat are discharged and they require more time to recharge. Currently, staff uses eruption data from a temperature logger to determine the next 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 education ranger staff. You can reach these 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, six 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, eight miles north of Old Faithful and two 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. In summer, 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.

The rock columns in the canyon north of Tower Fall were formed by a lava flow that cracked into hexagonal columns as it slowly cooled.

Tower–Roosevelt Area

Notable Places

- Lamar Valley
- Northeast Entrance Road

Historic Areas and Structures

- Lamar Buffalo Ranch
- Northeast Entrance Station
- Tower Ranger Station Historic District
- Roosevelt Lodge Historic District
- Roosevelt Lodge

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. 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 for 0.75-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 Petrified Tree become petrified?

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.

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 Mount Washburn, particularly in the spring when elk are calving. Road pullouts provide excellent places from which to watch wildlife.

West Thumb is the largest geyser basin on the shore of Yellowstone Lake. Hydrothermal features also lie under the lake, melting ice on the lake's surface during winter.

West Thumb and 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.

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 100ºF (38ºC) to just over 200ºF (93ºC).

How deep are Abyss and 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 a center of visitor services 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, 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.

People have spent time in the Yellowstone region for more than 11,000 years. Rock structures like this are evidence of the early presence of people in the area.

History of the Park

The human history of the Yellowstone region goes back more than 11,000 years. The stories of people in Yellowstone are preserved in objects that convey information about past human activities in the region, and in people's connections to the land that provide a sense of place or identity.

Today, park managers use archeological and historical studies help explain how humans left their mark in times gone by. Ethnography helps us learn about how groups of people identify themselves and their connections to the park. Research is also conducted to learn how people continue to affect and be affected by places that have been relatively protected from human impacts. Some alterations, such as the construction of roads and other facilities, are generally accepted as necessary to accommodate visitors. Information on the possible consequences of human activities both inside and outside the parks is used to determine when restrictions are needed to preserve each park's natural and cultural resources as well as the quality of the visitors' experience.

History of Yellowstone National Park

Precontact

- 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 Arrive

- European Americans began exploring in the early 1800s.
- Osborne Russel recorded early visits in the 1830s.
- First organized expedition explored Yellowstone in 1870.

Protection of the Park Begins

- Yellowstone National Park established in 1872.
- Railroad arrived in 1883, allowing easier visitor access.
- The US Army managed the park from 1886 through 1918.
- Automobiles allowed into the park in 1915, making visits easier and more economical.
- National Park Service created in 1916.
- First boundary adjustment of the park made in 1929.

Park Management Evolves

- "Leopold Report" released in 1963; its recommendations changed how wildlife is managed in the park.
- 1970: New bear management plan eliminated 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 protected the park.

Paleoindian Period

~11,000 years ago

A Clovis point from this period was made from obsidian obtained at Obsidian Cliff.

10,000 years ago

Folsom people were in the Yellowstone area as early as 10,900 years ago—the date of an obsidian Folsom projectile point found near Pinedale, Wyoming. Sites all over the park yield paleoindian artifacts, particularly concentrated around Yellowstone Lake.

Hell Gap point, 9,600–10,000 years ago

9,350 years ago

A site on the shore of Yellowstone Lake has been dated to 9,350 years ago. The points had traces of blood from rabbit, dog, deer, and bighorn. People seem to have occupied this site for short, seasonal periods.

The Earliest Humans in Yellowstone

Human occupation of the greater Yellowstone area seems to follow environmental changes of the last 15,000 years. How far back is still to be determined—there are no sites that date to this time—but humans probably were not here when the entire area was covered by ice caps and glaciers. Glaciers and a continental ice sheet 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 last period of ice coverage ended 13,000–14,000 years ago, and sometime after that and before 11,000 years ago, humans arrived here.

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. People adapted to these changing conditions and were eating a diverse diet of medium and small sized animals as early as 9,500 years ago. 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.

Cody knife (9,350 years ago) from the Yellowstone National Park Museum Collection

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.

More than 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, elk, deer, bear, cats, and wolves.

Campsites and trails in Yellowstone also provide evidence of early use. Some trails have been used by people since the Paleoindian period.

Some of the historic peoples from this area, such as the Crow and Sioux, arrived sometime during the 1500s and around 1700, respectively. We have little scientific evidence to conclusively connect other historic people, such as the Salish and Shoshone, to prehistoric tribes, but oral histories provide links. Prehistoric vessels known as “Intermountain Ware” have been found in the park and surrounding area, and link the Shoshone to the area as early as approximately 700 years ago.

Archaic Period (7,000–1,500 years ago)

7,000 years ago

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

Beginning 9,000 years ago until 1,000 common era (CE), people leave traces of camps on shores of Yellowstone Lake.

3,000 years ago

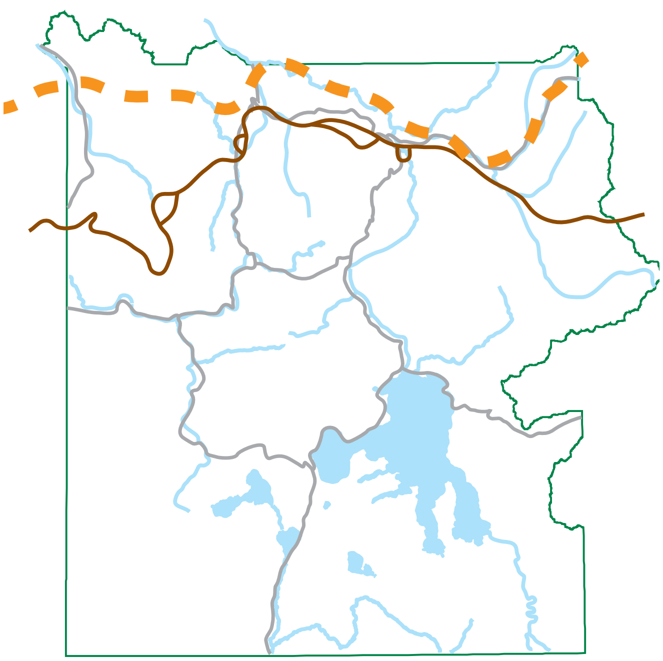
Oral histories of the Salish place their ancestors in the Yellowstone area.

1,500 years ago

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.

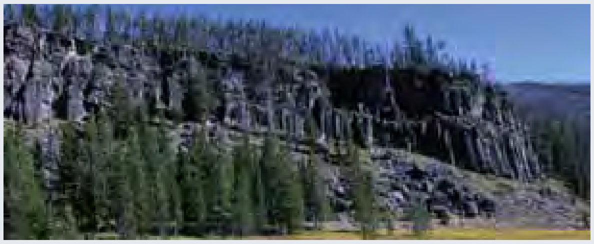
Increased Use

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. Archeologists and other scientists are working together to study evidence such as plant pollen,



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 1900s. Today, many scholars think the dashed line shows a more accurate location, which is based on an 1869 map by Henry D. Washburn.

Obsidian Cliff



Where to See
Grand Loop Road between Mammoth and Norris.

Significance

- Obsidian is found in volcanic areas where the magma is rich in silica and lava has cooled without forming crystals, creating a black glass that can be honed to an exceptionally thin edge.
- Obsidian was first quarried from this cliff for toolmaking more than 11,000 years ago and gradually spread along trade routes from western Canada to Ohio.
- Unlike most obsidian, which occurs as small rocks strewn amid other formations, Obsidian Cliff has an exposed vertical thickness of about 98 feet (30 m).
- It is the United States' most widely dispersed source of obsidian by hunter-gatherers.
- Obsidian Cliff is the primary source of obsidian in a large concentration of Midwestern sites, including about 90 percent of obsidian found in Hopewell mortuary sites in the Ohio River Valley (about 1850–1750 years ago).

Recent History
About 90 percent of the Obsidian Cliff plateau burned in 1988. Although the fire did not affect the appearance or condition of the cliff face, it cleared the surface and most of the lodgepole pine overstory, creating optimal conditions for archeological surveys. The surveys have added substantially to knowledge about how and where obsidian was mined from the bedrock and collected as cobbles deposited within the overlying glacial till. The site was designated a National Historic Landmark in 1996.

The kiosk at Obsidian Cliff, constructed in 1931, was the first wayside exhibit in a US national park. It was listed on the National Register in 1982.

1000–1700s CE

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

CE = Common Era (replaces AD)

landforms, and tree rings to understand how the area's environment changed over time.

The Little Ice Age

Climatic evidence 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, although more sites dating to this period are being found. 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

Greater Yellowstone's location at the convergence of the Great Plains, Great Basin, and Plateau Indian cultures means that many tribes have a traditional connection to the land and its resources. For thousands of years before Yellowstone became a national park, it was a place where Indians hunted, fished, gathered plants, quarried obsidian, and used the thermal waters for religious and medicinal purposes.

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 area generally east of the park, and the Blackfeet occupied the area 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.

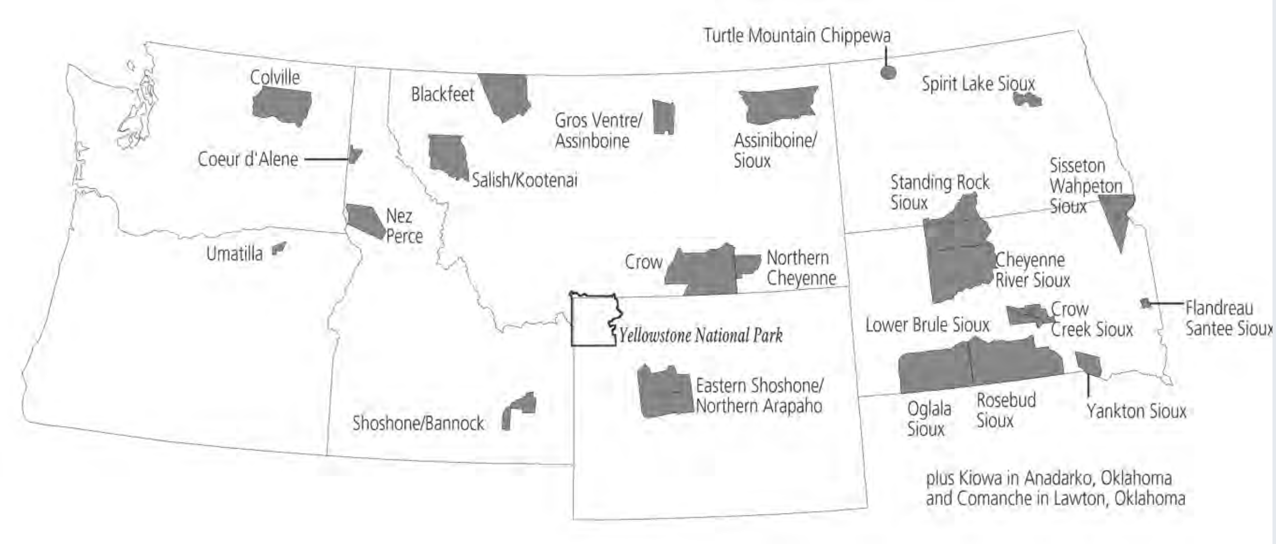
The "Sheep Eaters"

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

Wickiups provided temporary shelter for some Native Americans while they were in Yellowstone. No authentic, standing wickiups are known to remain in the park.

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.

Associated Tribes of Yellowstone National Park



- Assiniboine and Sioux
- Blackfeet
- Cheyenne River Sioux
- Coeur d'Alene
- Comanche
- Confederated Salish and 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 of the 26 tribal reservations; it does not show historic territory.

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. For example, they soaked sheep horns in hot springs to make them pliable for bows. They traded these bows, plus clothing and hides, to other tribes.

late 1700s–1840s CE

late 1700s	1804–1806	1807–1808	1820s	1834–1835	1840s
Fur traders travel the rivers into the Yellowstone region. Tribes in the Yellowstone area begin using horses.	The Lewis and Clark Expedition passes within 50 miles of Yellowstone.	John Colter explores part of Yellowstone.	Trappers return to Yellowstone area.	Trapper Osborne Russell encounters Sheep Eaters in Lamar Valley.	Trapper era ends.

European Americans Arrive

In the late 1700s, fur traders traveled the great tributary of the Missouri River, the Yellowstone, in search of Native Americans with whom to trade. 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 (1804–1806), 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.

The continued reports by mountain men about the wonders of the Yellowstone area, artist renderings of the area, and reports by explorers contributed to the establishment of Yellowstone National Park in 1872.

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 travel to see the real thing.

Osborne Russell wrote a book about fur trapping in and around Yellowstone during the 1830s and early 1840s.

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 made inside what is now Yellowstone National Park.

Expeditions Arrive in Yellowstone

Although Yellowstone had been thoroughly tracked by tribes and trappers, 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.

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

1850s–1871 CE

1850s	1860	1862	1869	1870	1871
Little Ice Age ends, climate begins to warm.	First organized expedition attempts but fails to explore the Yellowstone Plateau.	Gold strike northwest of Yellowstone.	Folsom–Cook–Peterson Expedition.	Washburn–Langford–Doane Expedition; Old Faithful Geyser named.	First Hayden Expedition.

Several early trappers and expeditions passed by Tower Fall, painted here by Thomas Moran who accompanied the Hayden Expedition. One of the first may have been John Colter, who left the Lewis and Clark Expedition as they returned east to join fur trappers in the Yellowstone area. He probably crossed the Yellowstone River near Tower Fall.

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 for 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 US Geological and Geographical Survey of the Territories, led the next scientific expedition in 1871, simultaneous with a survey by the US Army Corps of Engineers.

The history of science in Yellowstone formally began with Hayden's expeditions. Hayden's 1871 survey team included two botanists, a meteorologist, a zoologist, an ornithologist, a mineralogist, a topographer, and an agricultural statistician/entomologist, in addition to an artist, a photographer, and support staff. 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.

Hayden noted that in terms of scientific value, "The geysers of Iceland. . .sink into insignificance in comparison with the hot springs of the Yellowstone and Fire-Hole Basins."

1872–1900 CE

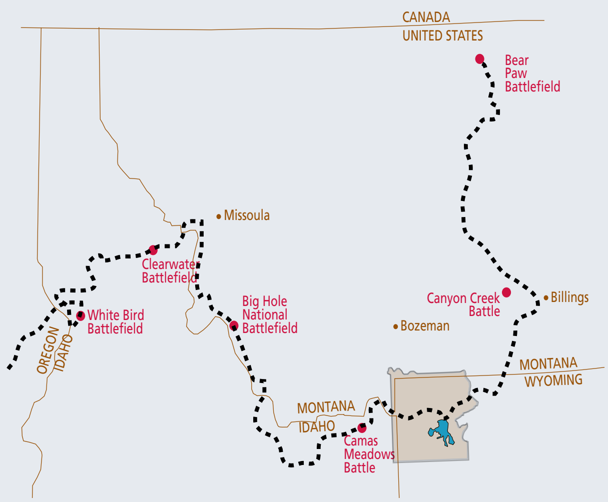
1872	1877	1883	1886	1894
Yellowstone National Park Protection Act establishes the first national park.	Nez Perce (Nee-me-poo) flee US Army through Yellowstone.	Northern Pacific Railroad reaches the North Entrance of the park.	The US Army arrives to administer the park. They stay until 1918.	Poacher Ed Howell captured; National Park Protection Act (Lacey Act) passed.

Birth of a National Park

One of the most enduring myths of Yellowstone National Park involves its beginning. As the myth goes, 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.

Though it is a myth, the explorers were real and their crowning achievement 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

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 pursued by the US Army. Settlers were moving into their homeland and the US 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.

In Yellowstone

Only a small part of the route taken by the Nez Perce who fled from the US Army in 1877 went through Yellowstone, and they largely eluded their pursuers while in the park. However, the 13 days that the Nez Perce spent in Yellowstone became part of the tragic story they continue to pass down to their children.

During the time they crossed the park, the Nez Perce encountered about 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 to Canada, but after fierce fighting and a siege, the rest of the band surrendered on October 5 and most of the survivors were sent to the Indian Territory in Oklahoma. This is where it is believed the flight ended and Chief Joseph said, "From where the sun now stands, I will fight no more forever."

Nez Perce Commemorative Sites

The Nez Perce National Historical Park, established by Congress in 1965 and managed by the National Park Service, includes 38 sites in Idaho, Montana, Oregon, and Washington that have been important in the history and culture of the Nez Perce.

Many of these sites are also on the 1,170-mile Nez Perce National Historic Trail, established in 1986 and managed by the US Forest Service. The route extends from Wallowa Lake, Oregon, to the Bear's Paw Mountains in Montana. Although none of the officially designated historic sites associated with the Nez Perce are located in Yellowstone, the historic trail goes through the park, and it is considered a sacred place by many Nez Perce who have continued to honor their ancestors and carry on their memories through ceremonies conducted in the park.

- Nez Perce National Historic Trail: http://www.fs.usda.gov/npnht/
- Nez Perce National Historical Park: http://www.nps.gov/nepe/

As Yellowstone's second superintendent, Philetus Norris set the future course of national parks on many fronts: protection, addressing visitors' needs and interests, and science-based management. Despite a lack of support from the Department of the Interior or Congress, he pleaded for legislation that would adequately protect the park and was a man ahead of his time in his vision and aspirations for Yellowstone.

FREQUENTLY ASKED QUESTION:

Did other national parks exist before Yellowstone?

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

Yosemite became a park before Yellowstone, but as a state park. In 1864, the Lincoln administration gave the area surrounding the Yosemite Valley and the Mariposa Grove of Big Trees to the state of California to administer for public use and recreation. Disappointed with the results 26 years later in 1890, Congress made Yosemite one of three additional national parks, along with Sequoia and General Grant, now part of Kings Canyon. Mount Rainier followed in 1899.

As an older state park, Yosemite did have a strong influence on the founding of Yellowstone in 1872 because Congress actually used language in the state park act as a model. It's entirely possible that Congress may have preferred to make Yellowstone a state park in the same fashion as Yosemite, had it not been for an accident of geography that put it within three territorial boundaries. Arguments between Wyoming and Montana territories that year resulted in a decision to federalize Yellowstone.

A generation later 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 world's second national park, established three years later in 1875, was Mackinac Island in Michigan. It was turned over to state jurisdiction a decade later.

wonders of Yellowstone—shown through Jackson's photographs, Moran's paintings, and Elliot's sketches—had caught the imagination of Congress. Thanks to their continued reports and the work of explorers and artists who followed, the United States Congress established Yellowstone National Park in 1872. 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 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, the federal government had the foresight to set aside land deemed too valuable to develop.

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

1901–1917 CE

1903

President Theodore Roosevelt dedicates arch at the North Entrance in Gardiner while on vacation.

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.

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 was succeeded by three powerless superintendents who could not protect the park. Even when ten assistant

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

Guidance for Protecting Yellowstone National Park

Yellowstone Purpose Statement
Yellowstone National Park, the world's first national park, was set aside as a public pleasuring ground to share the wonders and preserve and protect the scenery, cultural heritage, wildlife, geologic and ecological systems and processes in their natural condition for the benefit and enjoyment of present and future generations.

Significance of Yellowstone

- Yellowstone National Park is the world's first national park, an idea that spread throughout the world.
- Yellowstone was set aside because of its geothermal wonders—the planet's most active, diverse, and intact collections of combined geothermal, geologic, and hydrologic features and systems, and the underlying volcanic activity that sustains them.
- The park is the core of the Greater Yellowstone Ecosystem, one of the last, largest, nearly intact, natural ecosystems in the temperate zone of Earth. It preserves an exceptional concentration and diversity of terrestrial, aquatic, and microbial life. Here, natural processes operate in an ecological context that has been less subject to human alteration than most others throughout the nation—and indeed throughout the world. This makes the park not only an invaluable natural reserve, but a reservoir of information valuable to humanity.
- Yellowstone contains a unique and relatively pristine tapestry of prehistoric and historic cultural resources that span more than 11,000 years. The archeological, architectural, historical, and material collections constitute one of the largest and most complete continuum of human occupation in the western U.S. and collectively represent the material remains of the birth of the National Park and conservation movement.
- Yellowstone was the first area set aside as a national public park and pleasuring ground for the benefit, enjoyment, education, and inspiration of this and future generations. Visitors have a range of opportunities to experience its unique geothermal wonders, free-roaming wildlife, inspiring views, cultural heritage, and spectacular wilderness character.

Yellowstone Mission Statement
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.

1918–1939 CE

1918	1929	1932	1933	1934	1935
US Army turns over park management to the National Park Service.	President Hoover signs first law changing park's boundary.	President Hoover expands the park again.	Civilian Conservation Corps established, works in Yellowstone through 1941.	The National Park Service Director's Order prohibits killing predators.	The Historic Sites Act sets a national policy to "preserve for future public use historic sites, buildings, and objects."

superintendents were authorized to act as police, they failed to stop the destruction of wildlife. Poachers, squatters, woodcutters, and vandals ravaged Yellowstone.

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 US 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 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 park 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 Begins

National parks clearly needed coordinated administration by professionals attuned to the special requirements of these preserves. The management of Yellowstone from 1872 through the early 1900s 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.

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.

Two "Organic Acts"

The laws creating Yellowstone National Park and the National Park Service are both called "The Organic Act" because each created an entity. (Also called "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 US Code Table of Popular Names: The Yellowstone National Park Protection Act and The National Park Service Organic Act.

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."*

National Park Service Mission
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 National Park Service cooperates with partners to extend the benefits of natural and cultural resource conservation and outdoor recreation throughout the United States and the world.

1940–1959 CE

1948

Yellowstone receives one million visitors.

1949

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

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.

Today's National Park Service

Implementing the National Park Service Mission

The National Park Service 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 (biological and physical, esthetic values such as scenic vistas, natural quiet, and night skies, etc.) are managed to maintain, rehabilitate, and perpetuate their inherent integrity. Native species that have been exterminated should be reintroduced and nonnative 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, landscapes, archeological and ethnographic resources, and museum collections) are preserved.

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 National Park Service 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.

The National Park Service 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.

When Frances Pound applied for a position in 1926, Yellowstone Superintendent Albright suggested she use her nickname, Jim. She was one of the first women hired to do law enforcement in Yellowstone. Today's National Park Service workforce aims to reflect our nation's diversity.

Most other types of national park units are well defined by their titles.

Total National Park Service areas = 398

National Battlefields	11
National Battlefield Parks	4
National Battlefield Site	1
National Military Parks	9
National Historical Parks	46
National Historic Sites	78
International Historic Sites	1
National Lakeshores	4
National Memorials	29
National Monuments	75
National Parks	59
National Parkways	4
National Preserves	18
National Reserves	2
National Recreation Areas	18
National Rivers	5
National Wild and Scenic Rivers and Riverways	10
National Scenic Trails	3
National Seashores	10
Other Designations	11
Total Units	**398**

As of February 2013.

1960–1975 CE

1963	1966	1970	1971	1975
The Leopold Report is issued.	The thermophile *Thermus aquaticus* discovered in a Yellowstone hot spring.	New bear management plan begins, which includes closing open-pit dumps in park.	Overnight winter lodging opens in park.	Grizzly bear listed as threatened species in the lower 48 states.

Boundary Adjustments

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

In 1932, President Hoover 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.

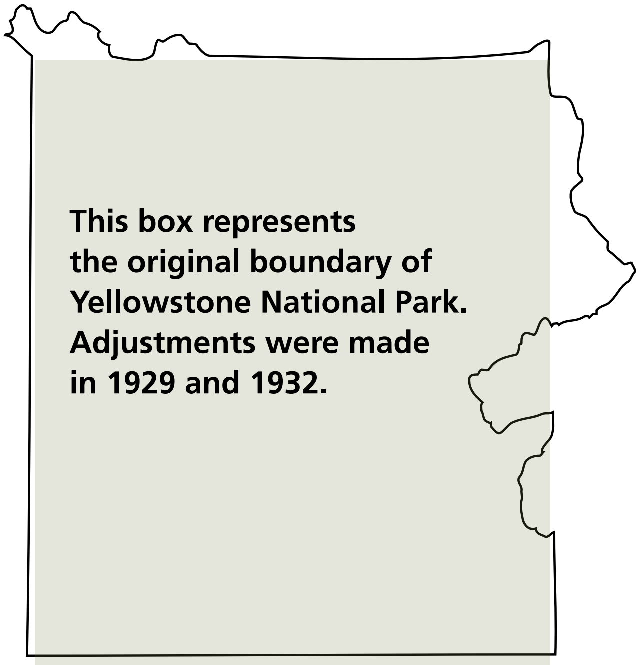
Yellowstone Superintendent Horace Albright, shown here with future president Herbert Hoover in 1928, was involved in the creation of the National Park Service. Later, as agency's director, he greatly increased the number of parks east of the Mississippi and expanded the agency's mandate to include preservation of historic sites, creating a more truly national park system.

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.

World War II

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 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.



1976–1998 CE

1988	1991	1994	1995	1996	1998
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.	Clean Air Act Amendments require air quality monitoring at sites including Yellowstone, a Class I airshed—one of the purest in the nation.	Congress enacts a law allowing a percentage of park entrance fees to be kept in the parks.	Wolves are restored to the park.	Federal buyout of gold mine on Yellowstone's northeast border is authorized.	The National Parks Omnibus Management Act is passed.

Mission 66

Neglected during World War II, the infrastructure in national parks continued to deteriorate as visitation soared afterward, leading to widespread complaints. In 1955, National Park Service Director Conrad Wirth persuaded Congress to fund an improvement program for completion by the National Park Service's 50th anniversary in 1966. Also designed to increase education programs and employee housing, Mission 66 focused mainly on visitor facilities and roads. Trained as an architect, Wirth encouraged the use of modern materials and prefabricated components to quickly and inexpensively construct low-maintenance buildings. This architectural style, which became known as Park Service Modern, was a deliberate departure from the picturesque, rustic buildings associated with national parks; their "fantasy land" quality was considered outmoded and too labor-intensive for the needed scale of construction.

Mission 66 revitalized many national parks; in Yellowstone, intended to be the program's showpiece, its legacy is still visible. It was a momentous chapter in the park's history, and as the park continues to reflect changing ideas about how to enhance the visitor's experience while protecting the natural and cultural resources, the question of how to preserve the story of Mission 66 is being addressed.

Work in Yellowstone included the development of Canyon Village. Aging visitor use facilities were replaced with modernistic visitor use facilities designed to reflect American attitudes of the 1950s. Visitor services were arranged around a large parking plaza with small cabins a short distance away. Canyon Village opened in July 1957, the first Mission 66 project initiated by the National Park Service.

Modern Management

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.

The elk and bison populations were actively managed until the mid-1960s, when park managers allowed "natural regulation."

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*.

Involving Native Americans

Yellowstone National Park has 26 associated tribes. Some have evidence of their ancestral presence in

1990 CE–present

2002

National Academy of Sciences confirms effectiveness of Ecological Process Management (aka natural regulation).

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 and 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 National Park through ethnohistoric documentation, interviews with tribal elders, or ongoing consultations. Others are affiliated because of documented spiritual or cultural connection to places or resources. Many 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 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.

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

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 1996, as part of a pilot program, Yellowstone National Park was authorized to increase its entrance fee and retain 80 percent of the fee for park projects. (Previously, park entrance fees did not specifically fund park projects.) In 2004, the US 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.

A Decade of Environmental Laws

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

The Wilderness Act of 1964 particularly influences the management of 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.

A Living Legacy

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 1800s, 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 United States' 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 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.

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Staff Reviewers

Tobin Roop, Chief of Cultural Resources
Lee Whittlesey, Historian

Yellowstone's cultural resources tell the stories of people, shown here around 1910 near the Old Faithful Inn, and their connections to the park. The protection of these resources affects how the park is managed today.

Preserving Cultural Resources

Yellowstone National Park's mission includes preserving and interpreting evidence of past human activity through archeology and historic preservation; features that are integral to how a group of people identifies itself (ethnographic resources); and places associated with a significant event, activity, person or group of people that provide a sense of place and identity (cultural landscapes). All of these materials and places tell the story of people in Yellowstone. Collectively, they are referred to as cultural resources.

Archeology

Archeological resources are the primary—and often the only—source of information about humans in Yellowstone for nearly the entire time that people have been in the area. Archeological evidence indicates that people began traveling through and using the area that was to become Yellowstone National Park more than 11,000 years ago. Because the intensity of use varies through time as environmental conditions become more or less favorable for humans, archeological resources also provide a means for interdisciplinary investigations of past climate and biotic change.

Many thermal areas contain evidence that early people camped there. At Obsidian Cliff, a National Historic Landmark, volcanic glass was quarried for the manufacture of tools and ceremonial artifacts that entered a trading network extending from western Canada to the Midwest. These remnants of past cultures must be preserved as they are invaluable in our understanding of early people in the area.

Cultural Resources in Yellowstone

Archeological

- More than 1,700 prehistoric and historic Native American archeological sites and historic European American archeological sites

Ethnographic

- More than 300 ethnographic resources (animals, plants, sites, etc.)

Historic

- 25 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

Collections

Housed in the Yellowstone Heritage and Research Center

- Museum collection of more than 300,000 museum items, including 30 historic vehicles
- Archives containing millions of historic documents
- Research library holds more than 20,0000 books and periodicals available to the public; plus manuscripts and rare books available to historians and other researchers

More modern archeological sites in Yellowstone include the remains of early tourist hotels and army soldier stations.

Findings in Yellowstone

Although more than 1,700 archeological sites have been documented since the archeology program began in 1995, only about 3 percent of the park has been surveyed. Most documented sites are in developed areas because archeological evidence has been discovered there inadvertently or as part of National Historic Preservation Act compliance related to construction activities and hazard fuel reduction projects. Salvage efforts have been made at some sites where archeological remains are especially vulnerable to disturbance or loss through erosion or illegal collecting. Multiple significant sites along the Yellowstone River have been nominated to the National Register of Historic Places. These contain projectile points or arrowheads, scrapers and other tools, and concentrations of burned and butchered bone, including the first evidence of fishing found in the park.

Radiocarbon dating is used to establish the age of organic artifacts such as charcoal or bone. However, organic materials (wood, bone, basketry, clothing) rarely persist in the Yellowstone environment, so stone artifacts provide most of the chronological information on Yellowstone's prehistory. Most of the stone tools that can be associated with a particular time period are projectile points. At Malin Creek, campsites from five distinct periods of indigenous use spanning over 9,000 years are stacked upon each other starting at five feet below the surface. These features have revealed how tool manufacture and foodways changed over time.

The earliest evidence of humans in Yellowstone is an 11,000-year-old Clovis type spear point found at the park's north entrance in Gardiner, Montana, made of obsidian from Obsidian Cliff. (Obsidian from different lava flows can be chemically finger-printed using x-ray fluorescence.) Later in time, point types increase in number and type which may indicate that the number of people in the area was becoming larger as well as more diverse. Most documented sites in the park are from the Archaic period (8,000 to 1,800 years ago), suggesting that it was the most intense period of use by prehistoric people. Recent archeological surveys have identified a large number of sites dating to later periods in prehistory (approx. 1400–1800 CE). Distinguishing use of these sites by different ethnic groups or tribes, however, has not yet been possible.

Yellowstone Lake

The earliest intact archeological deposits in the park have been found at a site on the shore of Yellowstone Lake. The site was excavated because it was at risk of erosion, and revealed evidence a 9,350-year-old camp where several families appear to have spent time seasonally at Yellowstone Lake. People probably used this area in the summer while hunting bear,

Cultural Resource Laws

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)
Requires that federal agencies take into account effects of their undertakings on historic properties. 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 ceremonial and traditional rites.

Executive Order 13007
Guarantees access to and ceremonial use of Indian sacred sites by Indian religious practitioners to ensure that these sites are not adversely affected.

The earliest intact cultural deposits in the park have been found at a site on the shore of Yellowstone Lake.

deer, bighorn, and rabbits, and perhaps making tools and clothes. Artifacts dating to 3,000 years ago have also been discovered on islands in Yellowstone Lake, leading some archeologists to speculate that indigenous peoples used watercraft to travel on the lake.

Town site of Cinnabar, Montana

In 1932, Yellowstone National Park increased in size by 7,609 acres to the north, on the west side of the Yellowstone River. Most of what are called the "boundary lands" was purchased from willing owners; the rest was taken by eminent domain. But the town of Cinnabar had been abandoned long before, the railroad having brought it to life and then finished it off. Construction of the branch line from Livingston in 1883 made Cinnabar a hub for passengers and freight until the last three miles to the park entrance were built 20 years later. Nothing remains of the town today except archeological evidence from which something can be learned about the lives of its residents in the late 1800s.

To prevent impacts to archeological resources during a native plant restoration project planned for the boundary lands area, it was necessary to document where such resources were located. The Montana-Yellowstone Archeological Project (MYAP), a collaboration between the University of Montana and the National Park Service, surveyed about 3,000 acres in 2007 and 2008 for that purpose. The MYAP field school confirmed the location of the Cinnabar depot, excavated the blacksmith shop, and discovered a mortared river cobble foundation five feet underground, most likely for the hotel. Historical artifacts found during the excavations included a railroad sign, revolver bullets, and, newspaper fragments.

The MYAP team also documented sites with prehistoric components, including a tipi ring cluster

The Northern Pacific Railroad established Cinnabar (shown here in 1901) in 1883 as the last stop on its branch line to Yellowstone National Park, and caused its abandonment after the railroad was extended to the park boundary in 1903.

approximately 5,000 years old, one of the oldest known in the Northern Plains. At two sites, they identified a total of 18 stone circles, data from which has helped determine their age and possible function. Five prehistoric fire pits that were eroding out of the banks of the Yellowstone River downstream from Cinnabar were salvaged. These were probably last used by the Pelican Lake culture that lived there 2,000 years ago.

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Staff reviewers

Tobin Roop, Chief of Cultural Resources
Staffan Peterson, Archeologist
Lee Whittlesey, Historian

PRESERVATION

Ethnography

Yellowstone's location at the convergence of the Great Plains, Great Basin, and Plateau Indian cultures means that many tribes have a traditional connection to the land and its resources. For thousands of years before the park was established, it was a place where Indians hunted, fished, gathered plants, quarried obsidian, and used the thermal waters for religious and medicinal purposes. Yellowstone's ethnographic resources are the natural and cultural features that are integral to how a group of people identifies itself. They include sites, plant and animal species, and objects associated with routine or ceremonial activities, migration routes, or the group's history that have an importance distinct from that recognized by other people. The resources are identified by those groups of people.

Federal law requires the National Park Service to consult with Yellowstone's associated tribes on a government-to-government basis on decisions about American Indian resources that are held "in trust" by the US Government.

Documentation and associated tribes

Documentation of ethnographic resources and issues is relatively new at Yellowstone. The park's ethnography program, which has been in place since 2000, has two major components: facilitating ethnographic research for use in park planning, resource management, and interpretation; and maintaining effective relationships with the park's associated tribes so that their perspectives can be considered in park management decisions.

The first tribes to request association came forward in 1996; by 2003, 26 tribes were formally associated with Yellowstone. Since 2002, park managers have met periodically with tribal representatives to exchange information about ethnographic resources. The tribes have requested to participate in resource management and decision-making, to conduct ceremonies and other events in the park, and to collect plants and minerals for traditional uses. They are most concerned about the management of bison that leave the park; many of these tribes' ancestors depended on bison for physical and spiritual sustenance and continue to see their survival as tribes linked to that of the bison.

Discussion

Yellowstone is one of five pilot sites for the National Park Service's Ethnographic Resources Inventory

Nez Perce tribal members in traditional regalia ride along the Firehole River during a memorial ceremony in 2004.

database. As a result of research and consultation with the tribes, the database contains information about more than 400 ethnographic resources in Yellowstone. More is being learned about Greater Yellowstone's ethnographic resources through 11 research contracts with historians, anthropologists, and tribes. A videotape and report documenting the uses and cultural significance of wickiups in what is now Yellowstone and Grand Teton national parks and Shoshone and Bridger–Teton national forests will be used to support tribal recommendations on wickiup preservation. Tribal representatives have also been involved in discussions about how to interpret the Yellowstone segment of the Nez Perce National Historic Trail and the associated sites and events of the 1877 Nez Perce War for park visitors.

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Staff reviewers

Tobin Roop, Chief of Cultural Resources
Lee Whittlesey, Historian

Cultural Landscapes

A cultural landscape reflects the historic setting and recognizes the influence of human beliefs and actions over time on the natural landscape. It is an indicator of cultural patterns, values, and heritage. Yellowstone National Park contains an array of landscapes that reflect the park's history, development patterns, and a changing relationship between people and the unique Yellowstone environment. These landscapes are often a physical record of the early and on-going efforts to balance resource preservation and facility development for public enjoyment. They also include areas significant to Native American cultures, such as Obsidian Cliff and 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.

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Staff reviewers

Tobin Roop, Chief of Cultural Resources
Lee Whittlesey, Historian

PRESERVATION

Historic Structures and Districts

In addition to objects that have been preserved because of the information they convey about past human activities in the region, the parks' historical resources include dozens of sites and structures listed on the National Register of Historic Places and many others that are eligible for inclusion. Most of these places are of interest because of their significance in architectural or park history, but archeological sites such as Obsidian Cliff are associated with American Indian use that pre-dates the arrival of the first park visitors. The need to protect and understand the importance of these resources affects how the parks are managed today.

Many Yellowstone structures have historical, architectural, and/or engineering significance in addition to providing facilities for visitor use and park management. This includes 954 buildings, roads and bridges, utility structures, grave markers, and other constructed features in Yellowstone. Yellowstone is also home to five influential examples of park "rustic" architecture—the Old Faithful Inn, the Northeast Entrance Station, and the Norris, Madison, and Fishing Bridge museums.

The Geyser Baths Bathhouse, opened in 1914, was a swimming pool at Old Faithful and was razed in the 1950s. Historic structures and the historical character of the park are carefully considered in park planning.

Historic Designations in Yellowstone

National Register of Historic Places
In Yellowstone, includes:

- Lake Fish Hatchery District
- Mammoth Hot Springs District
- North Entrance Road District
- Old Faithful Area District
- Roosevelt Lodge District
- Lake Hotel
- Lamar Buffalo Ranch
- Obsidian Cliff Kiosk
- Queen's Laundry Bathhouse
- Mammoth Post Office

The National Register of Historic Places is the Nation's official list of historic places worthy of preservation. Authorized by the National Historic Preservation Act of 1966, the National Register is 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, archeology, 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
In Yellowstone, includes:

- Fishing Bridge, Madison, and Norris Trailside Museums
- Northeast Entrance Station
- Obsidian Cliff
- Old Faithful Inn
- Fort Yellowstone District

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 2,500 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 work to preserve existing landmarks.

- **District:** A significant concentration, linkage, or continuity of sites, buildings, structures, or objects that are historically or aesthetically united by either a plan or physical development. Examples: residential areas, large forts, rural villages, canal systems, and large landscaped parks.
- **Building and Structures:** Construction that includes those that create human shelter. The units may be a historically and functionally related unit, such as a courthouse and jail or a house and barn. Examples: houses, barns, garages, churches, hotels, bridges, tunnels, firetowers, silos, roadways.
- **Site:** The location of a significant event where a historic occupation or activity occurred. It may be the site of a building or structure which is no longer standing or which exists only as a ruin. Examples: village sites, battlefields, ruins of historic buildings and structures, campsites, sites of treaty signings, trails, and natural features, such as springs and rock formations.

Lake Hotel, 1891

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 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.

Lake Hotel resembled other hotels financed by the Northern Pacific Railroad when it opened in 1891.

Yellowstone Lake Fish Hatchery, 1930

People began stocking western high-elevation lakes with fish in the 1800s. Hatchery operations at Yellowstone Lake became part of this undertaking when fish hatched from Yellowstone's trout were used to stock waters in the park and elsewhere, sportfishing was promoted to encourage park visitation, and satisfying a recreational interest took precedence over protection of the park's natural ecology. Built in 1930 by the National Park Service's Landscape Engineering and Architecture Division, the hatchery's log-framed design is also an example of the period of rustic architectural design in national parks.

The hatchery was thought to be among the most modern in the West. The main room was outfitted with tanks and raceways for eggs, fingerlings, and brood fish taken from 11 streams that flowed into the lake. Small fry were fed in three rectangular rearing ponds in a nearby creek until they were ready for planting. Superintendent Horace Albright explained that the hatchery had also been designed with visitor education in mind, by making it possible "to take large crowds through the building under the guidance of a ranger naturalist without in any way impairing the operations of the Bureau of Fisheries."

Yellowstone was the largest supplier of wild cutthroat trout eggs in the United States, and its waters received native and nonnative fish. A rift developed, however, between the federal fish agencies and the National Park Service, which began moving away from policies that allowed manipulation of Yellowstone's natural conditions. In 1936 Yellowstone managers prohibited the distribution of nonnative fish in waters that did not yet have them and opposed further hatchery constructions in the park's lakes and streams. After research showed that it impaired fish reproduction, egg collection was curtailed in 1953. Four years later, the fish hatchery ceased operations and the US Fish and Wildlife Service transferred ownership of the building to the National Park Service. Official stocking of park waters ended by 1959.

Current Status

Vegetation and stream flow have largely reclaimed the rearing ponds on Hatchery Creek, but their outlines can still be detected, and the most serious results of fish planting are irreversible. Nonnative fish can alter aquatic ecology through interbreeding or competition with native species. Although its condition has deteriorated, the hatchery building has changed relatively little. Nearly all of the exterior and interior materials are original to the building or have been repaired in kind. Now used as a storage facility, it is the primary structure of the nine buildings in the Lake Fish Hatchery Historic District, which was listed on the National Register in 1985.

Fishing has a long history as a recreation interest in Yellowstone. The Lake Fish Hatchery produced trout that were used to stock waters in the park and elsewhere.

Mammoth Hot Springs Historic District and Fort Yellowstone Historic Landmark District

The Mammoth Hot Springs Historic District includes Fort Yellowstone, where 35 structures remain from the 1890s and early 1900s when the US Army administered the park. Significant conservation policies were developed here that led to the origin of the National Park Service. The Mammoth Hot Springs Historic District has statewide significance as the administrative and concession headquarters of the largest national park in Wyoming. Fort Yellowstone is also listed as a National Historic Landmark District, the highest designation.

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

Mail Carrier's Cabin, 1800s

The origins of the building that became known as the mail carrier's house are a matter of debate, but it is significant as the only 1800s log structure still standing in Mammoth Hot Springs. Its rustic style is more typical of construction of the area and time than are the buildings put up by the US Army for Fort Yellowstone. It was probably built in the mid-1890s, and over the years it has provided quarters for mail carriers as well as concessions employees and National Park Service staff.

History

When mail delivery was not yet provided in rural areas, mail carriers delivered the mail from railroad distribution points to post offices, where people traveled, often from many miles away, to pick up their mail, their only link to the rest of the world. In the 1800s, a mail carrier was contracted to transport mail from the railroad station in Livingston, Montana, to Mammoth Hot Springs and then to Cooke City, Montana, before returning to Livingston, a trip of several days' duration.

The original house at the edge of Fort Yellowstone is believed have had two rooms with a front porch plus a sleeping loft. It was either built by or later sold to an early park concession, the Yellowstone Park Association. A lean-to with a shed roof was built onto the back of the structure in about 1903 to serve as a kitchen and dining area. In the 1930s, a mudroom and bathroom were added to the north side of the building, bringing the total square footage to 512, and concrete was poured around the walls in an apparent attempt to stabilize the building.

The authors of a 1972 historic structure report for Fort Yellowstone found that the building, then owned by a park concessioner, was "in a state of general deterioration and would appear to constitute a serious fire and safety hazard," and that it could "only be considered an eyesore." They recommended that the vacant house be demolished because they doubted that it "could serve any useful function" that would justify the "great cost" of restoration.

The house was listed on the National Register in 1982. Despite the building's poor condition, it continued to house park staff for another two decades.

The mail carrier's house, built around 1895, photographed at an unknown date (left) and in 2009 (right).

Current status

Stabilization, which began in 2005 with funding from the National Park Service Historic Structures Stabilization Fund and the assistance of the Montana Heritage Commission and the Montana Preservation Alliance, has been completed. The entire structure was lifted so that a concrete foundation could be poured beneath it. The floor system and roofing were replaced, the porches were rebuilt, the windows in the front porch were restored, and new logs were added, followed by historically correct daubing. Removal of the Celotex used on the walls and ceilings in the 1930s remodeling exposed a layer of newspapers beneath, announcing the 1903 flight of the Wright Brothers at Kittyhawk. As is, the structure provides a "living history" exhibit; to serve any other function it would need to have electrical wiring and plumbing re-installed.

Mammoth Post Office, 1938

Yellowstone's main post office was one of 1,007 post offices constructed from 1935 to 1938 "with a view to relieving countrywide unemployment." Using standardized plans developed from guidelines provided by the Treasury Department, these post offices were built in sizes and styles that reflect transitions in architectural design and the context of the communities in which the offices were located. The Yellowstone Post Office is a concrete building with a hipped roof in the French Renaissance Moderne style, compatible with the Art Moderne style ornament on the nearby Mammoth Hot Springs Hotel, which was partially rebuilt in 1936. The post office lobby has walls of travertine from a quarry outside the park's north entrance.

Current status

The Yellowstone post office was listed on the National Register of Historic Places in 1987 with 11 other Wyoming post offices built from 1908 to 1939. The buildings were said to "record the evolution of both the political/economic philosophies and the design philosophies of the federal government" during a period when building design was used "to provide a symbol of the monumental presence of the federal government in its post offices."

Roosevelt Arch, 1903

The road (five miles in length) from the park's boundary at Gardiner, Montana, to its headquarters at Mammoth Hot Springs, Wyoming, was built in 1884. The arch constructed over the road became known as Roosevelt Arch because President Theodore Roosevelt, who happened to be vacationing in the park, spoke at the ceremony to lay the cornerstone in 1903. The plaque on the arch is inscribed with a phrase from the legislation that established Yellowstone National Park: "For the Benefit and Enjoyment of the People." Today it would be considered inappropriate to embellish the park's landscape with such a conspicuous, non-functional structure, but Roosevelt Arch continues to serve as a historical marker for a time when cultural values called for a monumental entrance to Yellowstone.

The Roosevelt Arch is in the North Entrance Road Historic District and is part of the Fort Yellowstone Historic Landmark District. The structure was conceived by US Engineer Hiram Chittenden; Robert Reamer may have contributed to the design, and architect N.J. Ness also worked on it.

The two bears at the post office entrance were added in 1941 and commissioned by the Federal Works Agency to enhance federal buildings with artwork. Gladys Caldwell Fisher sculpted the cubs from Indiana limestone based on her observations of grizzly bears at one of the feeding grounds then permitted in the park. The three-ton bears were shipped by rail from Denver to Gardiner, Montana.

The Roosevelt Arch, pictured here on a Haynes postcard.

Old Faithful Inn Historic District

The Old Faithful Historic District, which includes the inn and many of the surrounding buildings, was listed on the National Register of Historic Places in 1982. Like the inn, the district is historically significant because of its rustic architecture and its role in the development of concessions to accommodate growing tourism in the early 1900s. The Old Faithful Lodge, located near the Inn, reached its present configuration in 1928 after numerous changes. The consolidation into one complex was designed by Gilbert Stanley Underwood, a famous architect.

The roof shingles of the Old Faithful Inn, shown here in 1912, were originally coated with a red mineral paint believed to hinder flammability.

Old Faithful Inn, 1904

Named for the geyser near which its construction began in 1903, the Old Faithful Inn exemplifies the use of rustic architecture at a large scale to complement a natural landscape. The rhyolite that formed Yellowstone's caldera during volcanic upheavals provided the stone for the building's foundation, and local lodgepole pine the logs for its walls. Skilled craftsmen embellished the windows and stairways with gnarled wood selected for its inherent beauty. As designed by architect Robert Reamer, the inn combines rugged materials and organic motifs in a way that expresses both frontier sensibilities and elegance.

History

After the only hotel in the Upper Geyser Basin burned down in 1894, park officials pressured the Yellowstone Park Association, which held the lease on the property, to replace it with something more substantial. In 1902 the president of the concession, Harry Childs, obtained financing from the Northern Pacific Railroad for a new structure, the first parts of which would become known as the Old House. The lobby, rising six stories beneath a steeply sloped roof, was flanked by a dining room and two three-story wings containing guest rooms.

The Old Faithful Inn opened in 1904, and was equipped with electric lighting, but Reamer designed the light fixtures to look like candlesticks. Both the electricity and the radiators were fueled by a steam generator. Evening meals were accompanied by a string quartet, and dancing was customary six nights a week. The east wing was added in 1919 and the west wing was added in 1927, both under Reamer's supervision and bringing the inn's total number of guest rooms to about 340.

The August 1959 Hebgen Lake earthquake shook the Old House from its foundation and damaged

Historic preservation has maintained the appearance and condition of the famous Old Faithful Inn lobby, shown here in the first half of the 1900s (left) and in 1998 (right).

the roof and chimneys, but no guests were seriously injured, and after closing early for the winter, the inn opened the following summer. Another evacuation took place in September 1988 when the North Fork Fire destroyed some small buildings nearby, but the Old Faithful Inn was preserved with the help of firefighters, roof sprinklers installed the previous year, and a shift in wind direction.

Current status

The Old Faithful Inn was designated a National Historic Landmark in 1987. A major renovation program of the Old House was launched in 2004 to meet current building codes and restore the lobby so that it more closely replicates Reamer's original design. The walls and roof were reinforced with steel to make the structure more seismically stable, and electrical, plumbing, and heating systems were replaced and made less conspicuous. With the completion of this program, the Old Faithful Inn is considered to be in good condition.

Queen's Laundry Bathhouse, 1881

On a sinter slope in the Lower Geyser Basin miles from any other structure, the bathhouse at Queen's Laundry spring was one of two buildings constructed by Superintendent Philetus Norris in 1881. It is the only building that remains from the first era of civilian park administration (1872–1886) and the first building in a national park constructed by the government for public use. According to its National Register listing, the Queen's Laundry bathhouse represents the "earliest recognition that providing for visitor accommodation was a legitimate use of federal funds within a National Park." It also turned out to be the first step toward what became a conflict between accommodating visitors and leaving the park's thermal features intact.

The Queen's Laundry Bathhouse, shown here in 1995, was never finished and never demolished.

The now roofless bathhouse is located on the edge of a sinter mound formed by the Queen's Laundry Spring, where deposition from the pool's run-off has engulfed it. The pine logs used to construct the building have been partially preserved by the silica and other minerals from the water that has permeated them. There is no evidence of a floor, but it may be buried beneath the silica deposits.

PRESERVATION

Lamar Buffalo Ranch Historic District, 1906

The extermination of bison herds throughout the West in the 1800s nearly eliminated them from Yellowstone; even after the park was established in 1872 poachers faced few deterrents. With only 25 bison counted in the park in 1901, Congress appropriated $15,000 to augment the herd by purchasing 21 bison from private owners. As part of the first effort to preserve a wild species through intensive management, these bison were fed and bred in Lamar Valley at what became known as the "buffalo ranch."

As the herd grew in size, it was released to breed with the park's free-roaming population and used to start and supplement herds on other public and tribal land. Today the Yellowstone bison population of approximately 4,000 is one the largest in North America and among the few that is genetically pure because it has not been interbred with cattle. The buffalo ranch is therefore significant for its role in the history of wildlife management and the preservation of the American bison.

Current status

A program to raise bison like domestic cattle in Yellowstone may seem incongruous and unnecessary in retrospect, but the buffalo ranch stands as a reminder that today's well-intended wildlife management policies may have unintended consequences and be overturned by changing values and advances in ecological knowledge.

As listed on the National Register of Historic Places, the Lamar Buffalo Ranch Historic District includes five buildings: a ranger station, constructed in 1915 as the buffalokeeper's residence; a pole fenced corral built and rebuilt from 1915 to the 1930s, a log barn for hay and horses (1927), a bunkhouse (1929), and a residence used for the assistant buffalo keeper

The Lamar Buffalo Ranch, in operation from 1906 until the 1950s, was the center of efforts to increase the herd size of bison in Yellowstone.

Bison calf butting park ranger at the buffalo ranch, 1930s.

that was moved to the ranch in 1938 from Soda Butte, where it had probably been a ranger station. The vegetation around the ranch is mostly sagebrush and nonnative grasses that were planted during the period of hay cultivation or migrated into the area. Remnants of irrigation ditches, fencing, and water troughs can still be found.

The bunkhouse, its interior remodeled, is used by the Yellowstone Association Institute, which conducts classes and seminars during the summer and by Expedition: Yellowstone!, the Division of Resource Education and Youth Programs' overnight program for school groups. In 1993 the Yellowstone Association replaced the old tourist cabins, brought from Fishing Bridge in the early 1980s, with insulated and heated cabins for participants in its programs. But except for the phone line, the cabins and other buffalo ranch facilities are off grid.

The main source of power is a 7-kilowatt photo voltaic array installed in 2000 with industrial battery storage and two alternating 12-kilowatt engine generators. In the summer of 2006, the Buffalo Ranch's hybrid power system operated entirely on renewable energy by using vegetable-based fuel instead of propane for the generators.

Funding from the Yellowstone Park Foundation is enabling the National Park Service to use the buffalo ranch as a model for off-grid environmental stewardship by adding more solar panels, low-flow water fixtures, micro-hydropower, on-demand hot water, zero-waste and recycling programs, and more energy-efficient windows, while preserving the historical integrity of the original structures.

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Roosevelt Historic District

The Roosevelt Lodge Historic District, which includes 130 buildings, was listed on the National Register of Historic Places in 1983, with a period of significance from 1906 to 1948. The accommodations are still rustic, with unpaved roads into and around the lodge and cabins. Although the Grand Loop Road can be seen from the corral, which is not part of the historic district, it is obscured from view of the lodge and most of the cabins by a stand of mature trees.

The area has undergone intermittent expansion and changes as visitor use has changed and facilities have aged over the years. The architectural appearance of the original lodge is retained only in the interior and exterior of the front portion (the lounge and dining room); the other sections of the building have been modified. The interior has become congested with multiple activities, some of which were not part of the original building—a bar, vending machines, gift shop, and offices.

In 2009, the National Park Service completed an environmental assessment for the Tower–Roosevelt area to set limits on the kind, location, and amount of development that will occur there in order to protect the area's natural resources and preserve its historical character, including the rustic architecture of Roosevelt Lodge and the small cabins, the arrangement of the lodge and cabins around a grassy meadow, and the view from the lodge porch across the meadow to the distant mountains. The chosen alternative will allow a maximum net gain of 1,300 square feet (2 percent) in the buildings' footprint for additional cabins, employee restrooms, and a shower house, and 2,000 square feet (6 percent) increase in the parking footprint to improve views and reduce congestion near the lodge.

Roosevelt Lodge, 1920

Indians, fur trappers, and explorers on the Bannock Trail camped in this area where a sagebrush meadow was encircled by Douglas fir, quaking aspen, and a mountain stream tumbled toward the Yellowstone River. President Chester Arthur camped here in 1883. In 1906, the Wylie Permanent Camping Company built a tent camp there that became known as "Camp Roosevelt," though Theodore Roosevelt never camped there. The tents were replaced by a lodge and cabins in the 1920s, and the Lost Creek has shifted course, but people still enjoy staying at this scenic spot on the park's northern range.

For dudes and scientists

Camp Roosevelt's location provided an overnight stop for visitors traveling between Mammoth Hot Springs and Canyon. As at other Wylie camps, guests slept in striped tents with wood floors, gathered at a larger tent for communal meals and sing-alongs, and were transported around the park in the Wylie company's vehicles. The successor to the Wylie company, the Yellowstone Park Camping Company, built the park's first and smallest lodge at Camp Roosevelt in 1919. The lodges were built to accommodate the increasing number of visitors arriving in their own automobiles who wanted something more than a tent but less expensive and formal than the park's hotels. During the 1920s and 1930s, the old hotels often stood empty while the new lodges overflowed with visitors.

At Camp Roosevelt, the concessioners wanted to create the atmosphere of a dude ranch, and Superintendent Horace Albright described it as "a place visitors would like to stay indefinitely." It did provide a base for fishing parties and saddle-horse trips, but it was also expected to serve as a field

The Roosevelt Lodge before it faced a parking lot (Haynes postcard, 1927).

Roosevelt Lodge interior with photograph of Theodore Roosevelt, 1920s.

laboratory where teachers and their students could conduct research at minimum expense, a purpose that the first director of the National Park Service, Stephen Mather, was promoting for the parks. In what was a forerunner to the educational programs found in the parks today, the National Park Service hired H.S. Conard, a naturalist at Grinnell College, to present lectures and conduct daily field trips for Camp Roosevelt visitors and collect botanical specimens for the park museum. Scientists based at the hotel conducted studies on the park's wildlife. From 1921 to 1923, the lodge was the headquarters for a boy's summer camp run by Alvin Whitney of the New York State School of Forestry at Syracuse University.

The buildings

The lodge, constructed of unpeeled logs and completed in 1920, was originally surrounded by 43 small log cabins, the first of which were completed in 1922. Over the years, the Roosevelt Lodge area became a repository for guest cabins brought from areas in the park where they were no longer wanted. By 1982, the corral had been moved farther from the cabins, of which there were now 110 of four main types.

Northeast Entrance, 1935

The entrance station and ranger residence at Yellowstone's northeast entrance were constructed in 1935 in a rustic style that was becoming emblematic of national park architecture. According to its listing as a National Historic Landmark in 1987, the entrance station "subconsciously reinforced the visitor's sense of the western frontier and the wilderness he was about to enter. The building was not only the physical boundary, but the psychological boundary between the rest of the world and what was set aside as a permanently wild place." The station is considered "the best of its type remaining in the National Park System."

The entrance station was constructed with two traffic lanes passing through it. When it became necessary to accommodate the increasing number of recreation vehicles too tall to fit in the passage, a lane was added to each side of the building rather than alter it. These drivers must walk around to the checking station office, but the system is workable because of the relatively low volume of traffic at the entrance.

The station is currently considered to be in good condition. Extensive rehabilitation of the entrance station in 1984 repaired log ends with epoxy and replaced log rafters and the roof. The oakum rope chinking remains. Two street lights and a flagpole were added, and concrete bollards were placed on the east and west side to prevent vehicles from driving into the building. The interior of the checking station has undergone little change over the years. Although the original plans called for earth floors, the rooms have concrete floors that were probably poured sometime after construction. The original wood stove that heated the central portion of the station was replaced with an oil stove in the same location.

Northeast Entrance station is considered "the best of its type remaining in the National Park Service."

Historic Roads, 1905

The road construction that began in Yellowstone in the 1870s became the United States' first large-scale road plan and served as a model for other parks, especially in its use of local materials. Even after Yellowstone could be reached by train in 1883, the difficulty of transport and road construction in a geologically and climatically challenging terrain required enormous labor and innovative engineering. The development of a road system was essential in making Yellowstone more accessible to the public. Over the years, advances in road standards and construction technology have led to changes in the roads' appearance, but the overall design has remained largely intact, along with many historical features such as bridges, culverts, and guardrails.

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 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 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.

Hiram Chittenden

The 300-mile, figure-eight road system that connects Yellowstone's five entrances, developed areas, and major attractions remains largely the same as when engineer Major Hiram Chittenden finished his work on it in 1905. Through his role in designing Yellowstone's roads, bridges, and other structures, Chittenden had a lasting effect on the appearance of our national parks. While stating that they should be maintained "as nearly as possible in their natural condition, unchanged by the hand of man," he would use masonry and add or remove trees and other landscaping so that "the roads will themselves be made one of the interesting features of this interesting region."

Throughout the park, he replaced many wooden bridges with steel or concrete. His most difficult project was the replacement of the rickety trestle at Golden Gate with a 200-foot viaduct, a series of 11 concrete arches built into the cliff wall over a canyon. In 1902 he persuaded Congress to make the appropriation needed to complete the park's road system. This included some of Chittenden's signature achievements: the road over Sylvan Pass, the road to Mount Washburn (now called Chittenden Road), and the bridge over the Yellowstone River above the Upper Falls, which at last provided a means of getting to the east bank of the river without going all the way north to Baronett's bridge. Over the years, the Golden Gate viaduct had to be reconstructed, and the bridge over the Yellowstone River was condemned in 1959. A campaign to preserve the original bridge by building the new Chittenden Memorial Bridge in a different place was thwarted by the discovery that Chittenden had used the only logical location.

Before leaving Yellowstone in 1906, Chittenden was also responsible for overseeing the redesign of the park's north entrance, including construction of the arch and, through irrigation, fertilization, and the planting of alfalfa, transforming 50 acres adjacent to Gardiner into a green field that would provide winter forage for pronghorn and other game animals. Today, efforts are being made to restore the field to its natural condition, but the Roosevelt Arch endures.

Trailside Museums (1929–1932)

The museums at Fishing Bridge, Madison Junction, and Norris Geyser Basin were designated National Historic Landmarks in 1982 because their exaggerated features and organic forms exemplify rustic design in the national parks and served as models for hundreds of park buildings constructed during work relief programs of the 1930s. As envisioned by the chairman of the American Association of Museums, Hermon Bumpus, they also established the idea of "trailside museums" where visitors could learn about an area within a park. Bumpus regarded national parks as "roofless museums of nature" with unlabeled exhibits and the trailside museum as the place to provide the labels.

Designed by Herbert Maier in a style that became known as "Parkitecture," the museums have the battered rubble masonry and clipped gables of a traditional bungalow style, but use locally available materials left in their natural condition to reflect the scale and roughness of the landscape. The asymmetrical boulders and gnarled logs display the irregularities of nature. Maier, who also designed museums for Grand Canyon and Yosemite, regarded buildings in national parks as "necessary evils" because even the best was "somewhat of an intruder." Their National Register nomination described the trailside museums as "a perfect solution for an architecture appropriate to the outdoors: informal through the use of natural materials and horizontal lines," but with "a strength of design and heavy-handed expressions" that "suggested the smallness of man in relation to nature."

History

In 1928, Yellowstone Superintendent Horace Albright proposed the construction of "small local museums" to provide visitors with information that would "make their sojourn educationally as well as recreationally profitable." With a grant from a foundation set up by John D. Rockefeller and the guidance of Dr. Bumpus, the American Association of Museums built four such museums in Yellowstone.

The Museum of Thermal Activity, constructed at Old Faithful in 1929, was razed and replaced by a visitor center in 1971. It opened in 1929 to acclaim for its quality materials and construction, and for the way it blended into its surroundings. The exteriors of the other museums have changed little since their completion by 1932, but the interiors have undergone small and large alterations in design and use.

In a 1942 report, park naturalist Bert Long pointed out that "due to lack of funds," there were "many obvious gaps and inadequately told phases" of the Yellowstone story as told in its museums, and that many of the exhibits contained obsolete scientific theories. "Every attempt should be made to include in each museum information pointing out what there is to do of a recreational nature in its surroundings," Long urged. "Get the people out of their cars, on the trails to the features and half the battle is more than won." The difficulty of funding and keeping exhibits up to date has not lessened over the years, nor has the goal of getting people out of their cars changed, but the efforts to do so have. Only the Norris Geyser Basin Museum still has its original name.

Fishing Bridge Museum, 1932

Now called the Fishing Bridge Visitor Center, the building was designed so that visitors approaching from the parking lot could see through it to Yellowstone Lake, where stone steps lead down to the shore. In 1933, Superintendent Roger Toll complained that the irregular steps at the Norris and Fishing Bridge museums were "unsatisfactory for the considerable number of people that use these museums." He asked the park's landscape architect to "take advantage of this experience and not use any more native stone for the treads in park buildings." Some of the stone steps at the Fishing Bridge Visitor Center have been replaced by rounded concrete steps and a ramp for accessibility.

Antlers, rams' horns, and bighorn sheep skulls still decorate the two wrought-iron chandeliers, but they were removed from the log frame around the screen in the adjacent amphitheater, where the original log seats were replaced with thick plank seats. No longer used, the fireplace beneath the large stone chimney is concealed from public view in a small area used

The Fishing Bridge Visitor Center and Museum, 2007.

for offices. Other changes include the linoleum tiles over the concrete floor, fluorescent lighting, plywood covers on some of the windows to allow removable walls for the exhibits, and replacement of the window glass with green plastic to accommodate lighting for exhibits.

Norris Museum, 1930

The open foyer through the middle of the Norris Museum still functions as the visitor's gateway to the Norris Geyser Basin. One of the two rooms on either side of the foyer originally contained bird specimens; both now have exhibits explaining geothermal activity and life in thermal areas. Also designed by Maier with rustic architectural features, the nearby comfort station, as it was then called, was converted to a Yellowstone Association bookstore after a larger restroom of more contemporary style was built closer to the parking lot.

Madison Museum, 1930

Overlooking a meadow beyond which the Gibbon and Firehole rivers join to form the Madison River, the Madison Museum was intended to focus on park history, especially the nearby site where the 1870 Washburn expedition was thought to have originated the idea of a national park as a way to protect the thermal areas from commercial development. In accordance with Bumpus's vision of the museum's "function as a national monument," a large glass transparency created from a 1930 photograph was placed prominently in a window where the light shone through a re-enactment of the Washburn party gathered around a campfire.

In 1940, a park naturalist suggested that the main room's floor, made of large, uneven pieces of rhyolite, should be covered with oak or pine to "avoid possible hazards to visitors from stumbling falls" and make it easier to clean. That did not happen, but when the building was transformed into the "Explorers' Museum" as part of Yellowstone's 1972 centennial celebration, carpeting and track lighting were installed, the wood stove that used to heat the building was removed, and the exhibits were redesigned.

In acknowledgement of evidence long put forth by historian Aubrey Haines that refuted the "campfire story," the re-enactment transparency and references to the Washburn party's role in establishing the first national park were removed from the museum. However, in deference to Albright, still influential in retirement, and National Park Service officials who would not abandon the story, the purported campfire discussion was commemorated in a sign placed outside the museum: ". . .there emerged an idea... that there should be no private ownership of these wonders but that the area should be preserved for public enjoyment." The sign is still there, but by 1975 the museum was unstaffed and vandalized.

What remained of the exhibits was removed and the building was vacant until 1991, when it became home to an "Artists in Residence" program for several years. Since 1995, the Yellowstone Association has had a bookstore there, and what is now called the "Madison Information Station" also bears a "Junior Ranger Station" sign, making it a stop for those earning their badges.

Haynes Photo Shops

As leaders in concessions development in Yellowstone from 1884 to 1962, Frank Jay Haynes and his son Jack Ellis Haynes constructed many buildings for their enterprises. Among the few that remain, the stores at Old Faithful (1927) and in Mammoth Hot Springs (1929) were most important to the primary Haynes business of taking, developing,

The Norris Geyser Basin Museum, 2009.


The Madison Information Station, 2009.

and selling photographs. By helping Yellowstone gain international recognition for its natural wonders, the Hayneses' photography promoted both tourism in the West and the idea of a national park.

The Old Faithful building is an example of the rustic style that was becoming popular in western parks, while the Mammoth building displays a transitional architectural style influenced by the Crafts movement, a departure from more traditional revival styles prevalent in Mammoth that was unrelated to the rustic architecture prevalent elsewhere in the park.

History

F. Jay Haynes first photographed Yellowstone National Park in 1881 to publicize the Northern Pacific Railroad. Encouraged by Superintendent Philetus Norris, who wanted to promote park visitation, Haynes built stores on land leased in Mammoth Hot Springs in 1884 and at Old Faithful in 1897. After he retired, his son Jack took over the business, and in 1927 built stores, called photo or picture shops, in the Mammoth and Fishing Bridge campgrounds, and a larger facility near what was then the Old Faithful Auto Camp. Eventually, 13 Haynes stores were opened in hotels or their own buildings.

The 1927 Old Faithful store, designed and constructed in two months by contractor George Larkin, had living quarters on the second floor over a photo finishing operation as well as a retail shop. A two-story dormitory for Haynes employees was added in 1951, and an addition to the rear of the building several years later.

The Mammoth Hot Springs facility, designed by Fred Willson and completed in 1929, served as the headquarters for the Haynes photographic business in the park. It included a dormitory, an overnight photo finishing service, and retail space that carried an assortment of photographs, books, camera film and other supplies. The drive-through canopy acknowledged the growing influence of the automobile on architectural design.

From a Haynes postcard of the Haynes Picture Shops Headquarters at Mammoth Hot Springs, 1934.

Current Status

Jack Haynes operated the family business until his death in 1962. After running the company for another five years, his wife Isabel sold it to Hamilton Stores, owned by the Povah family. After most of the Old Faithful building was moved in three pieces and reconfigured near the newly constructed Snow Lodge in 1971, Hamilton Stores renovated the dormitory and added a front porch. Nearly all of the exterior materials on the original store are still present or have been replaced in-kind. By 1998, the original Snow Lodge had been razed and a new Snow Lodge opened immediately adjacent to the Hamilton Store.

When the Hamilton Stores contract expired in 1999, the National Park Service purchased the buildings at Old Faithful and Mammoth. The Old Faithful store detracted from the appearance of the new Snow Lodge, and after considering several alternatives, in 2009 the National Park Service dismantled the dormitory and moved the original portion of the building to a site near its original location. The Yellowstone Park Foundation will use the old Photo Shop when remodeling is completed. Its former site has been landscaped as public open space.

Except for the stairway, nearly all of the exterior materials in the Mammoth building are original. Finishes and fixtures in the kitchen and bathrooms date from the 1950s to the 1970s; most of the other interior materials are original. Although the National Park Service is currently using it as a storage facility, other options are under consideration.

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.

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.

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Staff reviewers

Tobin Roop, Chief of Cultural Resources

Lee Whittlesey, Historian

The Fountain Hotel is one of several hotels that are no longer in Yellowstone.

Construction of Other Park Buildings

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

Tower General Store, 1932

West Thumb Ranger Station 1925; now an information station

Collections

Yellowstone's collections document the cultural and natural history of the world's first national park and the conditions of its resources. The historic collections document the park from pre-history through the present. The collections include objects and written records that document the history and science of the park, changes in perception and meaning over time, and the interaction between people and nature. Specimens range from geologic and natural history to Native American and European American cultural materials.

It is National Park Service policy to collect, protect, preserve, provide access to, and use objects, specimens, and archival and manuscript collections to aid understanding and advance knowledge. Collections play important roles in resource management, research, and education programs, and function as baseline databases for park natural and cultural resources.

With several million items, Yellowstone has one of the largest collections in the National Park Service. Yellowstone National Park's collections grow continuously with the addition of archival records (generated mostly by National Park Service staff), archeological and natural science objects, important donations, and occasional purchases.

The Heritage and Research Center houses Yellowstone's museum collection, archives, and research library.

Heritage and Research Center

For years, the collections were housed in various locations within and outside of the park, where they were frequently threatened by flood, fire, environmental degradation, theft, and inattention. With the opening of the Heritage and Research Center in 2005, the collections of "Wonderland" are finally housed together, with the exception of the historic vehicles, and their storage brought up to the standards demanded by the National Park Service, the American Association of Museums, and the National Archives and Records Administration.

Collections in Yellowstone

Number in Yellowstone

- More than 300,000 museum items, including 30 historic vehicles
- Two archive collections, containing millions of documents, 330 subject finding aids, and 175 16mm films documenting the park's history
- A research library containing more than 20,000 books, periodicals, theses and dissertations, unpublished manuscripts, microfilm and other micrographic formats of historical newspapers and scrapbooks, brochures, technical reports, and audio visual material

Together, several million items, one of the largest in the National Park Service.

Where to See

Gardiner, Montana

- The Heritage and Research Center is open Monday–Friday, 8 am–5 pm (except federal holidays); the public is welcome to tour the temporary exhibits located in the lobby.
- The library is open to the public Monday–Friday.
- The archives and museum collections may be accessed for research purposes by appointment.
- Public tours may be available from June to September. Call (307) 344-2662 to reserve a slot.

Conducting Collections Research

Researchers range from local high school students working on term papers to tourists re-tracing an ancestor's visit, and from park staff developing education programs or researching climate change to filmmakers preparing a miniseries for PBS.

Researchers are encouraged to complete their preliminary research at other archives, libraries, and/or museum collections with a broad topical focus before approaching the holdings of Yellowstone National Park. Yellowstone has limited reference staff and resources that must be made available to researchers whose work focuses on materials available only at the park. Access to materials is dependent upon their physical condition and the level of processing to date by the park staff. All research must be done on-site in the museum research room or the library reading room.

For more information, visit http://www.nps.gov/yell/historyculture/collections.htm

Most of these items are kept in the Heritage and Research Center, which is located outside the park entrance in Gardiner, Montana. The Heritage and Research Center is a collections storage facility that also houses the park's herbarium and archeology lab, and features small rotating exhibits in the lobby.

Museum collection

Yellowstone's museum collection contains more than 300,000 items that, along with the archives and library collection, document the cultural and natural history of the park. The museum collection consists of natural history, archeological, and cultural objects, including obsidian points, skulls from the first wolves reintroduced in the park, Thomas Moran's original watercolor field sketches, William Henry Jackson's photographs, furniture from the historic hotels and other historic structures, and an extensive historic vehicle collection ranging from stagecoaches and wagons, through early buses and automobiles, to fire trucks and a snowmobile.

The collection is used each year by park staff and other researchers looking for background information on Yellowstone history, specific reference material, and illustrations for commercial products, school programs, special events, and adult education. The televised series, "The National Parks: America's Best Idea," by Ken Burns contained hundreds of images from Yellowstone's collections.

While the Heritage and Research Center does have some rotating exhibits in the lobby area, the facility was not designed to be a museum, but rather a research center and a state-of-the-art storage facility. With exception of some restricted collections, such as Thomas Moran's original watercolor field sketches, William Henry Jackson's photographs, and other rare or fragile items, the museum collections are accessible to researchers by appointment only and require at least 24-hours advanced notice.

One of almost 100 skulls and skeletal materials in the museum collection from the park's Wolf Project, wolf 007F was released in Yellowstone in 1995 as a Rose Creek pup. She joined 002M from the Crystal Creek pack in 1996 to form the Leopold Pack, the first naturally formed pack of the new era. She was killed by Geode Creek wolves in 2002.

Historic vehicle collection

Yellowstone National Park's historic vehicle collection currently includes thirty horse-drawn and motorized vehicles. They range from stagecoaches operated by the Yellowstone Park Transportation Company (later the Yellowstone Park Company) and Monida and Yellowstone Stage Company (later the Yellowstone-Western Stage Company), to early Yellowstone Park Transportation Company touring cars, buses, and service trucks, to National Park Service scooters and a fire engine. Also represented in the collection are numerous human-powered vehicles, including fire hose carts and handcarts, or "Mollys" used by hotel maids and bellboys.

The vehicle collection is one of the largest in the National Park Service. Currently housed in an historic structure (a former Yellowstone Park Transportation Company structure built in 1925 to replace the original transportation facilities destroyed by fire), it is hoped that a more suitable storage/exhibit facility will eventually be constructed, possibly as a wing of the Yellowstone Heritage and Research Center. The vehicle collection is currently not open to the public.

The majority of the vehicles were received from TW Recreational Services, Inc. (successor of the Yellowstone Park Company) in 1991. Others have been added to the collection (such as the Willys fire

Yellowstone's historic vehicle collection, one of the largest in the National Park Service, includes this car.

truck) when they became obsolete or surplus to National Park Service needs. Volunteers performed initial cleaning of the vehicles, and the Yellowstone Association and Yellowstone Park Foundation have also provided funding for preservation and conservation efforts.

More recently, some federal funding was provided for extensive preventative conservation treatment (cleaning and stabilizing some of the vehicles) by National Park Service staff. Some of the vehicles have been loaned to other museums and institutions for special exhibits, and the entire collection was the focus of a segment in "Hidden Yellowstone," a film aired by the Discovery Channel.

Archives

The Yellowstone National Park archives house records that document natural and cultural resources of the park as well as how the national park idea developed after Yellowstone's establishment, how policies for managing the world's first national park were developed, and how they continue to develop today. The Yellowstone Archives is an affiliate of the US National Archives and Records Administration and houses a unique record of physical and administrative development beginning with early civilian superintendents and pioneer entrepreneurs, through the turn-of-the-century military era, to the founding and development of the National Park Service.

The collections include documents from the military administration of the park (1886–1918), administrative records from the establishment of the National Park Service (1916) to the present, resource management records that document how the natural and cultural resources are protected, records of major projects that have occurred in the park, the records of park concessioners such as the Yellowstone Park Company, and donated manuscripts. The collection also contains historic maps, photographs, films, oral histories, administrative records, and scientific data.

The park is allowed to permanently hold federal records created by the park's administration instead of transferring them to the National Archives because of its affiliation with the National Archives and Records Administration. While legal custody of these records belongs to NARA, physical custody is kept by Yellowstone National Park to allow researchers to have the best access to both current and historical resources in one location. Finding aids, or detailed descriptions, of the collections as well as information about accessing the documents may be found on the Yellowstone's archives webpage.

Research library

The mission of the Yellowstone Research Library is to collect published and unpublished materials related to Yellowstone and to make these materials available to park staff, researchers, and the general public. The library collection consists of more than 20,000 books, periodicals, theses and dissertations, unpublished manuscripts, microforms of historic newspapers and scrapbooks, brochures, technical reports, and audio visual material.

The Map Room collection includes a large number of published maps from 1865 to the present. In the Rare Book Room are the personal papers and books of notable figures from Yellowstone history, including Major Hiram Chittenden and several early superintendents. Donations from the Yellowstone

The archives are an affiliate of the National Archives and includes records from the US Army's administration of the park.

The Yellowstone Research Library is in the midst of a digitization project that will make library records accessible online.

Association, the Yellowstone Park Foundation, and private donors, as well funding provided by the National Park Service, have made possible an impressive, possibly unsurpassed, example of Yellowstone National Park resources.

The library has also hosted teacher training seminars focusing on primary documents and teacher-led high school writing groups. In 2006, the library staff began a bookmobile service that travels around the park interior once a month during the summer. Participation in the program has grown by at least 30 percent every year since it began.

The Yellowstone Library and Museum Association, predecessor of today's Yellowstone Association, was organized in 1933 in part "to assist in the establishment and development of a Yellowstone Park Library for the use of rangers, ranger naturalists and others dealing with park visitors and the public." While the library collection is now the property of the National Park Service, the Yellowstone Association continues to support the library by employing librarians and providing most of the funding for purchases and subscriptions as well as for specific library projects.

FREQUENTLY ASKED QUESTION:

Can I access the collections online?

The Yellowstone Research Library's catalog is available through the Wyoming Library Databases consortium (http://wyld.state.wy.us/yrl/) and the National Park Service's libraries (http://www.library.nps.gov). Records that are available online are linked through the library catalog. Finding aids for processed archives collections may be accessed at http://www.nps.gov/yell/historyculture/archives.htm.

The Yellowstone Research Library and Clemson University are working to digitize the library's collection. To follow the progress of this project, go to http://archive.org/details/clemson and search "collection:clemson Yellowstone".

Staff reviewer
Colleen Curry, Supervisory Museum Curator

The Greater Yellowstone Ecosystem, with Yellowstone at its core, is one of the largest intact temperate-zone ecosystems on Earth.

Greater Yellowstone Ecosystem

Yellowstone National Park forms the core of the Greater Yellowstone Ecosystem. At 28,000 square miles, it is one of the largest intact temperate-zone ecosystems on Earth. Greater Yellowstone's diversity and natural wealth includes the hydrothermal features, the wildlife, the lakes, the Grand Canyon of the Yellowstone River, and the petrified trees of Yellowstone National Park.

Heart of an Ecosystem

Yellowstone National Park was established in 1872 primarily to protect geothermal areas that contain about half the world's active geysers. At that time, the natural state of the park's other landscapes, waters, and wildlife was largely taken for granted. As development throughout the West increased, however, the park's 2.2 million acres of forests, meadows, river valleys, and lakes became an important sanctuary for the largest concentration of wildlife in the lower 48 states and the Greater Yellowstone Ecosystem.

The abundance and distribution of these animal species depend on their interactions with each other and on the quality of their habitat, which in turn is the result of thousands of years of volcanic activity,

Greater Yellowstone Ecosystem

Space and Ownership

- 12–18 million acres; 18,750–28,125 square miles (Sizes, boundaries, and descriptions of any ecosystem can vary.)
- 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

Wildlife

- One of the largest elk herds in North America
- Largest free-roaming, wild herd of bison in United States
- One of few grizzly populations in contiguous United States
- Rare sightings of wolverine and lynx

In Yellowstone

- 67 mammals
- 322 bird species; 148 species nest here
- 16 fish species: 11 native, 5 nonnative
- 10 reptiles and amphibians
- 12,000+ insect species, including 128 species of butterflies
- 1,150 species of native vascular plants

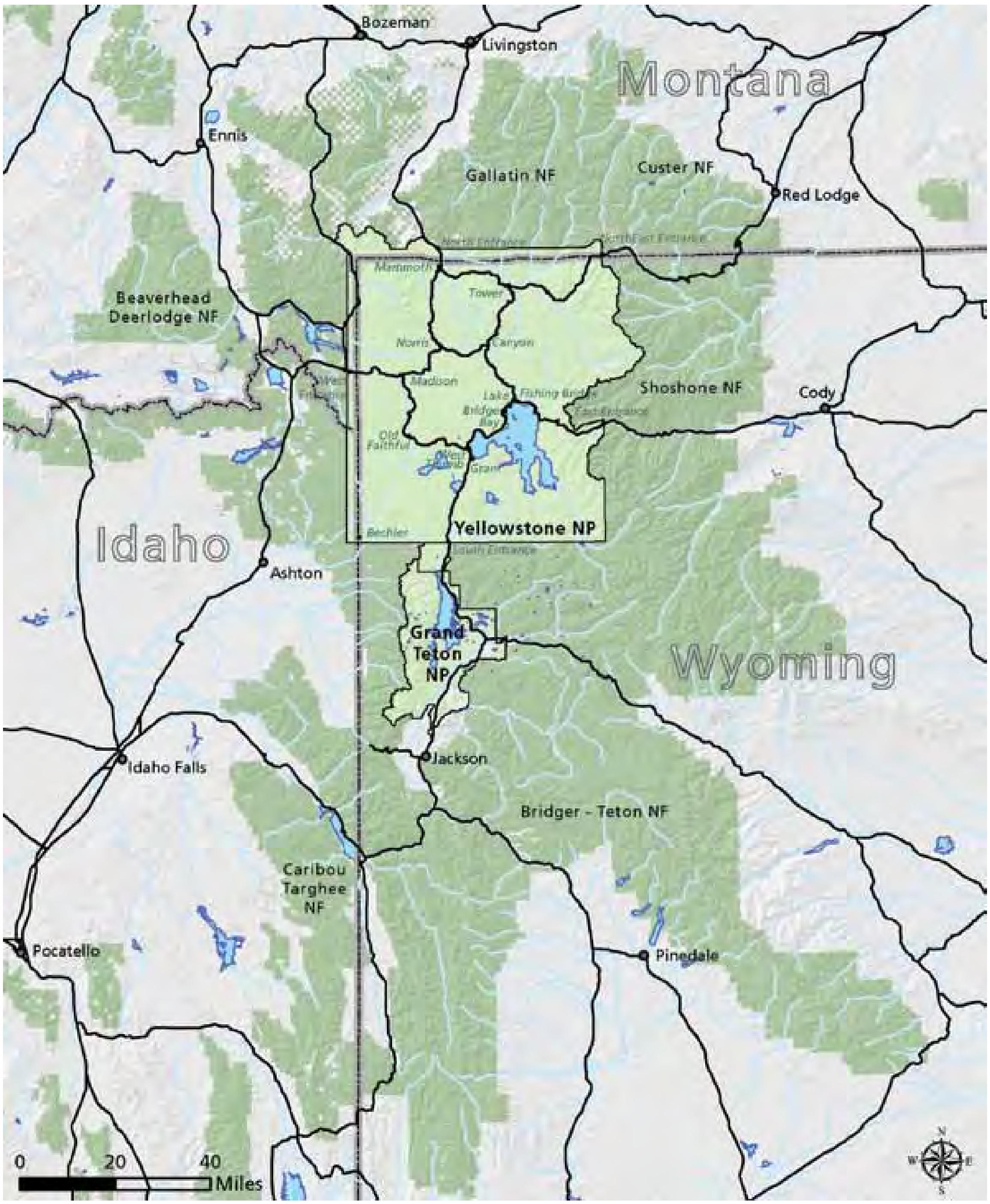
Management Challenges

- Climate change
- Invasive species
- Winter use
- Bioprospecting and benefits sharing
- Yellowstone's northern range
- Managing an ecosystem across political boundaries

forest fires, changes in climate, and more recent natural and human influences. Most of the park is above 7,500 feet in elevation and underlain by volcanic bedrock, a terrain that is covered with snow for much of the year and supports forests dominated by lodgepole pine and interspersed with alpine meadows. Sagebrush steppe and grasslands on the park's lower-elevation northern range provide essential winter range for elk, bison, and bighorn sheep.

Influence of geology

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. Some scientists believe the Yellowstone Plateau itself is a result of uplift due to hotspot volcanism.



The Greater Yellowstone Ecosystem. Sizes, boundaries, and descriptions of any ecosystem can vary—and the Greater Yellowstone Ecosystem is no exception.

Today's landforms even influence the weather, channeling westerly storm systems onto the plateau where they drop large amounts of snow.

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.

Because of the influence rock types, sediments, and topography have on plant distribution, some scientists theorize that geology also influences wildlife distribution 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 Mount 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. The many hydrothermal areas of the park, where grasses and other food remain uncovered, provide sustenance for animals during winter.

Air quality

Even at relatively low levels, such as those found in the Greater Yellowstone Ecosystem, air pollution and deposition can leach nutrients from soil, injure vegetation, and acidify and fertilize lakes and streams. The Clean Air Act Amendments of 1977 designated Yellowstone and Grand Teton among the 156 national parks and wilderness areas that are Class I airsheds, requiring the most stringent air quality protection within and around their boundaries. The thin soils, sparse vegetation, short growing seasons, and snowmelt-dominated hydrology of high elevation basins that limit the amount of nitrogen that can be effectively assimilated make these areas more vulnerable to the effects of acidification and nutrient enrichment from nitrogen deposition.

Yellowstone and Grand Teton are in compliance with federal air quality standards for human health. However, air-quality trends may be affecting other aspects of the ecosystem. For example, nitrogen in precipitation has increased at many Western sites as a result of ammonium ion concentrations associated with fertilizer use and feedlots. By stimulating plant growth, nitrogen can alter species abundance and distribution. Although nitrogen is a nutrient needed for plant growth, too much nitrogen disrupts native plant communities that are adapted to low nitrogen conditions; high nitrogen levels can advance the spread of nonnative species that increase fire frequency. Acidification in high alpine lakes from sulfur and nitrogen deposition can cause the loss of macroinvertebrates and fish. Changes in the algal composition in sediment cores from several alpine lakes in Yellowstone and Grand Teton that began in about 1980 are correlated with increased nitrogen loading.

While naturally-occurring ozone in the upper atmosphere protects life by absorbing the sun's ultraviolet rays, ground-level ozone is a pollutant that can travel hundreds of miles after forming when nitrogen oxides from vehicles, power plants, and other sources combine with volatile organic compounds emitted by a variety of artificial and natural sources. Ozone concentrations in Yellowstone typically peak in spring rather than summer, indicating that human influences are less significant than changes in atmospheric circulation and lengthening daylight. Nonetheless, in addition to causing respiratory problems in people, ozone levels during the growing season (the exposure index) may be high enough to cause biomass loss in sensitive species such as aspen.

Sources of particulate matter

The largest source of particulate matter in Greater Yellowstone is smoke from wildland fires, which is considered part of the area's "natural background conditions" and is taken into consideration in establishing the threshold for "good" visibility. Emissions from prescribed fires have been relatively insignificant. Because of prevailing winds, Wyoming oil and gas development has not had a detectable effect on air quality in Yellowstone.

ECOSYSTEM

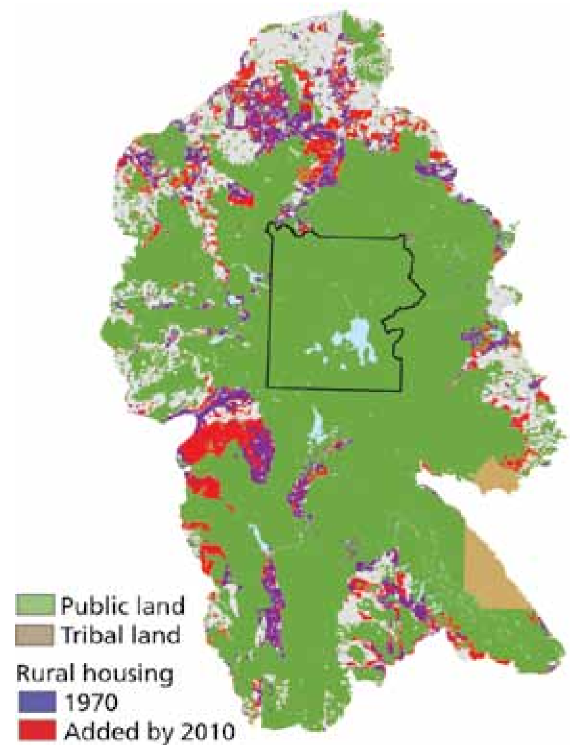
Soundscapes

The natural soundscape of the Greater Yellowstone Ecosystem has many biological sounds with important ecological functions for reproduction and survival. Birds, mammals, amphibians, and insects often need to hear or produce sounds to attract mates, detect predators, find prey, and/or defend territories.

The natural soundscape of the Greater Yellowstone Ecosystem delights visitors during the fall elk rut, during birds' spring choruses, along rushing streams, and in the delightfully still and profoundly quiet days and nights of winter. Natural soundscapes are a resource and are protected by National Park Service policies. Many park visitors come to national parks to enjoy serenity and solitude and expect to hear sounds of nature. Sounds associated with human activity, including road traffic, aircraft, and snowmobiles often impact these natural soundscapes and are an important and growing source of concern. Yellowstone and Grand Teton national parks initiated a soundscape monitoring program in 2003.

Land use

How land is used outside the park can disrupt ecological processes within the park. Still sparse in the early 2000s, the population in Greater Yellowstone has grown steadily since 1970. Data compiled by the Greater Yellowstone Inventory and Monitoring Network show that from 1990 to 2010, the population of census block groups in and near the Greater Yellowstone Ecosystem increased nearly 50 percent (approximately 220,000 to 323,000). Much of the growth occurred in rural residential areas with one home per 0.4 to 16.2 hectares. Development density is expected to increase, but with rural residential development continuing to dominate. Agriculture is still a significant use of the land. In 2007, the percentage of land in the counties in and near the Greater Yellowstone Ecosystem on which crops were grown ranged from less than 5 percent to more than 50 percent.



Rural housing and land ownership in the Greater Yellowstone Ecosystem.

More information

McIntyre, C.L., and C. Ellis. 2011. Landscape dynamics in the Greater Yellowstone Area. Natural Resource Technical Report NPS/GRYN/NRTR–2011/506. National Park Service, Fort Collins, Colorado.

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

Yellowstone to Yukon: www.Y2Y.net

Staff reviewer

David Hallac, Chief of Yellowstone Center for Resources

Biodiversity, or the assortment of living organisms, is important to ecosystem integrity and resilience, particularly in response to the threat of climate change.

Biodiversity and Processes

Biological diversity

Biological diversity is a benchmark for 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). Significantly, Greater Yellowstone's natural diversity is essentially intact. The region appears to have retained or restored its full historical 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 living representatives of the primitive life forms now recognized as the beginnings of life on this planet. Cyanobacteria found in Yellowstone's hot springs are similar to the cyanobacteria that were among the first organisms capable of photosynthesis (the process by which plants use sunlight to convert carbon dioxide to oxygen and other byproducts). Because Earth's original atmosphere was anoxic (without oxygen), cyanobacteria's photosynthesis began to create an atmosphere on Earth that would eventually support plants and animals. Knowledge of the park's biodiversity expanded in 2009 with Yellowstone's first bioblitz.

Cycles and processes

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

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

The ecosystem is constantly changing and evolving. A wildland 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 re-sprout. 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.

Bioprospecting: Innovation through science

Yellowstone's extremophiles, especially thermophiles, have been the subject of scientific research and discovery for more than 100 years. The discovery of *Thermus aquaticus* bacteria in the 1960s has had scientific and economic benefits far beyond what anyone could have imagined and played into the growing scientific interest in bioprospecting and extremophiles, calling greater attention to the research potential of Yellowstone.

Today, several scientific research projects sponsored by universities, NASA, and corporations are underway in the park to investigate extremophiles. Some of their discoveries have helped researchers create inventions suitable for commercial purposes. When this happens, we call it bioprospecting. 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. 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 know-how gained during research on park specimens, may be commercialized—not the specimens themselves.

Park science informs innovation and inventing

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 discover new enzymes that can withstand harsh manufacturing processes better than inorganic catalysts, improving efficiency, which saves energy. In some cases, using enzymes instead of inorganic chemicals can also help reduce toxic industrial byproducts. Research on these extremophiles has recently helped scientists invent a wide variety of potential commercial applications, from methods for improving biofuel production to helping agricultural crops withstand drought and high temperatures.

Bioprospecting and Benefits-sharing in Yellowstone

The Issue

Many different extremophiles have been studied. A few extremophile researchers have also created inventions that might be used commercially, which can be the basis of benefits-sharing for Yellowstone and the National Park Service.

Researchers who study material obtained under a Yellowstone National Park research permit are 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 discovery of 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.
- **Extremophile:** A microorganism living in extreme conditions such as heat and acid, and cannot survive without these conditions.
- **Thermophile:** Heat-loving extremophile.

History in Yellowstone

- 1980s: Yellowstone National Park first becomes aware that biological specimens from the park are potentially being studied for commercial applications and that patent applications are being made involving study of park organisms. In 1989, Taq polymerase, a commercial enzyme discovered in a Yellowstone extremophile and reproduced in the laboratory, becomes *Science* magazine's first-ever "Molecule of the Year."
- 1995: The National Park Service begins work on prototype contracts between the park and industry. A conference convened by Yellowstone, "Biodiversity, ecology and evolution of thermophiles," draws 180 attendees from industry, universities, and agencies and includes a roundtable on bioprospecting and benefit sharing.
- 1998: Yellowstone and Diversa, a biotechnology research firm that had been performing permitted research in Yellowstone since 1992, enter into a benefits-sharing agreement promising that a portion of Diversa's future profits from research in Yellowstone National Park will go toward park resource preservation.
- 1998: The National Parks Omnibus Management Act of 1998 increased the emphasis on scientific research activities in the national parks. The law authorizes "negotiations with the research community and private industry for equitable, efficient benefits-sharing arrangements" in connection with research activities conducted in units of the National Park System.
- 1999: A legal challenge puts on hold implementation of the agreement between Yellowstone and Diversa until an environmental analysis (EA or EIS) is completed.
- 1999–2012: Many Yellowstone extremophiles are under study, some of them are grown in researchers' laboratories so they can be studied for decades. Research on a few microbes developed from specimens collected as early as 1986 leads to about a dozen patented inventions with potential for commercial use.
- 2010: The National Park Service decides to adopt benefits-sharing following the completion of the Benefits-Sharing Environmental Impact Statement.

The biggest innovation from Yellowstone, so far

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 did not exist. 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. However, the heat necessary to do the PCR process inactivated the enzymes making the process extremely slow and expensive. They found the solution to this problem in one of the hot spring organisms isolated from Yellowstone by park researcher Thomas Brock in the 1960s; *Thermus aquaticus*. 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. In 1989 Taq polymerase was named *Science* magazine's first-ever "Molecule of the Year." Many laboratory-made versions of this enzyme are still in use allowing DNA studies to be practical, effective, and affordable. Companies that sell the Taq enzymes have earned profits, but Yellowstone National Park and the United States public receive no direct benefits even though this commercial product was developed from the study of a Yellowstone microbe.

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. The National Park Service examined benefits-sharing options and decided to require it for new inventions made through study of park resources. Procedures for benefits-sharing are under development and expected to be implemented soon.

More information

www.nature.nps.gov/benefitssharing

Staff reviewer

Sue Mills, Environmental Protection Specialist

Of Yellowstone's 2.2 million acres, a little more than 2 million are recommended for federal designation as wilderness. Though Congress has not acted on this recommendation, the land is managed as wilderness.

Wilderness

Yellowstone National Park has always managed its backcountry to protect natural and cultural resources and to provide visitors with 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, all lands that fall within Yellowstone's Recommended Wilderness are managed to maintain their natural wilderness character so as not to preclude wilderness designation in the future. The last Yellowstone wilderness recommendation sent to Congress was for 2,032,721 acres.

FREQUENTLY ASKED QUESTION:

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.

Wilderness in the National Park System

Congress specifically included the National Park Service in the Wilderness Act and directed the National Park Service 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 to (1) not diminish their suitability as wilderness,

Wilderness

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: Yellowstone writes a draft Backcountry Management Plan and environmental assessment, which is never signed. It begins to provide management guidance even though not official document.
- 1999: Director's Order 41 issued to guide National Park Service 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: The National Park Service 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.
- In 2012, approximately 18,000 visitors camped in the backcountry

Areas of Concern for Park Wilderness

- Accommodating established amount of visitor use.
- Protecting natural and cultural resources.
- Managing administrative and scientific use.
- Monitoring wilderness character.
- Educating users in Leave No Trace practices.

Current Status

Yellowstone does not yet have a wilderness plan to manage wilderness within the park.

and (2) apply the concepts of "minimum requirements" to all management decisions affecting those lands, regardless of the wilderness category. Some activities that are typically prohibited under the Wilderness Act are motorized or mechanized equipment use and the installation of structures.

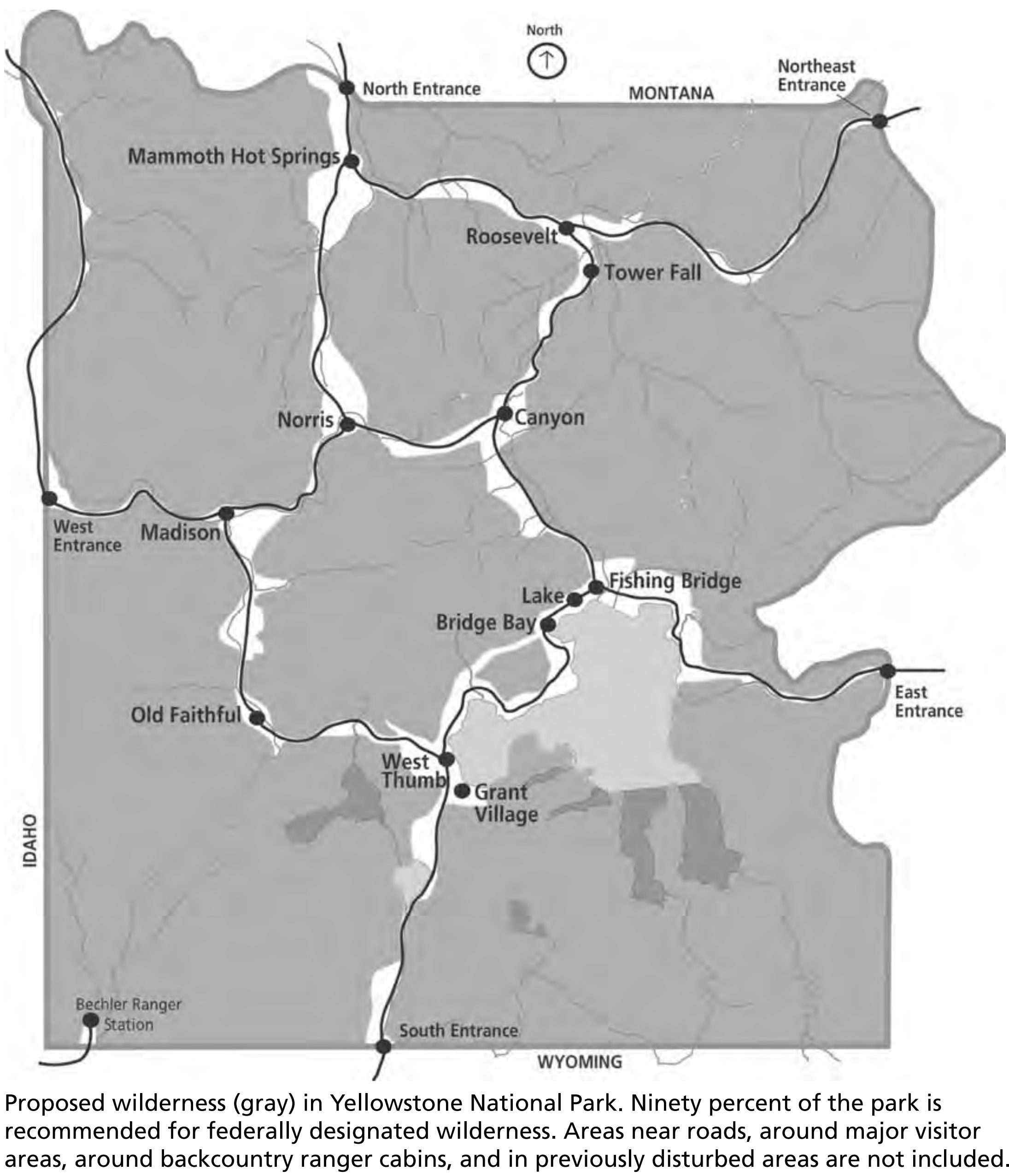
Director's Order 41

Director's Order 41, issued in 1999, provides accountability, consistency, and continuity to the National Park Service's wilderness management program, and guides the National Park Service 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 National Park Service 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 National Environmental Policy Act 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 National Park Service's Intermountain Regional



Proposed wilderness (gray) in Yellowstone National Park. Ninety percent 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.

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

Director said "all management decisions affecting wilderness must be consistent with the minimum requirement concept." This concept allows managers to assess:

1. if the proposed management action is appropriate or necessary for administering the area as wilderness and does not impact wilderness significantly (Why must the activity occur in recommended wilderness?)
2. what techniques and type of equipment are needed to minimize wilderness impact. (If the project is necessary to conduct in wilderness, what is the appropriate means to conduct it that will cause the minimum impact to the wilderness resource, qualities, and experience that will still get the job done?)

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 consider managing wilderness in 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 wilderness character 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.
- All research projects in Yellowstone are evaluated based on impacts to wilderness resources among other parameters.

Outlook

Yellowstone will continue to manage its backcountry to protect park resources and provide a wilderness experience to park visitors. Park managers continue to 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.

More information

Leave No Trace: www.LNT.org
National Park Service. 1972. Wilderness Recommendation: Yellowstone National Park.
National Park Service. 2003. NPS Annual Wilderness Report 2002–2003.
National Park Service Wilderness System: wilderness.nps.gov and www.youtube.com/user/NPSWilderness
National Wilderness Preservation System: www.wilderness.net
Wilderness Act of 1964. U.S. Code, 16: 1131–1136.
Wilderness Preservation and Management: NPS Reference Manual 41. www.nps.gov/policy/DOrders/RM41.doc

Staff reviewer

Ivan Kowski, Backcountry Program Manager

Managers from local, state, and federal agencies across the Greater Yellowstone Ecosystem make efforts to coordinate the management of public land and cross-boundary issues, and seek scientific guidance.

Managing Across Political Boundaries

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.

Several factors strongly influence the Greater Yellowstone Ecosystem and its management:

- Volcanic activity drives the ecosystem, wildfire influences the species that live here, and political heat also affects decisions.
- The Greater Yellowstone Ecosystem spans different climate regimes and vegetation zones, crosses multiple jurisdictional boundaries, and is the last remaining large, intact 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.
- 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 National Park Service recognizes ecological boundaries do not match the social and political boundaries established in the ecosystem. Thus, most work groups in the park have some sort of transboundary relationship with neighboring jurisdictions to smooth out management actions that in some cases are quite different on each side of the park boundary. The park chooses to work with the states on most issues, including wolf and bison management.

Time also affects 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 their 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.

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 Greater Yellowstone Ecosystem joined the committee. During its almost five decades, the Greater Yellowstone Coordinating Committee has provided guidance and decisions for managing the Greater Yellowstone Ecosystem.

Currently, the Greater Yellowstone Coordinating Committee is helping to develop a science agenda for the next 10–12 years. In 2009, federal agency managers, scientists from the US Geological Survey and from universities met to identify the external drivers threatening to dramatically alter the Greater Yellowstone Ecosystem: climate change, land-use change, and invasive species. The participants summarized the challenge as:

> *Understanding how large-scale stressors impact ecosystems, and then determining the best way to manage landscapes based on that understanding.*

They identified 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 Greater Yellowstone Ecosystem; how will climate change and land-use change affect invasive species and their management?

As a first step to understanding climate change impacts, the Greater Yellowstone Coordinating Committee supported a project to review and summarize existing literature on climate change. The two reports present climate information from the past and potential ecological effects of climate change in the future.

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Staff reviewer

David Hallac, Chief of Yellowstone Center for Resources

The ecological diversity of the Greater Yellowstone Ecosystem contributes to its value, and its controversy. Yellowstone's northern range has been the focus of debate for more than 80 years.

ECOSYSTEM

Complexity and the Northern Range

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 species eats ungulate meat. The rest prey on other small scavengers, especially the larvae of flies and beetles. Others consume carcass by-products 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.

> **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**

Trophic cascades

Scientists in Yellowstone have been exploring the hypothesis that wolf restoration is causing changes in predator–prey–vegetation relationships or 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.

Balancing nature?

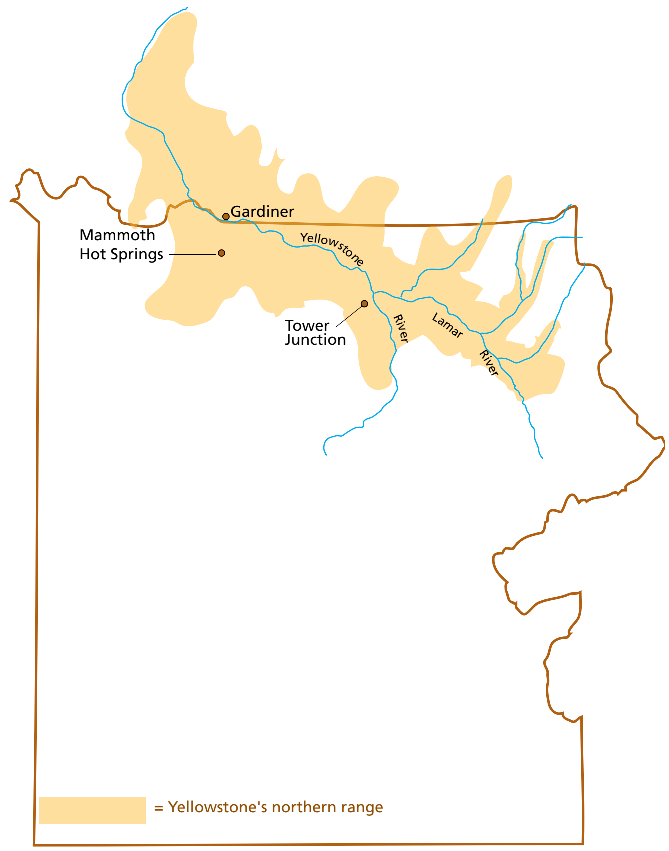
In some circles, some people expected wolves would restore a "balance" to park ecosystems, meaning that animal populations would stabilize at levels pleasing to humans. Instead, a more dynamic variability is present, which probably characterized this region's wildlife populations for millennia. Nature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

Consider the northern Yellowstone elk herd, which has been declining in numbers. The recovery of the wolf occurred simultaneously with increased grizzly bear and mountain lion populations, sustained 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 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.

The northern range

The northern range refers to the broad grassland that borders the Yellowstone and Lamar rivers in the northern quarter of the park. 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



The northern range refers to the broad grassland that borders the Yellowstone and Lamar rivers in the northern quarter of Yellowstone National Park.

ECOSYSTEM

Northern Range in Yellowstone

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.

Background
- For decades, park administrators 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 75% since 1994 and numbers of bison have increased substantially.

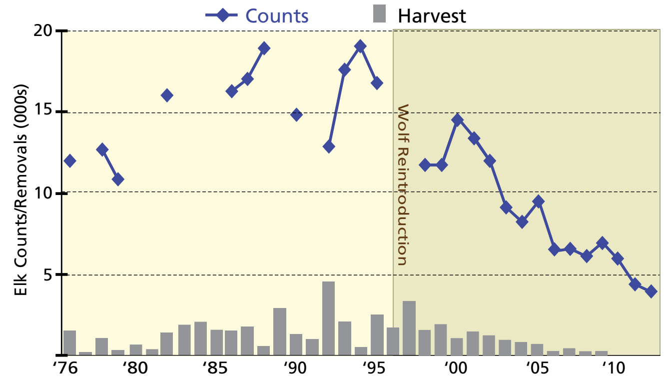
south-facing hillsides are clear of snow, a result of wind and sun. Animals take advantage of this lack of snow, finding easy access to forage.

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 counts 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 less than 4,000 animals.

As the result of public pressure and changing National Park Service 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

Yellowstone's largest elk herd winters along and north of the park's northern boundary. After decades of debate over whether this range was overgrazed by too many elk, public concern has shifted to the herd's small size.



Winter counts and hunting harvests of the northern elk herd in Yellowstone National Park and adjacent areas of Montana, 1976–2012. Counts were not adjusted for factors that may decrease the detection of elk.

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 other areas outside the park.

Another set of statistics also alarms 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 National Park Service, encompassed more than 40 projects by National Park Service 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

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.

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 several 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 in past years a 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 was to regulate the northern Yellowstone elk population that migrates outside the park during winter and limit grazing of crops on private lands. During 1996–2002, approximately 5–19 percent (mean approximately 11 percent) of the adult female portion of this population was harvested each year during the late hunt. However, the hunt has not been held in the last couple 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.

Outlook

There is some indication that the dynamic northern grassland system is in a state of flux. The density of northern Yellowstone elk decreased to approximately 3 to 5 per square kilometer during 2006 through 2011 from a high of 12 to 17 per square kilometer in the late 1980s and early 1990s before wolf reintroduction. Fewer elk have resulted in less forage consumed and less intense feedbacks by elk on soil and plant processes, which likely has contributed to lower plant production and forage quality.

However, the effects of an increasing bison population on soil and plant processes remain to be determined. Bison and elk have a substantial degree of dietary and habitat overlap, which may result in competition between bison and elk for food resources. Also, large concentrated groups of bison that repeatedly graze sites throughout the summer could potentially have quite different effects on the dynamics of Yellowstone's northern range than herds of elk that graze sites for relatively short periods during their migration to high elevation summer range.

Research has been initiated to elucidate the influence of recent changes in the Yellowstone grazing community on ecosystem processes such as the spatial pattern and intensity of ungulate grazing and grassland energy and nutrient dynamics. Scientists predict that the transition to an increasing population of bison will influence the grasslands in northern Yellowstone differently than elk.

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Staff reviewers

Roy Renkin, Vegetation Management Specialist
P.J. White, Chief, Wildlife and Aquatic Resources

Though the wildlife and plants of Greater Yellowstone are adapted to its cold, snowy winters, surviving the winter season can be a struggle.

Winter Wonderland

As remarkable as Greater Yellowstone and Yellowstone National Park are during the rest of the year, the park in winter is a magical place: steam and boiling water erupt from natural cauldrons in the park's ice-covered surface, snow-dusted bison exhale vaporous breaths as they lumber through drifts of white, foxes and coyotes paw and pounce in their search for prey in the deep snow, and gray wolves bay beneath the frozen moon. Yellowstone in winter also is a place of vulnerability.

Wildlife endure extremes of cold, wind and the absence of ready food, their tracks through deep snow tell of tenacious struggles through the long winter. Park conditions in this most severe of seasons become critical to the mortality of wildlife and even to survival of park species.

No wonder the park is so popular in this magical, vulnerable season with those who have enjoyed its charms. It is often said among park staff who live in Yellowstone that winter is their favorite season. Many park visitors who try a winter trip to Yellowstone come back for more.

Animal adaptations

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.

FREQUENTLY ASKED QUESTION:

Is Yellowstone open in winter?

Yes. You can drive into the park through the North Entrance year-round. The winter season of services, tours, activities and ranger programs typically spans from mid-December to mid-March.

At Mammoth, you can take self-guiding tours of Fort Yellowstone and the Mammoth Terraces, join a guided walk or tour, cross-country ski, snowshoe, ice skate (sometimes), rent a hot tub, watch wildlife, attend ranger programs, and visit the Albright Visitor Center. Visitors may legally soak in the Gardner River where hot thermal water mixes with cool river water. 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 cross-country ski or snowshoe a number of trails along this road.

The interior of the park is open to various oversnow vehicles. Tours can be arranged through the park concessioner or operators at the various gates.

You can also stay at Old Faithful Snow Lodge, from which you can walk, snowshoe, or ski around the geyser basin, take shuttles to cross-country 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.

How cold is Yellowstone in winter?

Average winter highs are 20–30°F (–6 to –1°C); average lows are 0–9°F (–17 to –13°C). The record low was –66°F (–54°C) at Riverside Ranger Station, near the West Entrance, on February 9, 1933.

Behavioral

- Red squirrels and beavers cache food before winter begins.
- 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

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.

snow for insulation.
- Bison, elk, geese, and other animals find food and warmth in hydrothermal areas.

Morphological and physical

- Mammals molt their fur in late spring to early summer. 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 and physiological

- Mammals and waterfowl exhibit counter-current heat exchange in their limbs that enables them to stand in cold water: cold temperatures cause surface blood vessels to constrict, shunting blood into deeper veins that lie close to arteries. Cooled blood returning from extremities is warmed by arterial blood traveling towards the extremities, conserving heat.
- At night, chickadees' body temperature drops from 108°F to 88°F (42–31°C), 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 antifreeze. 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.

Oversnow vehicles are a source of noise and emissions. Here, a snowmobile guide checks in at the West Entrance in 2003.

ECOSYSTEM

The howl of wolves contributes to the winter soundscape of Yellowstone National Park. Here, a wolf howls on a glacial erratic at Little America Flats.

Winter soundscapes

Greater Yellowstone's soundscape is the aggregate of all the sounds within the park, including those inaudible to the human ear. Some sounds are critical for animals to locate a mate or food, or avoid predators. Other sounds, such as those produced by weather, water, and geothermal activity, may be a consequence rather than a driver of ecological processes. Human-caused sounds can mask the natural soundscape. The National Park Service goal is to protect or restore natural soundscapes where possible and minimize human-caused sounds while recognizing that they are generally more appropriate in and near developed areas. The quality of Greater Yellowstone's soundscape therefore depends on where and how often non-natural sounds are present as well as their levels.

Human-caused sounds that mask the natural soundscape used by wildlife and enjoyed by park visitors are to some extent unavoidable in and near developed areas. However, the potential for frequent and pervasive high-decibel noise from oversnow vehicles has made the winter soundscape an issue of particular concern in Yellowstone. Management of the park's winter soundscape is important because oversnow vehicles (OSVs) are allowed on roads in much of the park.

Winter air quality

Under the Clean Air Act Amendments of 1977, Yellowstone is one of 156 national parks and wilderness areas that are designated Class I airsheds, requiring the most stringent protection. The winter air quality at a given location in Yellowstone depends primarily on proximity to roads, parking areas, employee housing, and visitor lodging. During the 2010–2011 winter, 52 percent of visitors entered the park on the plowed road (North Entrance) and 24 percent each by snowmobile and snowcoach on a groomed road. Although visitation is far lower in the winter than in the summer, OSVs produce more emissions. Prolonged exposure to air pollutants such as carbon monoxide (CO), fine particulate matter (PM <2.5 micrometers), and hydrocarbons can pose health risks.

CO and PM are monitored at the West Entrance and Old Faithful, where OSVs are most concentrated. The levels of these pollutants have declined since 2002 because of fewer snowmobiles in the park and because they are required to have "Best Available Technology" (BAT) and be accompanied by a licensed guide. Compared to summer levels, the maximum winter one-hour CO level at the West Entrance is lower but the average level for the season is higher.

Winter inversion layers, which impede dispersion of pollutants by trapping the cooler surface air, are a major factor in the difference between summer and winter air quality. However, PM levels are often higher in the park in summer than in winter, primarily because of smoke from wildland fires. Peak PM2.5 levels in the winter do not coincide with peak OSV use in the park, indicating that other sources such as wood stoves contribute to them. Nitrogen deposition is emerging as an issue because although the BAT-required 4-stroke engines emit less CO than 2-stroke snowmobiles, they emit about 15 times more nitrogen dioxide, which can affect plant growth. At the West Entrance, the daily maximum one-hour concentration was 82 parts per billion (ppb) in winter 2011, below the national standard of 100 ppb for human health, but much higher than the maximum of 26 ppb during the previous summer.

Effects of winter recreation

The impacts of the use of OSVs on wildlife has been a key issue in winter use policies in Yellowstone for two decades. OSVs are required to stay on groomed roads, but the roads are often situated where wildlife may be concentrated in winter. The proximity of humans can cause increased vigilance or wildlife displacement from preferred habitat, resulting in expenditure of more energy or reduced foraging or care of offspring at a time of year when staying warm and nourished may already be difficult, potentially affecting a species' reproduction, distribution, and abundance.

Research indicates that disturbance by winter visitors is not a primary influence on the distribution,

Research indicates that disturbance by winter visitors is not a primary influence on the distribution, movements, or vital rates of bison, trumpeter swans, elk, coyotes, and bald eagles.

movements, or vital rates of bison, trumpeter swans, elk, coyotes, and bald eagles. Monitoring of OSV use in Yellowstone has found that nearly all OSV users remain on groomed roads and behave appropriately toward wildlife, rarely approaching unless animals are on or adjacent to the road. In most of 7,603 encounters observed between people on OSVs and wildlife, the animals either had no apparent response or looked and then resumed what they were previously doing: bison, 91 percent of the encounters; swans, elk, and bald eagles, 81 percent; and coyotes, 74 percent.

The possibility that road grooming increases bison migration out of the park where they may be killed has not been borne out by research. Data on bison road use and off-road travel collected from 1997 to 2005 found bison on the road less often from December to April when the roads were groomed than during the rest of the year, and no evidence that bison preferentially used groomed roads during winter.

Compared to similar studies done in other places, the relatively low intensity of wildlife responses in Yellowstone suggests that because the encounters near roads are predictable and apparently not harmful to the animals, some habituation to OSVs and associated human activities may be occurring.

An evaluation of 121,380 GPS locations from 14 female bison during 2003–2004, done in collaboration with Montana State University and California State University–Monterey Bay, found that the bison's travel network was defined by streams that connected foraging areas. The probability of bison travel was higher in canyons and other places where the topography constrained movements. Roads may facilitate bison travel in certain areas, but many road segments used by bison appear to coincide with or have similar landscape features as natural travel corridors. These data indicate that changes in bison distribution during the past three decades have likely been the result of the natural phenomenon of density-dependent range expansion rather than caused by road grooming.

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Staff reviewers

Wade Vagias, Management Assistant

The enjoyment of Yellowstone and its unique resources during the wintertime has drawn deep and passionate interest in the park since the 1930s. Here, skiers pass bison on Slough Creek trail.

Winter Use

The National Park Service's mission is a dual mandate: Preserve Yellowstone's resources, and make the park available and accessible for enjoyment and appreciation. The ways in which visitors experience Yellowstone in winter can affect the park's plants, animals, geothermal features and wild character in ways more profound—and potentially more damaging—than at other times of the year. To meet its mission, the National Park Service must develop carefully a long-range plan for winter use in Yellowstone that both protects the park's wild creatures, vegetation and landscape and provides outstanding recreational opportunities "for the benefit and enjoyment of the people."

For years, the National Park Service has managed the park in winter with interim management plans in the face of repeated courtroom challenges over snowmobiles and other winter operations. In May 2011, a Draft Environmental Impact Statement (EIS) was released for public review and comment. The Draft EIS analyzed a wide range of alternatives that present different ways visitors could experience the park in winter while protecting the park's natural resources and values. Nearly 60,000 comments were filed during a more than 60-day public comment period that followed the draft document's release.

History of winter use debate

Winter use (or recreation) in Yellowstone has been the subject of debate since the 1930s. Since then, the National Park Service, its interested observers, and park users have formally debated what winter in Yellowstone should be at least 12 times.

Beginning in the early 1930s, communities around the park began asking the National Park Service to plow Yellowstone's roads year-round so tourist travel and associated spending in their communities would be stimulated. Each time, the National Park Service resisted, citing non-winterized buildings, harsh weather conditions, and roads too narrow for snow storage. Meanwhile, snowbound entrepreneurs in West Yellowstone began experimenting with

Visitor Use in National Parks

Use by visitors is both a primary reason for the establishment of national parks and a factor in the condition of many of the natural and cultural resources that the parks are intended to protect. While poaching and road collisions have immediate consequences for wildlife, most visitor impacts are less obvious. The long-term consequences of some previous park policies carried out for the presumed benefit of visitors—such as predator control and the introduction of nonnative fish—continue to be evident in the parks today. In addition, ongoing visitor activities and associated infrastructure affect many park resources, including:

- air and water quality, and the natural soundscape;
- wildlife habitat, distribution and habituation;
- the spread of nonnative plants, diseases, and aquatic organisms;
- the functioning of geothermal features; and
- the preservation of archeological sites and other cultural artifacts.

After exceeding 3 million for the first time in 1992, annual visitation at Yellowstone fluctuated between 2.8 and 3.1 million until new records were set in 2009 (3.3 million) and 2010 (3.6 million). About 70 percent of the visitation occurs from June through August. Although there are no day use quotas, lodging and campgrounds in the park can accommodate only about 14,300 visitors during the summer, while daily visitation during July 2010 averaged 30,900. Fall visitation has increased since the 1980s and now comprises about 21 percent of annual use; winter visitation has never been more than 6 percent of the annual total.

Similar to trends at other western parks, overnight backcountry use in Yellowstone peaked in 1977 at more than 55,000 "people use nights" (the total number of nights spent in the backcountry). Since the mid-1990s years backcountry use has remained fairly steady, ranging between 37,000 and 46,000 person use nights annually.

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 10 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 Snow Lodge 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

Winter Use in Yellowstone

The Issue

People have debated appropriate winter use in the park for more than 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

- 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 oversnow use instead of plowing.
- 1971: Managers begin grooming roads and Yellowstone Park Co. opens Old Faithful Snow Lodge.
- 1990: The National Park Service issues first winter-use environmental assessment (EA) for Yellowstone and Grand Teton.
- 1997: The National Park Service is sued by groups who believe bison used groomed roads to leave the park, which led to their slaughter. The National Park Service 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: The National Park Service 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. The National Park Service writes a new EA, allowing 750 BAT, guided snowmobiles daily; 95,000 comments received.
- 2004–2007: Winter use proceeds per 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.
- 2010: The National Park Service begins preparing a next long-term plan.
- 2011: The planning process is extended for another year to consider factors raised by public input.
- 2012: A draft Supplemental EIS (SEIS) released.

Updates: www.nps.gov/yell/planyourvisit/winteruse.htm

Recent Winter Use Debate

1992–2001

1992	1993	1997	1999	2000	2001
Winter visitation exceeds threshold of 140,000 people per year, 8 years earlier than expected.	The National Park Service begins to evaluate winter recreation in the greater Yellowstone area.	Fund for Animals files lawsuit; results in the National Park Service agreeing to develop a new winter use plan and EIS.	Draft EIS released. Bluewater Network and other organizations petition to prohibit trail grooming and snowmobile use in all national parks.	Final EIS released and Record of Decision signed. Snowmobile group sues to stop this winter plan.	Snowmobilers lawsuit settled, which requires the National Park Service to prepare SEIS.

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 National Park Service began an analysis of all types of winter recreation on all National Park Service and Forest Service (FS) 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.

Snowcoaches entered the park in 1955.

A decade of planning and litigation

The winter of 1996–1997 was one of the three harshest winters of the 1900s, 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. 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 US District Court for

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.

2002–present

2002	2003	2004	2007	2008	2009	2011
Draft SEIS released; >350,000 comments received.	March: Record of Decision signed; Dec 11: Final rule published in Federal Register; Dec. 16: Federal judge directs YNP to begin phasing out snowmobiles.	Feb: Another federal judge stops phase-out; requires temporary rules for rest of winter; Aug: EA for temporary winter plan released; Nov: Plan approved.	March: Draft FEIS released; 122,000 comments; Dec.: Final rule published in Federal Register.	Courts stop new winter plan. Season opens using modified plan from 2004–2007.	Winter season opens under interim plan during EIS process.	Planning process extended another year through a Supplemental EIS to consider factors raised by public input on 2011 Draft EIS

the District of Columbia against the National Park Service in May 1997. The groups alleged that the National Park Service had failed to examine the environmental impacts of winter use. In 1999, Bluewater Network filed a legal petition with the National Park Service to ban snowmobiles from all national park units nationwide. These two actions inaugurated more than 15 years of winter use planning and associated lawsuits, and catapulted the issue into one of the National Park Service's most visible and enduring environmental controversies.

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

Legal Actions Related to Winter Use in Yellowstone National Park

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 National Park Service reinstated 2004 rule to provide certainty for winter visitation in the winter of 2008-09.
2008	EA: Allow 318 snow-mobiles (all BAT; all commercially guided)	27,000	State of Wyoming, ISMA, and Park County, Wyoming	Upheld in Wyoming court; appealed to U.S. District Court.

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 National Park Service to gauge the effects of these actions 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 US District Court for the District of Columbia. The International Snowmobile Manufacturer's Association, the State of Wyoming, the Blue Ribbon Coalition, and others consistently file their lawsuits in the US 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 National Park Service has responded by addressing the concerns of the courts.

Improving conditions in the parks

With the conversion to BAT snowmobiles, mandatory commercial 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 more than 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 61 percent of the day at Old Faithful and 51 percent of the day at Madison Junction, per the 2010–2011 monitoring report, down from 67 and 54 percent, respectively. (National Park Service vehicles account for approximately one-fourth of this noise.) In a new long-term plan, the National Park Service intends to implement BAT requirements for snowcoaches, which will reduce noise even more. Snowcoaches account for 94 percent of the loud oversnow vehicles. Guided snowmobile groups and snowcoaches contribute nearly equally to the percentage 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.

Concerns Raised by the Public

- Overcrowding
- Visitor impacts on natural resources
- Noise and 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 and human safety

The recent science on winter use indicates park resources are in very good condition. Research shows that both snowmobiles and snowcoaches are similarly contributing 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.

Recent action

During the 2009–2010 and 2010–2011 winter seasons, an Interim Winter Use Plan was in effect. The plan allowed up to 318 commercially guided, BAT snowmobiles and up to 78 commercially guided snowcoaches into the park each day. These maximums were not reached. The plan also continued to provide for motorized oversnow travel over Sylvan Pass and the East Entrance Road.

To determine the type and extent of winter use in the park starting in winter 2012–2013, the National Park Service proposed a plan that would vary the number of OSVs allowed in the park on certain days to provide a variety of motorized and non-motorized experiences. Snowmobile use would continue to require a commercial guide and a BAT vehicle that meets a new limit on nitrogen oxide emissions. By the winter of 2014-2015, snowcoaches would be required to meet the Environmental Protection Agency's 2010 emission standards for new wheeled vehicles. Ongoing monitoring will help determine the extent to which the plan succeeds in maintaining acceptable air quality during the winter.

In May 2011, the National Park Service released a Draft Environmental Impact Statement (EIS) for public review on the potential effects of the plan for motorized oversnow travel in the park. After months of public comment and review, the National Park Service decided additional study was needed before putting a long-term plan in place. While the final plan is being developed, the National Park Service chose to manage snowmobile and snowcoach access in the park starting in December 2011 under the same transition plan used the previous two winters.

Among the subjects identified for further analysis in a new Supplemental EIS are requirements for entry into the park by 10:30 am daily, sound and air quality computer modeling assumptions, "best available technology" standards for snowcoaches, the impacts of Sylvan Pass avalanche hazard mitigation, and opportunities for park access by non-commercially guided snowmobile groups.

In 2012, Yellowstone National Park released a draft Supplemental EIS that contains alternatives for managing the park in winter. This draft plan/SEIS was used to determine whether motorized winter use in the interior of the park is appropriate, and if so, the type, extent, and location of this use.

Final Winter Use Plan/SEIS released in 2013

The National Park Service released a final Winter Use Plan/ Supplemental EIS to guide the future of winter use in Yellowstone National Park in February 2013. Under the preferred alternative of the Plan/ Supplemental EIS, the park would manage oversnow vehicles based on their overall impacts to air quality, soundscapes, wildlife and visitors, rather than focusing on the total number of snowmobiles and snowcoaches allowed in the park each day. The park would allow up to 110 "transportation events" a day. A transportation event is defined as one snowcoach or a group of seven snowmobiles (averaged seasonally; daily maximum number of 10 snowmobile per event) traveling together within the park, and is based on evidence that, when managed appropriately, New BAT snowmobile and BAT snowcoach transportation events have comparable levels of adverse impacts to park resources and the visitor experience. No more than 50 transportation events a day would be allocated for groups of snowmobiles and the remaining 60 for snowcoaches. No more than 50 transportation events a day would be allocated for groups of snowmobiles.

The preferred alternative would provide for one entry a day per entrance for a non-commercially guided group of up to five snowmobiles. It would continue to allow for motorized oversnow travel on the East Entrance road over Sylvan Pass. Additional information and the Final Winter Use SEIS is available at parkplanning.nps.gov/yell.

The park superintendent will use the analysis and recommendations contained in the final plan/ Supplemental EIS to make a recommendation to the National Park Service Intermountain Regional Director regarding the direction of winter use. The Regional Director is expected to issue the Record of Decision sometime in the spring of 2013.

Once the Record of Decision has been issued, a final rule to implement the decision will be published in the Federal Register in order to allow the parks to open for the winter 2013/2014 winter season.

Current information on winter-use planning is available at www.nps.gov/yell/planyourvisit/winteruse.htm.

More information

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Staff reviewers

Wade Vagias, Management Assistant
Ivan Kowski, Backcountry Program Manager
Dan Reinhart, Vegetation and Resource Operations

The global climate is changing, and is already affecting the Greater Yellowstone Ecosystem. Scientists predict wolverine, lynx, and pikas (shown here) may lose habitat in the park.

Climate Change

Climate change presents significant risks to our nation's natural and cultural resources and is already affecting the Greater Yellowstone Ecosystem. Climate is one of the primary drivers of the physical and ecological processes that determine the distribution, structure, and function of ecosystems.

Climate change is happening

To a casual observer, it can be difficult to detect climate change because our observations of changes in weather—which refers to conditions over days to weeks—can seem chaotic. Climate refers to weather conditions over a longer time, usually several decades. Scientists examining climates across the planet see a warming pattern emerging. During the last 50 years, it is likely that global temperatures were higher than at any time during the last 1,300 years. Scientists compare that temperature data with sea levels, the size and number of glaciers, the length of fire seasons, and the condition of arctic permafrost and conclude that climate change is here.

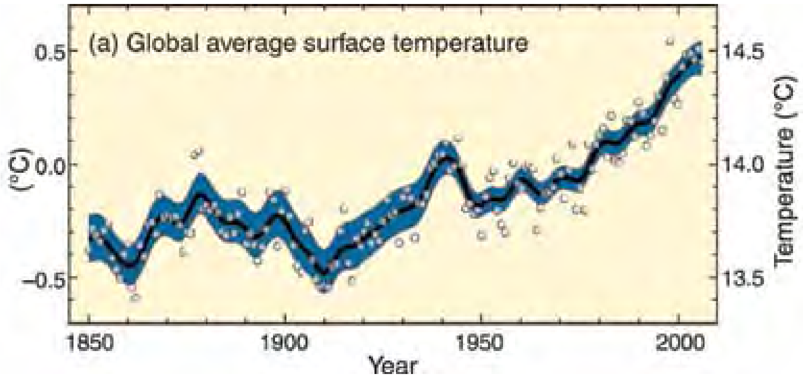
Though natural evolution and change are an integral part of our national parks, climate change is fundamentally transforming the natural and cultural landscapes of national parks and will continue to do so for many years.

Climate change will affect your experience in a national park. What will some of these transformations look like?

- Less permafrost, rising sea levels and shrinking packs of sea ice
- Longer fire seasons and changes in the places different plants and animals can survive
- More frequents pests and disease

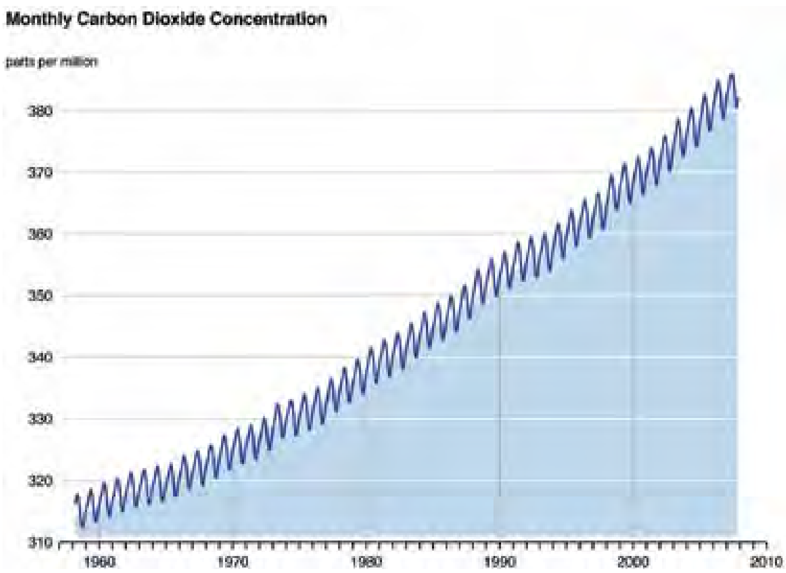
Climate science

The study of climate change dates to the 1700s when scientists began trying to understand how the ice ages occurred. In 1824 it was discovered that certain gases trap heat within the Earth's atmosphere. This is called the Greenhouse Effect because the process reminded people of the way the glass of a greenhouse seals warm air inside. Though it comprises less than 0.04 percent of the atmosphere, carbon dioxide is the most abundant greenhouse gas. Without it, the average temperature of the planet would be close to freezing (See: www.ncdc.noaa.gov/cmb-faq/global-warming.html). The carbon dioxide and other greenhouse gases in the atmosphere have a powerful impact; they warm Earth's average temperature to about 60° F. So it is no surprise that adding more carbon dioxide to the atmosphere can further warm the planet. This is the basic premise of global warming/climate change, which increases the temperature of the land, sea, and atmosphere. Calling it global climate change may be more clear, because changing the amount of greenhouse gases in the atmosphere leads to more than just warming the globe (e.g., changes in storms,



2007 IPCC FOURTH ASSESSMENT REPORT AR4 WG I

Over the past 50 years, average global temperature has risen 1.4 degrees Fahrenheit (0.75 Celsius). 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.



CO_2 PROGRAM OF THE SCRIPPS INSTITUTE OF OCEANOGRAPHY, SCRIPPSCO2.UCSD.EDU

Atmospheric concentrations of CO_2 began a marked increase that coincides with the Industrial Revolution of the late 1800s. CO_2 levels rose by more than 20 percent in the 50-year period 1958-2008.

changes in local climates, droughts, and oceans).

In 1896, a Swedish scientist connected climate with pollution. Savre Arrehnius studied how carbon dioxide (CO_2) might have affected the ice ages.

During the first half of the 1900s, scientists continued to research the ice ages, developing methods and data essential to future understanding of climate change. Scientists began studying pollen found in sediment layers. Based on the vegetation types represented, the scientists could assume past climate conditions would resemble present climate conditions where such vegetation is found. 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.

Research continued and in 1988, the United Nations established the Intergovernmental Panel on Climate Change (IPCC), which is comprised of 2,000 scientists from around the world. Based in part upon the IPCC's

Climate Science History

- 1700s: The Industrial Revolution is underway; manufacturing begins producing greenhouse gases such as carbon dioxide and methane.
- 1827: Jean-Baptiste Joseph Fourier describes what is later termed, the "greenhouse effect."
- 1896: Savre Arrehnius calculates that increasing atmospheric greenhouse gases will cause global warming.
- 1958: Charles David Keeling begins measuring atmospheric carbon dioxide from Mauna Loa, Hawaii.
- 1963: Keeling warns of 10.8°F temperature rise in next century.
- 1965: First Global Climate Models (GCM) developed.
- 1969: Weather satellites begin providing atmospheric data.
- 1978: Satellites begin measuring sea ice in both the Arctic and Antarctic.
- 1988: The Intergovernmental Panel on Climate Change (IPCC) is established.
- 1997: The Kyoto Protocol sets targets for greenhouse gas emissions for most industrialized nations (US does not sign).
- 2007: IPCC begins its 4th report, "Warming of the climate system is unequivocal."
- 2009: President Obama Announces National Fuel Efficiency Policy for Cars and Trucks (http://www.whitehouse.gov/the-press-office/president-obama-announces-national-fuel-efficiency-policy)
- 2009: Secretary Salazar signed Secretarial Order 3289 which mandates a department-wide strategy to address climate change. This order also established 8 Climate Science Centers, to conduct high-level climate science. DOI established 21 Landscape Conservation Cooperatives where climate science is being applied for resource management.
- 2009: Copenhagen Summit held; an accord reached for nonbinding actions to address climate change.
- 2009: The EPA Administrator, Lisa Jackson, signed an Endangerment Findings for greenhouse gases which says the current and projected concentrations of the six key well-mixed greenhouse gases — carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and sulfur hexafluoride (SF6) — in the atmosphere threaten the public health and welfare of current and future generations (See: http://www.epa.gov/climatechange/endangerment/).
- 2010: The NPS releases:
  - The Climate Change Response Strategy which conveys the NPS vision centered around four climate change components: science, adaptation, mitigation, and communication.
  - The Green Parks Plan which helps guide parks in sustainable national park operation.
  - Climate Change Action Plan 2012–2014 which describes prioritized actions either underway or that the National Park Service is committed to undertake.

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.

Several key studies, including those represented by the US Global Change Research Program's report Global Climate Change Impacts to the United States and the IPCC 4th Assessment Report, conclude that the observed changes in climate are due primarily to human-caused emission of heat-trapping gases such as carbon dioxide (CO_2). These greenhouse gases have been on the rise since the 1800s, and their effect on climate will persist for many more decades. Levels of carbon dioxide and methane (another greenhouse gas) in the atmosphere are higher now than in the last 650,000 years. As humans continue burning more and more fossil fuels, scientists believe the impacts of global warming will accelerate in the future.

Outlook

More than 2,000 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 10 feet (3 m) 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. The technology for this change exists, as does the technology to produce climate-safe energy and power.

Climate change and national parks

While scientists have a high certainty in the global trend of atmospheric concentrations of CO_2, the future of a specific regional or local climate is not as certain. Scientists are working with state-of-the-art

Changes in the area covered by snow are especially important because snow reflects solar radiation and tends to keep land cool.

FREQUENTLY ASKED QUESTIONS:

Is the current warming trend natural and is the Earth capable of coping?

The Earth's temperature fluctuates naturally over very long periods of time—tens of thousands to millions of years and sometimes on shorter time scales due to phenomena like El Niño and La Niña. The recent sharp rise in atmospheric carbon dioxide and other greenhouse gases due to human activity over the past few decades, is contributing significantly to the climate change we are observing now. While life on Earth copes with gradual change in a dynamic environment, the current warm up, and the speed at which it happens, is unprecedented over the last 1,300 years.

Do most climate scientists think that climate change is occurring?

Yes. A recent survey of climatologists reveals that 97 percent of those scientists think that global climate change is occurring presently and that human activity is the primary cause. The scientific method allows for uncertainty. Scientists may disagree about certain aspects of climate change, but this is part of the scientific process and not a sign that a theory is inaccurate. Some scientists think that the outcomes will slowly increase like turning a dial; while other scientists think it will be more like flipping a switch. Despite the uncertainty, the National Park Service will move forward with the best science available and adapt its management practices to new evidence.

Can humans affect something as big as the planet?

The sites of the National Park Service tell the stories of human impacts on global systems, including damming rivers to plowing much of the Midwest. Climate change reflects the collective impact of individual actions and we all have to take actions that collectively impact the global system. We find evidence of how humans have affected natural and cultural resources in our national parks. Petrified Forest National Park was once covered with pieces of petrified wood, but because many visitors have taken one piece of petrified wood, the park is facing the possibility that it may lose the thing that defines it.

Are we seeing the impacts of climate change already?

The most visible impacts of climate change appear in northern latitudes, along coasts, and in high-elevation habitats around the world. Glacier National Park once had 150 glaciers larger than 25 acres in size, though only 25 remain today. They are shrinking and are predicted to be completely gone by 2020. Joshua trees in Joshua Tree National Park or sugar maples in many eastern parks need a particular temperature zone to survive. They have already begun to grow in different places, leaving once hospitable habitats to reach the right growing conditions. Fire seasons in the West appear to start earlier and last longer into the fall. Park facilities and homes in Alaska are sinking due to thawing permafrost.

FREQUENTLY ASKED QUESTIONS:

Can a cold day or a hot day prove or disprove global warming?

Weather is what happens day-to-day, climate is the average weather conditions over long periods of time. Climate scientists tell us we can expect more flooding, more drought, extended heat waves, and more severe storms. One cold winter does not significantly change the long-term average or climate. A particular severe storm may not be directly attributable to climate change, but the increased frequency of such storms predicted with a changing climate will certainly impact parks.

Is the sun changing significantly?

Solar radiation reaching the Earth varies by about 0.1 percent. That change is too small to explain documented warming over the past 50 years, and scientists have not found any long-term trend in solar output to that warming. Two factors control how much energy the Earth receives from the sun: subtle wobbles in our planet's orbit around the sun vary the amount of solar radiation received and change the seasonal cycles. These "Milankovitch Cycles" affect the Earth on time scales of thousands of years and their impact on climate change is well understood. Second, the sun's energy output changes following the 11-year sunspot cycle, but also may vary gradually over longer periods of time.

Is it possible for renewable energy to solve our energy needs?

In the short term, today's renewable energy producers are often more expensive than traditional energy sources. However, when long-term costs like pollution, global warming, and quality of life are factored into the economics of energy, alternative energy shines. When faced with the need to change, America produces innovative solutions that lead the world, and many of these changes were expensive and limited at the beginning. America's national parks were innovative, but expensive and controversial 100 years ago. Today they are priceless and connect us to nature and our heritage.

What happens if we wait to react to climate change?

Changes in the Earth's climate, because of the increased level of greenhouse gases like carbon dioxide, already affect our national parks and visitors' experience in the parks. The amount of greenhouse gases we have already released into the atmosphere will linger for decades and continue to raise the temperature at the surface of the Earth where we already see the effects of climate change. By the time we realize such climatic effects, it is often too late to do something about it.

For more climate change information from the National Park Service, visit www.nps.gov/climatechange.

ECOSYSTEM

The management implications for protecting species, biological communities, and physical resources within finite land management boundaries in a rapidly changing climate are complex and without precedent.

—National Park Service Director Jon Jarvis

computer models and new data collection methods to sharpen our picture of climate change from world-wide to local scales. We are likely to find that our future climate presents additional challenges to parks and people:

- Animal migration patterns will shift.
- Plants that once thrived will struggle on the edges of their habitat.
- Storms may increase in intensity.
- Pests, pathogens, and invasive species will increase.
- While some places will experience increased drought, others will experience more pronounced flooding.
- The iconic views visitors enjoy from our national parks may look upon very different landscapes.

Climate "drivers"

Global temperature is the master driver affecting climate and everything else that climate affects. Other climate drivers are important to consider:

- *Temperature*. The effects of temperature include not only the annual average, but also the daily high and low temperatures, the onset of warm spring temperatures and the delay of the first frost, and the extremes of hot and cold.
- *Sea level rise*. Melting polar ice and the expansion of seawater as it is heated, cause the sea level to rise.
- *Evaporation and precipitation*. Where there is heat, there is increased evaporation. This in turn changes precipitation patterns. Moisture laden clouds create their own climate influence. Many locations will get more rainfall, but storms will be shunted away from other areas causing drought.

Climate change will affect streams differently, but increased variability is expected along with a shift in the timing of peak flows.

One of the most precious values of the national parks is their ability to teach us about ourselves and how we relate to the natural world. This important role may prove invaluable in the near future as we strive to understand and adapt to a changing climate.

—National Park Service Director Jon Jarvis

- *Snowfall and snowcover.* Warming temperatures lead to increases in evaporation, more moisture in the air can lead to more snowfall and cloud cover. But increased temperature can also limit snowfall because it rains instead, drive the snowline further up the mountain, or melt snow rapidly once it falls. Changes in the area covered by snow are especially important as the snow reflects more solar radiation out to space and tends to keep the land cool; reduced snowcover can lead to a feedback effect (where changes tend to drive further changes and the effects are compounded). When land is exposed, sunlight is absorbed by the ground. This raises the overall temperature, which leads to more melting. Sea ice and glaciers. Like snowcover, ice on the land cools the planet by reflecting solar energy back to outer space instead of being absorbed and emitted as heat by the land or sea.
- *Streamflow.* Glaciers, snowpack, and rainfall produce water that flows through streams, lakes and rivers. These waterways are critical to life, and complete the planet's water cycle. Climate change will affect streams differently, but increased variability is suspected along with a shift in the timing of peak flows.
- *Growing season.* Changes in temperature, precipitation, and moisture for plants lead to a change in growing season. In many cases, growing seasons will shift earlier in the spring.
- *Extreme events and storminess.* Often it is not the average weather that matters, but the extremes. Record warm days, cold snaps, and the intensity and frequency of storms often dictate plant life, wildlife, and human civilization. Though it is difficult to predict, many climate models forecast greater swings in the weather.

Consequences of climate change

Each natural and human system is based upon a certain climate. Alpine tundra is defined by a very short growing season, cool summers, winter snow cover, and sufficient summer water availability. Likewise, the state of Minnesota's character is based on a climate that provides numerous lakes for fishing and recreation, supports corn, pea, and spring wheat agriculture, and offers adequate snowfall for winter sports.

Many national parks and other protected areas were set up to safeguard a wide range of plant and animal life assuming a certain set of climate conditions. As the climate drivers change, the natural ecosystem and human use of that landscape are bound to change. Even subtle shifts in climate can create substantial changes—earlier snowmelt, a slight increase in summer temperatures, and a slight decrease in rainfall can combine to change the intensity of forest fires, or render forests more susceptible to pests and diseases. With climate change, nature will begin to rearrange itself, and our ability to protect and manage national parks will be challenged.

Scientists are understanding more about the changes to climate drivers, and now focus their attention on the subsequent impacts to natural and cultural resources. The US Fish and Wildlife Service has collected a list of Possible Impacts on Fish and Wildlife in the United States and the US Forest Service has published two atlases on the potential redistribution of trees and birds due to global climate change.

ECOSYSTEM

Regional climate effects

Bioregions are areas that tend to have the same suite of climate effects. For example the western mountains will be significantly impacted by decreased snowpack, while the Atlantic coast is vulnerable to sea level rise. The National Park Service and US Fish and Wildlife Service have developed 11 regional talking point documents to help staff, collaborators, and the public understand the consequences of climate change. The talking points are available on the National Park Service Climate website, http://www.nature.nps.gov/climatechange/resources.cfm.

The role of the National Park Service

Climate change will impact the natural, cultural, and historic resources the National Park Service protects, how its mission is implemented, and how it will maintain a high-quality visitor experience. To meet the challenge of managing national parks in the face of global climate change, it is critical that the National Park Service has high-quality natural resource monitoring and inventory data to track changes as they occur. The National Park Service is adjusting its operations to become a leader in "climate-friendly" management and serving its education mission.

To learn what visitors can do about climate change, visit: http://www.epa.gov/climatechange/wycd/index.html.

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Staff reviewers

Elisabeth Cohen, Education and Training Specialist, National Park Service Climate Change Response Program

Roy Renkin, Vegetation Specialist

Ann Rodman, Spatial Analysis Center

Scientists with the National Park Service and other organizations closely monitor variables that may reflect a changing climate. In Yellowstone, these include whitebark pine, snowpack, the greening of plants, and wildlife.

Climate Change in Greater Yellowstone

Higher temperatures and changes in precipitation patterns can greatly change ecosystems. The alpine zone, which begins at 9,500 feet, may migrate higher, with habitat for important species like whitebark pine substantially reduced. Changes in snowpack and timing of spring runoff may disrupt native fish spawning and increase nonnative 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.

The National Park Service Greater Yellowstone Inventory and Monitoring Network collaborates with the Rocky Mountain and Upper Columbia Basin networks to implement a High Elevation Climate Change Response Strategy. This strategy focuses on high-elevation parks and enhances monitoring of variables in park units, including climate, pikas, five-needle pine trees, snowpack and vegetation phenology, and alpine habitats.

Scientists are developing new small-scale models that more accurately predict climate change effects at local levels. Yellowstone's managers are using these predictions to think about future climate scenarios and consider how climate change might affect park resources. The Greater Yellowstone Area Climate Explorer (http://www.greateryellowstonescience.org/climate_explorer_project) allows users to compare historic averages to future predictions for climate variables in Greater Yellowstone. Yellowstone's thermophilic plants may also provide clues to how other plants will respond to global climate change. Scientists are studying them to understand how they withstand high amounts of carbon dioxide.

Climate

Climate is one of the primary drivers of the physical and ecological processes that determine the distribution, structure, and function of ecosystems. Moreover, there is evidence that climate has changed in the past century and will continue to change. The Greater Yellowstone Network, in partnership with the Rocky Mountain Network, uses climate data collected by national networks to analyze the status and trend of five variables in park units: temperature, precipitation, streamflow, drought, and snowpack. By accessing and analyzing climate data for the high-elevation parks, park and network staff will be better able to understand and interpret changes in status and trends of other vital signs. Annual reports document the current status of climate; trend reports, produced every five years, will examine long-term variability and changes in key variables in a separate document.

Climate Change and the Greater Yellowstone Ecosystem

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

Influences of climate change may be detected by studying

- Vegetation
- Snowpack and phenology (timing of significant biological events like the budding of trees or arrival of migratory birds in the spring)
- Alpine habitats
- Wildlife
- Water
- Fire
- Insect infestations
- Wetlands

Both minimum and maximum temperatures have been increasing in the northern US Rocky Mountains. All global climate models predict that temperatures in the Greater Yellowstone Area will continue to increase and by the 2040s will exceed observed 1900s variability. How much they increase is dependent on the rate of greenhouse gas emissions in the next few decades. Temperatures will increase more in the summer than in the other seasons. Precipitation is generally predicted to increase in fall, winter and spring, but to decrease in the summer. In most places, warmer temperatures will mean more moisture falling as rain during the cooler months and the snowpack melting earlier. At the highest elevations, where temperatures are coldest, more snow might accumulate. April 1 snow water equivalent is predicted to decline by 34 percent averaged over the Greater Yellowstone Area. The increased temperatures in the summer will decrease the moisture available to plants during the hotter months. Eventually this will cause a change in vegetation communities because the rate of change will be different for different species.

Whitebark pine

Five-needle pine trees are foundational species in high-elevation ecosystems across the West. All western species of five-needle white pines and their associated ecosystems could be affected by changes in climate by causing a shift in pathogen ranges, which may lead to an increase in nonnative white pine blister rust, increased frequency and intensity of native mountain pine beetle outbreaks, changes in the frequency of severe fires, and drought stress.

A decrease in extremely cold winter temperatures was implicated as the driving force of a recent, widespread epidemic of the mountain pine beetle. In 2009, concern over this issue contributed to a federal judge ordering the restoration of Endangered Species Act protection to the Yellowstone grizzly bear. In 2011, the US Fish and Wildlife Service added whitebark pine as a candidate species eligible for endangered species protection.

Given the ecological importance of whitebark pine, and that 98 percent of the species occurs on public lands, an interagency whitebark pine monitoring group, including the National Park Service, US Forest Service, and US Geological Survey, have been monitoring the status and trend of whitebark pine stands since 2004 in Greater Yellowstone.

Scientists are studying the greenness and snow cover for the Electric Peak area of northern Yellowstone and other sites in the region. A longer observation record will help determine if the underlying cause of a decline in greenness in the last 11 years is climate related.

Snowpack extent and vegetation phenology

Snowmelt in the alpine areas of the Rocky Mountains is critical to both the quality and quantity of water in freshwater lakes, wetlands, and streams, providing 60–80 percent of streamflow in the West. Climate change is expected to affect both snow accumulation and rate of spring melt and scientists are studying what impacts to expect. Phenology, or timing of significant biological events like the budding of trees or arrival of migratory birds in the spring, is also widely accepted as an indicator of climate change.

The Greater Yellowstone Network tracks changes in seasonal patterns of vegetation "greening," and snowpack melt with satellite imagery. To improve our understanding of snowpack extent and vegetation phenology patterns, snow extent image products are combined with climate data and 11 years of satellite date to assess vegetation.

Analysis of greenness and snow cover has been completed for the Electric Peak area of northern Yellowstone and other sites in the region. The forested flanks of Electric Peak show a decline in greenness over an 11-year period coinciding with tree mortality. A longer observation record will help determine if the underlying cause is climate related. Snow cover extent and timing of melt in the alpine region of the peak provide insight to the variability of annual weather patterns that fluctuate within longer-term cycles. For instance, 2011 snow cover in the alpine region lingered 24 days longer than the average duration of snow cover in the previous 10 years.

Alpine vegetation and soils

The cold and relatively little-studied alpine ecosystems, are among those where climate change impacts are expected to be pronounced and detectable early on. The Greater Yellowstone and Rocky Mountain networks collaborated to implement alpine vegetation and soils monitoring in high elevation parks. National parks including Glacier, Yellowstone, Rocky Mountain, and Great Sand Dunes are now participants in the Global Observation Research Initiative in Alpine Environments (GLORIA) monitoring network. Monitoring includes sampling of vascular plants, soil temperature, air, and temperature at a set of four alpine summits along an elevation gradient. This set of sites span alpine environments from northwest Montana to southern Colorado. Information is available through the GLORIA website at http://www.gloria.ac.at/ as well as on network-affiliated sites.


Climate change is predicted to cause birds to shift their range, migratory patterns and timing, and interfere with reproduction.

Wildlife

The effects of climate change on large mammals are hard to determine and predictions are not easy to find.

- Grizzly bear males are tending to den later, which exposes them to risks associated with hunting of elk outside of the park boundary.
- Wolverines will have less deep snow for dens where they find shelter and give birth.
- Foxes have to adapt to harder snow surfaces. Harder snow surfaces decrease access to rodents but increase access to carcasses.
- Climate change is predicted to cause birds to shift their range, migratory patterns, and timing, and interfere with reproduction.

Climate change is anticipated to cause changes in the distribution and abundance of amphibians on a global scale. In Greater Yellowstone, impacts could include earlier breeding, resulting in more frequent exposure to killing frosts and a longer larval period because water temperatures warm more slowly in early spring, leading to higher larval mortality. Reduced water storage as snow, earlier runoff, and an increase in evaporation due to warmer summer temperatures may reduce habitat for adult amphibians. The Greater Yellowstone Network is working in collaboration with the US Geological Survey's Amphibian Research and Monitoring Initiative to determine the status of amphibians in Yellowstone and Grand Teton national parks. This work includes annually monitoring the status and trend of amphibians, including the percentage of area used for breeding and changes in wetland habitat availability over time.

Sagebrush steppe

Sagebrush steppe is one of the most altered ecosystems in the intermountain West. Substantial sagebrush areas have been converted to agriculture, heavily grazed, and degraded through altered fire regimes and the invasion of nonnative plants. Changes in climate are expected to further alter fire regimes (see Fire section below) and increase invasive species in sagebrush steppe and low-elevation woodlands. Yellowstone National Park also has upland vegetation monitoring data that may be useful in addressing climate change responses in sagebrush-steppe and grassland systems.

Water

Water resources in Greater Yellowstone are projected to be profoundly influenced by climate change, including changes in timing and duration of hydrologic regimes and water temperatures, altering food web interactions, species diversity, and nutrient dynamics. Substantial range reductions are predicted for salmonids due to changes in water temperature. Since 2005, the Greater Yellowstone Network has been annually monitoring alpine lakes, rivers, and streams for five core parameters (dissolved oxygen, pH, specific conductance, temperature, and discharge), water chemistry, and macroinvertebrates.

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.

Rapid climate and associated ecosystem transitions in the Rocky Mountains have occurred in the past and will likely occur in the future. Projections include a higher frequency of large fires, longer fire seasons, and an increased area of the western US burned by fire.

JENNIFER WHIPPLE

In the past several decades, Yellowstone staff have noticed drops in pond water levels on the northern range. Alterations in water availability and forage could have huge implications for wildlife, especially waterfowl and amphibians.

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 or not this holds true for the future remains to be seen. Such potential feedbacks into the process clearly demonstrate the complexity of predicting the consequences of climate change. Continued monitoring will shed light on these potential interactions and outcomes.

Insect infestations

Forest insects that attract our attention by killing trees show episodic outbreaks related to favorable warm and dry conditions and the availability of large trees as food. 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 successfully defends itself again and the infestation diminishes. In the previous decade, five native insects of ecological and economic importance were active simultaneously—a condition not readily apparent from historical records. Currently, all epidemics are declining.

Wetlands

Wetlands in Yellowstone are few and far between, 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. Recognizing that many of these small water basins are already drying, the park began to monitor groundwater hydrology in 2012 to understand the drivers and variability in groundwater flow patterns. The baseline information to be obtained from these select sites will further inform the anticipated consequences under changing climatic conditions.

As wetlands diminish, sedges, rushes, and other mesic (water-loving) plants will lose habitat. In turn, amphibians and some birds will also lose habitat.

Willows, however, are responding with widespread, but locally patchy, increases in height growth. In some locales, 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.

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Staff reviewers

Roy Renkin, Vegetation Specialist
Ann Rodman, Spatial Analysis Center

Yellowstone National Park strives to demonstrate and promote sound environmental stewardship. Through these efforts, more than 5,000 small propane cylinders are crushed and redeemed as steel each year.

ECOSYSTEM

Sustainable and Greening Practices

Support and direction for environmental stewardship in Yellowstone is embedded in both the National Park Service mission and Yellowstone's significance. Recent executive orders and acts require the federal government to protect resources through sustainable operations and facility adaptation. Yellowstone has been working toward becoming a greener park for many years. Early efforts in sustainability included developing a regional composting facility, operating alternatively fueled vehicles, replacing toxic solvents, and overhauling the park's recycling program. In 2003 and 2007, Yellowstone hosted greening conferences that highlighted environmental stewardship and successes in the region.

The park's continued commitment to sustainability is made more urgent due to a changing climate and increasing impacts to natural resources both locally and globally. Yellowstone's complexity creates challenges and requires collaboration among managers and assistance from partners. Many sustainable efforts are facilitated by the Yellowstone Environmental Coordinating Committee consisting of representatives from the National Park Service, Xanterra Parks & Resorts, Delaware North Companies, the Yellowstone Association, Medcor, Yellowstone Park Service Stations, and the Yellowstone Park Foundation.

Yellowstone's Strategic Plan for Sustainability was developed in 2011 and 2012 by Yellowstone staff, concessioners, educational institutions, and corporate partners. The Strategic Plan for Sustainability presents a clear direction by which everyone—employees, visitors, and partners—can

Sustainable and Greening Practices in Yellowstone

The Issue
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 blend; 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.
- 2007: Park completes a greenhouse gas inventory, leading to initiatives to reduce greenhouse gas emissions; interns begin gathering data for sustainability efforts.
- 2011: Representatives from corporate partners and educational institutions participate in a "Greening Yellowstone Symposium."

Park Waste Diverted from Landfills
- 2006: 70%
- 2010: 80%
- 2011: 72% (50% recycling, 22% compost)

Recycling
- 2011 recycling in the park:
  - newspapers, magazines, office paper: 92 tons
  - aluminum and steel: 235 tons
  - glass: 151 tons
  - plastics: 57 tons
  - cardboard: 258 tons
  - small propane canisters: 15 tons
  - food waste and other garbage composted: 1,042 tons
  - manure: 962 tons

work collaboratively to make Yellowstone greener. The plan builds upon servicewide direction and previous greening efforts, such as the Yellowstone Environmental Stewardship (YES!) Initiative. It focuses on specific goals to reduce greenhouse gas emissions, energy use, water use, and waste production, to adapt facilities, and to conduct operations in an environmentally responsible manner.

More information, including goals and objectives for sustainability in Yellowstone, can be found at www.nps.gov/yell.

Energy conservation

Yellowstone National Park is the largest consumer of energy in the National Park Service. Currently, most of Yellowstone's energy comes from coal-fueled power plants, but the park is increasing the use of more sustainable energy. Yellowstone strives to make facilities more energy efficient, reduce the use of fossil fuels for all infrastructure systems, and use renewable energy where possible.

There are several developed areas within the park and a varied assortment of aging buildings. Most buildings need energy efficiency improvements including updates to old and inefficient heating systems. Inventories of energy performance have been carried out on several buildings to determine the biggest heat loss problems.

Constructing, remodeling, and updating Yellowstone's buildings present opportunities for improving energy conservation. National Park Service staff is installing new windows, improving insulation, and adding weather stripping to doors. New efficient heating and lighting systems with easy-to-control switches and thermostats reduces energy use. The Old Faithful Visitor Education Center, completed in 2010, is LEED (Leadership in Energy and Environmental Design) certified and the Old Faithful Haynes Photoshop will be Yellowstone's first LEED historic renovation.

All improvements to outdoor lighting are fully shielded, energy efficient, and provide only the level of light needed for night safety. This minimizes energy use for outdoor lighting while promoting a park goal to protect the night sky. High-efficiency LED lights are used wherever possible, significantly reducing the amount of energy used for lighting.

Yellowstone now has several small renewable energy systems and managers continue to look for similar new opportunities. Photovoltaic (PV) systems have been a great success at locations that do not have main line electric power. At Bechler, a portable trailer with a 9 kW array meets 90 percent of the electrical needs in the summer season. The 14 kW system at Lamar Buffalo Ranch meets 70 percent of electrical needs year-round. Feasibility studies are underway to address further development of solar PV, solar heated water, and micro hydro capabilities.

In 2012, a 175 kW micro hydro generator was brought on-line in Mammoth, providing renewable electric power to the grid. Tapping natural thermal energy in Yellowstone is not being considered by park managers as the effects are likely to be detrimental to the park's hydrothermal features.

Water conservation

Climate change is expected to cause drier conditions in the Rocky Mountain West, so it is critical that the park conserves water and ensures that facilities and operations have minimal impact on water resources. Yellowstone is reducing its use of potable water by using water-smart technology and integrating design

This portable photovoltaic system at Bechler provides power during the summer season, meeting 90 percent of the site's electrical needs.

The aging irrigation system used to water the historic lawns of Fort Yellowstone and Mammoth Hot Springs, pictured here in 1916, was upgraded in 2012.

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changes during remodeling projects. Park staff are replacing toilets and faucets with the most efficient models as well as repairing leaks in old water pipe infrastructure throughout the park. A water vulnerability study is underway for the Old Faithful area to assess future demand and the impacts of structures on natural surface water systems.

The historic lawns of Mammoth Hot Springs, 37 acres total, have been irrigated since they were planted by the US Cavalry in 1902. In 2012, smart controllers that sense weather and soil moisture were installed to reduce the water used annually for irrigation in Mammoth by 30 percent, a reduction of approximately 3.5 million gallons per year.

Fleet and transportation

Yellowstone is using more fuel-efficient vehicles and choosing the most efficient vehicles for each job. In 2004, the park's hybrid fleet began with four models donated by Toyota USA. Today, out of 615 total vehicles, about 19 percent are hybrid vehicles. This includes 29 gas hybrid models like the Prius, Escape, Camry, and Highlander; 2 electric-dedicated manlifts; 1 electric compact pickup; and 1 hybrid bus.

Through a partnership with Michelin, the park has used 874 experimental fuel efficiency tires on park vehicles since 2009. Since installing these tires, the park has recorded about 3 percent savings on gas consumption, which lessens the amount of greenhouse gas emissions produced by the park fleet and reduces the park's contribution to climate change.

In January 1998, Yellowstone initiated a ride share program at the suggestion of park employees living north of the park—some more than 50 miles away—who were willing to help finance the program. A bus now transports employees from Livingston to Mammoth each day. Approximately 45 employees participate in the ride share program, which reduces fuel consumption and air pollution, improves safety, reduces parking needs, and saves employees money.

Yellowstone has partnered with the Greater Yellowstone/Teton Clean Energy Coalition (part of the Department of Energy Clean Cities Coalition) on several fuel-reduction projects including a recent idle-reduction campaign. The coalition promotes clean fuels to reduce particulate matter entering the atmosphere.

Environmental purchasing and waste reduction

The park minimizes waste by purchasing environmentally-preferred items, including items with

In 2011, Yellowstone diverted approximately 72 percent of its waste from landfills, including 235 tons of aluminum and steel.

minimal packaging, biodegradable or recyclable materials, and without toxic components as well as items requiring minimal energy to produce and transport. In 2012, Yellowstone employees switched to office paper with 100 percent post-consumer recycled content, rather than 30 percent. The purchase of single-use plastics is being reduced.

Yellowstone also reduces waste by composting and recycling. A study done in 1994 showed that 60–75 percent of the solid waste generated in the park could be composted. 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. The facility began operating in July 2003 and now transforms 60 percent of the park's solid waste into compost. The recycling program has also expanded with recycling bins for glass, plastic, paper, aluminum, steel, and cardboard. In 2011, park employees, visitors, and partners diverted approximately 72 percent of waste from the landfill through recycling and composting initiatives. Recycling of construction waste has also been increased.

In August 1998, the US Environmental Protection Agency (EPA) helped the park to assess its cleaning products. The EPA found some products with toxic ingredients that posed health hazards, so the park switched from more than 130 risky products to fewer than 10 safe products, helping to protect the environment, improve human health, and save money.

In 2005, Yellowstone became the first national park to recycle small propane cylinders, such as those used for lanterns and camp stoves. More than 5,000

Bear spray canisters are now recyclable throughout the Greater Yellowstone Ecosystem.

cylinders are crushed and redeemed as steel each year. In 2011, Yellowstone and its partners began recycling bear spray containers. More information about this project is available at http://www.bearsprayrecycling.info/.

Yellowstone has more than 15 miles of wood boardwalk, most of which is several decades old. As these boardwalks age, toxic chemicals from wood preservatives may leach into the ground and nearby waterways. To reduce pollutants and the amount of new wood products used, the park has replaced some wood walkways with boards made of recycled plastic. This effort began in 1998 when Lever Brothers Company donated plastic lumber, the equivalent of three million plastic milk jugs, for the Old Faithful Geyser viewing platform.

Yellowstone is experimenting with permeable pavement for sensitive resource areas and installed a permeable recycled glass pavement on the west side of the Old Faithful Visitor Education Center in 2011. Recycled plastic from Yellowstone is used in carpet backing through a partnership with the park's recycling contractor and Universal Textiles and Signature Crypton Carpet.

Greening of concessions

Yellowstone National Park's major concessioners have made corporate commitments to an environmental management system that meets international business standards for sustainability.

Ecologix: Xanterra Parks & Resorts

Xanterra, which provides lodging and other guest services in the park, calls its environmental management system "Ecologix." Xanterra's environmental commitment includes the development and implementation of sustainable practice such as:

- Installing tens of thousands energy efficient LED (light-emitting diode) lamps and compact fluorescent lamps to replace incandescent bulbs.
- Replacing two-stroke engines of rental boats and snowmobiles with cleaner burning and more efficient four-stroke engines.
- Using paper products containing 100 percent post-consumer recycled content and soy-based inks for most printed materials.
- Serving organic, fair-trade coffee (pesticide-free, grown and harvested in a manner supporting habitats for birds and other wildlife, purchased from local farmers at a fair price), and serving sustainable foods including meat from local ranches raised without hormones or antibiotics.
- Offering a variety of environmentally-friendly products in its retail outlets and the creation of the For Future Generations: Yellowstone Gifts retail store, which is devoted to educating guests about the threats of climate change and supporting sustainable retail products through a unique environmental scorecard system.

Xanterra is also committed to waste diversion. Through innovative composting and recycling programs, Xanterra was able to keep more than 4.2 million pounds of material from entering local landfills. In addition to conventional recyclables (cans, bottles, paper, etc.), Xanterra also recycles used oil, tires, laundry bags, linens, electronic waste, curtains, batteries, cooking oil, manure, solvents, and more. In 2011, Xanterra donated 141,000 pounds of used mattresses and 37,000 pounds of linens to non-profits and businesses. All of these recycled items added up to more than 2 million pounds.

In 2011, the Mammoth Hotel Dining Room became certified as a Green Restaurant by the Green Restaurant Association. The Mammoth Dining Room is Xanterra's first certified green restaurant, and with a three-star rating, it is the first three-star certified restaurant in Wyoming, and one of only 71 in the country. To achieve this certification, Xanterra installed waterless urinals, high-efficiency hand dryers, dual-flush toilets, and super energy-efficient LED lamps, and sources of local, organic, and sustainable cuisine, including Marine Stewardship Council certified salmon.

GreenPath: Delaware North

Delaware North Companies, which operates twelve general stores in the park, calls its award winning system "GreenPath.®" This environmental management system was the first in Yellowstone to attain ISO 14001 Registration, which means it exceeds strict environmental standards recognized internationally. Practices include:

- Purchasing responsibly wherever possible. For example, using biodegradable dishware and cutlery in all food service operations, which are then composted at a local facility.
- Conserving energy by improving fleet efficiency with hybrid technology, retrofitting old lights with new LED and compact fluorescent bulbs, and purchasing Energy Star rated equipment.
- Conserving water by installing low-flow showerheads, kitchen sprayers, faucets and toilets.
- Reducing or eliminating the use of hazardous materials and production of waste.
- Operating an aggressive recycling program with 22 types of materials recycled where approximately 55 percent of all waste produced goes to recycling.
- By recycling and composting nearly 62 percent of all waste is diverted from the landfill.
- Sustainable development can be seen as Delaware North Companies was awarded the first ever certification to the Greater Yellowstone Framework for Sustainable Development (fulfills LEED requirements plus additional requirements specific to the area) for accomplishments on the Lake and Tower stores.
- Partnering with the National Park Service, other concessioners, not-for-profit organizations, and others to improve environmental efforts in Greater Yellowstone.
- Training nearly 600 seasonal associates on GreenPath® and how they can help to educate others on a great program.
- Installing free water-filling stations to reduce the production, shipping, and use of approximately 35,000 plastic water bottles.
- Using renewable energy sources to help heat water at the Grant Village dormitory.

Yellowstone National Park's major concessioners have made corporate commitments to incorporating sustainability into their operations. This water filling station is located in the Tower Fall Delaware North store.

More information

National Park Service Green Parks Plan: www.nps.gov/greenparksplan
Yellowstone's Vision for Sustainability: www.nps.gov/yell
Yellowstone Park Foundation www.ypf.org

Staff reviewers

Lynn Chan, Landscape Architect
Katy Duffy, Interpretive Planner

In 2012, 164 researchers were permitted to use study sites in Yellowstone National Park. Many more conduct research at the Heritage and Research Center.

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Research in the Park

In part because Yellowstone National Park was established by Congress in 1872, early in the European American history of the West, the park is one of the last, nearly intact, natural ecosystems in the temperate zone of Earth. Natural processes operate in an ecological context that has been less subject to human alteration than most others throughout the nation and throughout the world. This makes the park not only an invaluable natural reserve, but a reservoir of information valuable to humanity.

In Yellowstone, scientists conduct research ranging from large studies of landscape-level changes affecting the local ecosystem to studies of tiny organisms that have the potential to change the lives of people the world over. Yellowstone also has a rich history that includes an archeological record of more than 11,000 years of human use. As the world's first national park, Yellowstone's modern history is no less significant; the park's Heritage and Research Center houses materials documenting the development of the national park idea, the history of science in the park, and major efforts in American wildlife conservation, as well as the park's broader natural and human history.

A long history of scientific study

As a research location, Yellowstone has long attracted scientists. In any given year, 150–200 scientific researchers are permitted to use study sites in the park, and many more conduct research at the park's Heritage and Research Center. Yellowstone is one of the most high-profile research locations in the National Park Service and has one of the most active research programs. Researchers from universities, other agencies, and the National Park Service come to Yellowstone to conduct scientific studies. In 2012, permitted researchers came from 26 states and nine foreign countries.

Some of the first written accounts about the wildlife and thermal features of the Greater Yellowstone area were in journals and letters from settlers, trappers, Indian scouts, and the military. These early accounts brought about expeditions to explore

Research in Yellowstone

Number in Yellowstone
2012: 164 permitted scientific researchers

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

Types of Research
In 2008, permitted research included:

- Microbiology: 23%
- Geology and geochemistry: 22%
- Other: 13%
- Flora: 12%
- Fauna: 10%
- Fish and aquatic ecology: 7%
- Terrestrial ecology: 7%
- Archeology and paleontology: 6%

Conducting Research

- Research permits are required for studies and collections. (Research conducted at the Heritage and Research Center facility does not require a permit.) The park's Research Permit Office, located in the Yellowstone Center for Resources, is responsible for issuing and tracking research permits, and provides support to permitted researchers in the park.
- Each permit application undergoes a formal, standard process for research permit review and issuance.
- All researchers required to submit an annual report of their study progress and results. These annual reports available online at https://science.nature.nps.gov/research/ac/ResearchIndex.
- Publications resulting from research may be on file in the Yellowstone Heritage and Research Center Library.

Yellowstone in the 1860s and 1870s (See also: "History"). It is in these explorations that the history of science in Yellowstone formally began with the expeditions of geologist Ferdinand V. Hayden, who led US Geological Survey expeditions to the Yellowstone area in the 1870s.

Modern research

By the 1960s, scientific research in Yellowstone had extended beyond the study of the park itself. Yellowstone was also a place where researchers advanced techniques for scientific study. The National Park Service changed its permitting policy at this time, requiring researchers to demonstrate their projects directly benefited park managers and would help make important decisions. As a result, many permits were denied. This gave some permit-seekers that impression that research in the park was not as welcome as it had been in the past. Around this time, the National Park Service also adopted a goal to host mission-oriented research, and managers sometimes felt free to suggest researchers accordingly adjust their proposals to meet that goal.


WILLIAM H. JACKSON

In one of the earliest scientific studies of Yellowstone, the 1871 Hayden Expedition determined Yellowstone Lake was less than 300 feet deep.

As important as wildlife science has been in Yellowstone's history, the park's hot springs have demonstrated immeasurable scientific value. In 1966, researcher Thomas Brock discovered *Thermus aquaticus*, a microorganism capable of surviving in temperatures extreme enough to kill most other living organisms, in a Yellowstone hot spring. In 1985,

History of Science in Yellowstone

- 1871–1878: Expeditions of US Geological Survey Geologist Ferdinand Hayden to the Yellowstone area.
- 1877–1882: Park superintendent Philetus Norris establishes scientific inquiry as an important aspect of park management and argues for employing a resident scientist in the park.
- 1935: Eugene Thomas Allen and Arthur Lewis Day publish Hot Springs of the Yellowstone National Park (Carnegie Institution), the definitive literature on the park's thermal environment for many decades.
- 1959–1971: A team of researchers led by John and Frank Craighead use the park to pioneer the field of radio telemetry in their groundbreaking studies of Yellowstone's grizzly bears. The Craigheads were also at the forefront of technological innovation in other methods of identifying and classifying grizzly bears.
- 1967–1971: Park managers differed with the Craigheads over some of their scientific conclusions and were disinclined to implement most of their recommendations. The Craigheads concluded their work in the park. The disagreements were so well-publicized in the news media that a widespread, enduring mythology developed that the National Park Service was generally anti-research, especially when it came to outside researchers.
- 1960s: The National Park Service changes its research permitting policy, only permitting projects that are of direct benefit to park managers and would help make important decisions.
- 1966: Park researcher Dr. Thomas Brock discovers *Thermus aquaticus* in a Yellowstone hot spring. An enzyme discovered in the microorganism is eventually used to rapidly replicate DNA.
- 1968: Yellowstone begins "natural regulation" management. The resource management philosophy has been highly controversial over the years, and has itself become a major focus of scientific study in Yellowstone.
- 1970s and 1980s: Evolving management priorities—in which the need for scientific research became progressively more compelling both politically and practically—combined with increasing attention and interest in Yellowstone by the scientific community was reflected in an increase in the volume of research.
- 1984: Total research permits exceed 100 for the first time.
- 1987: Total research permits exceed 200.
- 1990s–2000s: Total research permits average about 250 annually.
- 1993: The Yellowstone Center for Resources is established as a separate operational division, further elevating the formal recognition of research as an essential element of management.
- 2005–2011: Total research permits are approximately 195 annually.

the Cetus Corporation obtained a sample of *T. aquaticus* from for use in developing the Polymerase Chain Reaction (PCR) process for rapidly replicating DNA.

Amplifying a segment of DNA to a billion exact copies in a few hours gives a scientist enough material to seriously study. The use of an enzyme discovered in *T. aquaticus*, called Taq polymerase (which does not break down at the high temperatures required in the PCR process), made PCR practical and is seen as the biggest advance in PCR. Today, PCR is still the main process used to study nucleic acids, and DNA sequencing is a multibillion dollar business. More than 40 patents involve research from Yellowstone. (See: "Biodiversity and processes" in this chapter.)

Research studies provide valuable information to the park. Dozens of comprehensive studies were completed in the 20 years following the 1988 fires. The restoration of wolves in 1995 lead to increased research interest on the northern range and continues today. The active volcanic ecosystem also fuels a wide variety of geologic studies. Many of these scientific studies have ramifications far beyond Yellowstone National Park.

Research projects in Yellowstone

Today, permitted researchers study everything from archeology to zoology. Current research examples include:

- Evaluating the effects of winter recreation on air quality, wildlife, and natural soundscapes.
- Understanding prehistoric and historic use of the park, with emphasis on Yellowstone Lake and park developed areas.
- Monitoring plant and animal populations that are, or may be, affected by changing climatic conditions.
- Studying the interrelationship between carnivores, herbivores, and vegetation on Yellowstone's northern range.
- Conducting detailed population ecology studies on mammals such as wolves, elk, bison, grizzly bears, bighorn sheep, and mountain goats.
- Understanding the effects of landscape-scale disturbances (such as fires, insect outbreaks, and disease outbreaks) on the park's forests.
- Surveying rare, unusual, or thermally-adapted flora.
- Monitoring of various geophysical systems that provide indicators of change within the Yellowstone caldera (seismicity; heat, chemical, or gas flux; deformation; subsidence and uplift).
- Monitoring geochemical cycling in hot springs and thermally-influenced waterways.
- Identifying new microbial species (and their survival mechanisms) found in the park's numerous and diverse thermal features.
- Studying the ecology and life-history strategies of nonnative plants and aquatic species to better understand ways to control or eradicate them.
- Using tree ring data, pollen records, and charcoal evidence to understand past climatic patterns.

More information

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National Park Service Research Permit and Reporting System: https://science.nature.nps.gov/research/ac/ResearchIndex

Staff reviewers

Christie Hendrix, Research Permit Office
Stacey Gunther, Research Permit Office

Many organizations and programs support Yellowstone National Park and the management across the Greater Yellowstone Ecosystem.

Partnerships

Yellowstone National Park is privileged to have the support of numerous organizations and programs. Partners provide important support for education, sustainability initiatives, management solutions, and park research.

Greater Yellowstone Network

The Greater Yellowstone Network was established by the National Park Service Inventory and Monitoring Program in 2000 to help enhance the scientific basis for stewardship and management of natural resources in Bighorn Canyon National Recreation Area, Grand Teton National Park (including John D. Rockefeller, Jr. Memorial Parkway), and Yellowstone National Park. The Greater Yellowstone Network is one of 32 units nationwide that group some 270 national parks into networks based on geographic similarities, common natural resources, and resource protection challenges. This collective approach to inventory and monitoring helps to facilitate collaboration and information sharing between the parks and with other natural resource management agencies and interests. For more information about this program, visit science.nature.nps.gov/im/units/gryn.

Rocky Mountains Cooperative Ecosystem Studies Unit

The Rocky Mountains Cooperative Ecosystem Studies Unit brings together the region's best scientific talent and scholarship to help manage resource problems across social, cultural, economic, political, and environmental arenas. The Rocky Mountains Cooperative Ecosystem Studies Unit conducts research, education, and technical assistance on both agency specific issues and on issues concerning areas of mixed ownership. This information is made available to those who need it, including land managers, and political and industry leaders. For more information about this program, visit www.cfc.umt.edu/CESU.

Great Northern Landscape Conservation Cooperative

The Great Northern Landscape Conservation Cooperative is an alliance of conservation partners with common landscape conservation goals for building ecosystem resilience within the Great Northern geographic area, extending from the Columbia Basin, Rocky Mountains, and Sage Steppe of the Interior West in the United States and Canada. The partnership shares data, science, and capacity and works across boundaries and jurisdictions. The cooperative links local resource needs with national conservation priorities. For more information about this program, visit greatnorthernlcc.org.

The physical landscape of Yellowstone National Park is the result of many geological forces. Here, glacial erratics (foreground), ground moraines (midground), and Cutoff Mountain (background) appear near Junction Butte.

Geology

Yellowstone National Park's physical landscape has been and is being created by many geological forces. 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.

Throughout the Greater Yellowstone Ecosystem, many different geologic processes are occurring at the same time, in different proportions. While these mountains and canyons may appear to change very little during our lifetime, they are still highly dynamic and variable.

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. The distance from the Earth's surface to its center or core is approximately 4,000 miles. The core of the earth is divided into two parts. The mostly iron and nickel inner core (about 750 miles in diameter) is extremely hot but solid due to immense pressure. The iron and nickel outer core (1,400 miles thick) is hot and molten. The mantle (1,800 miles thick) is dense, hot, semisolid layer of 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 crust and upper mantle (lithosphere) is divided into many plates, which are in constant motion. Where plate edges meet and one plate may slide past another, one plate may be driven beneath

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 formed by a series of andesitic volcanic eruptions 45 to 50 million years ago.

another (subduction). Upwelling volcanic material pushes plates apart at mid-ocean ridges. Continental plates are made of less dense rocks (granites) that are thicker 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.

At a Glance

Although a cataclysmic eruption of the Yellowstone volcano is unlikely in the foreseeable future, monitoring of seismic activity and ground deformation by the Yellowstone Volcano Observatory helps ensure public safety. The University of Utah's seismograph stations detected more than 3,200 earthquakes in the park in 2010, the largest count since 1985. New technology contributed to this increase in detected earthquakes by allowing extensive scientific analysis of small earthquakes. This technology was not available during the 1985 swarm.

From mid-January to mid-February 2010, a swarm of about 2,300 quakes occurred about 10 miles northwest of Old Faithful. The two largest earthquakes, magnitude 3.7 and 3.8, were felt throughout the park and in surrounding communities, but both occurred after 11 pm and had little effect on park visitors.

Beginning in 2004, GPS and InSAR measurements indicated that parts of the Yellowstone caldera were rising up to 7 cm per year, while an area near the northern caldera boundary started to subside. The largest vertical movement was recorded at the White Lake GPS station, inside the caldera's eastern rim, where the total uplift from 2004 to 2009 was about 25 cm. The caldera began to subside during the first half of 2010, about 5 cm so far. Episodes of uplift and subsidence have been correlated with earthquake occurrence in the park.

Energy and groundwater development outside the park, especially in known geothermal areas in Island Park, Idaho, and Corwin Springs, Montana, could alter the functioning of geothermal systems in the park.

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Staff reviewers

Henry Heasler, Geologist
Cheryl Jaworowski, Geologist

GEOLOGY

Between 542 and 66 million years ago—long before the "supervolcano" became part of Yellowstone's geologic story—the area was covered by inland seas.

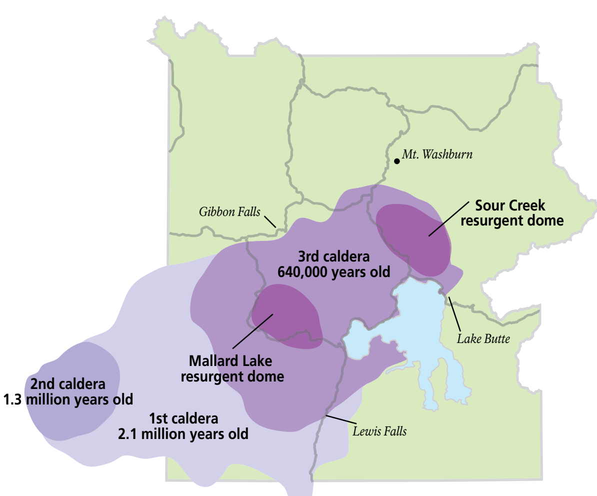
Geologic History of Yellowstone

Most of Earth's history (from the formation of the earth 4.6 billion years ago to approximately 541 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 (541 to 66 million years ago), the western United States was covered at times by oceans, sand dunes, tidal flats, and vast plains. From the end of the Mesozoic through the early Cenozoic, mountain-building processes formed 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 today's 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 the Yellowstone are.

About 16.5 million years ago, an intense period of volcanism appeared near the intersection of present-day Nevada, Oregon, and Idaho. Repeated volcanic eruptions can be traced across southern Idaho towards Yellowstone. 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 closer to the shallow magma body. This volcanism remains a driving force in Yellowstone today.



ADAPTED WITH PERMISSION FROM *WINDOWS INTO THE EARTH* BY ROBERT SMITH AND LEE J. SIEGEL, 2000.

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

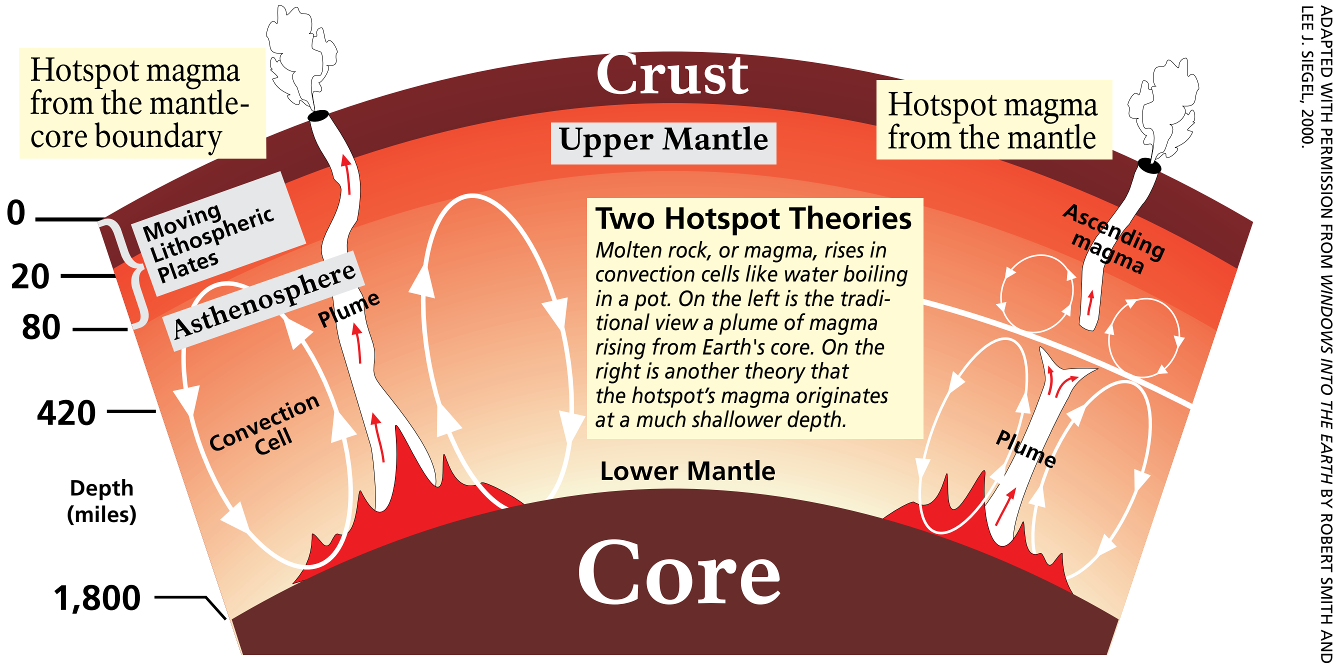
Magma and hotspots

Magma (molten rock from Earth's mantle) has been close to the surface in Yellowstone for more than

Yellowstone Geologic History

542 to 66 Ma	Area covered by inland seas
50 to 40 Ma	Absaroka volcanics
30 Ma to present	"Basin and Range" forces creating Great Basin topography
16 Ma	Volcanics begin again in present day Nevada and Idaho
2.1 Ma	1st Yellowstone eruption
1.3 Ma	2nd Yellowstone eruption
640 ka	3rd Yellowstone eruption
174 ka	West Thumb eruption
157 to 151 ka	Bull Lake Glaciation underway
20 to 16 ka	Pinedale Glaciation maximum

Ma = mega annum, or millions of years ago
ka = kilo annum, or one thousand years ago



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

GEOLOGY

FREQUENTLY ASKED QUESTIONS:

Is Yellowstone a volcano?

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

What is the caldera shown on the park map?

The Yellowstone Caldera was 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, Lake Butte, and Flat Mountain Arm of Yellowstone Lake are part of the rim.

When did the Yellowstone volcano last erupt?

An eruption approximately 174,000 years ago created what is now the West Thumb of Yellowstone Lake. The last lava flow was about 70,000 years ago.

Is Yellowstone's volcano still active?

Yes. The park's many hydrothermal features attest to the heat still beneath this area. Earthquakes—1,000 to 3,000 per year—also reveal activity below ground. The University of Utah Seismograph Station tracks this activity closely.

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.

What is a supervolcano?

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

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/.

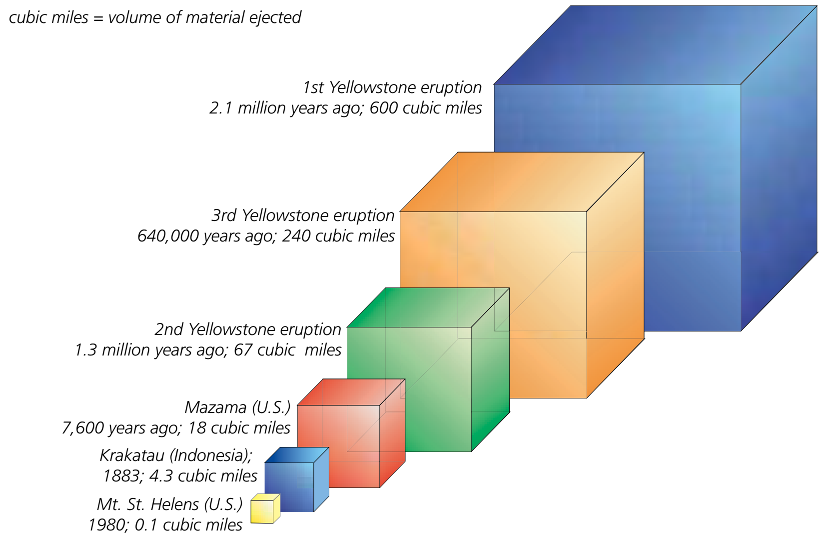
If Old Faithful Geyser quits, is that a sign the volcano is about to erupt?

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.

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 an area of the upper crust to expand, rise, and erode. The Yellowstone Plateau became a geomorphic landform shaped by episodes of volcanic activity. 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 into the atmosphere and causing fast 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 within the western edge of the first caldera. Then 640,000 years ago, a third massive volcanic eruption 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 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.



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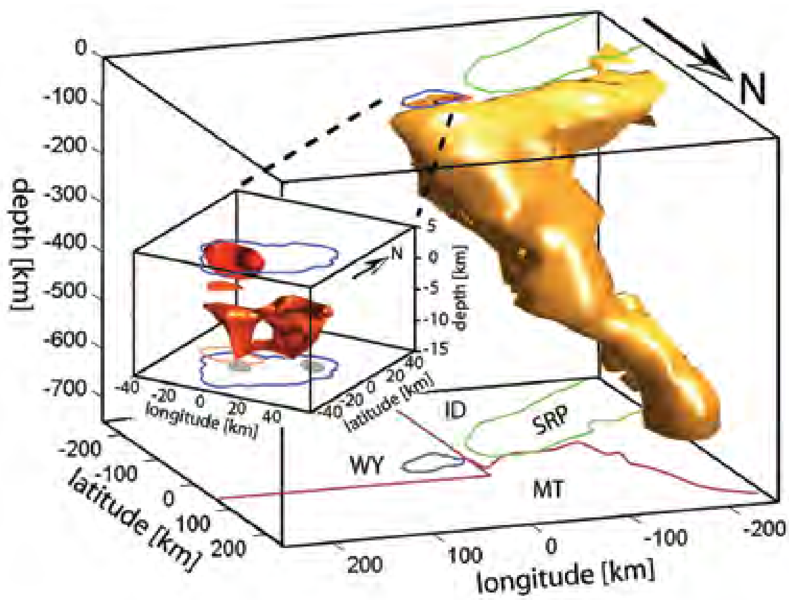
Volume comparison of volcanic eruptions.



ROBERT B. SMITH

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. Diagram courtesy Robert B. Smith; appeared in *Journal of Volcanology and Geothermal Research*, 2009.

Volcano

A plume of molten rock that rises beneath Yellowstone creates one of the world's largest active volcanoes, evident in the frequency of earthquakes in the area, the thousands of geothermal features, and the measurable ground deformation over time. The first major eruption of the Yellowstone volcano, which occurred 2.1 million years ago, is among the largest volcanic eruptions known, covering over 5,790 square miles (15,000 km^2) with ash. After the most recent major eruption, 640,000 years ago, the ground collapsed into the magma reservoir, leaving a caldera 75 km long and 55 km wide. Since then, 80 smaller eruptions have occurred, most recently 70,000 years ago, partially filling the caldera. Although a cataclysmic eruption is unlikely in the foreseeable future, continuous monitoring of seismic activity, ground deformation, and changes in underground strain rates helps ensure public safety.

Recent activity

Ground deformation has been documented along the central axis of the caldera between Old Faithful and White Lake in Pelican Valley. The largest vertical movement was recorded at the White Lake GPS station, inside the caldera's eastern rim, where the total uplift from 2004 to 2009 was about 25 cm. The rate of rise slowed in 2008 and the caldera began to subside during the first half of 2010. The uplift is believed to be caused by the movement of deep hydrothermal fluids or molten rock at a depth of about 10 km beneath the surface. A caldera may undergo episodes of uplift and subsidence for thousands of years without erupting. Episodes of uplift and subsidence have been correlated with earthquake occurrence.

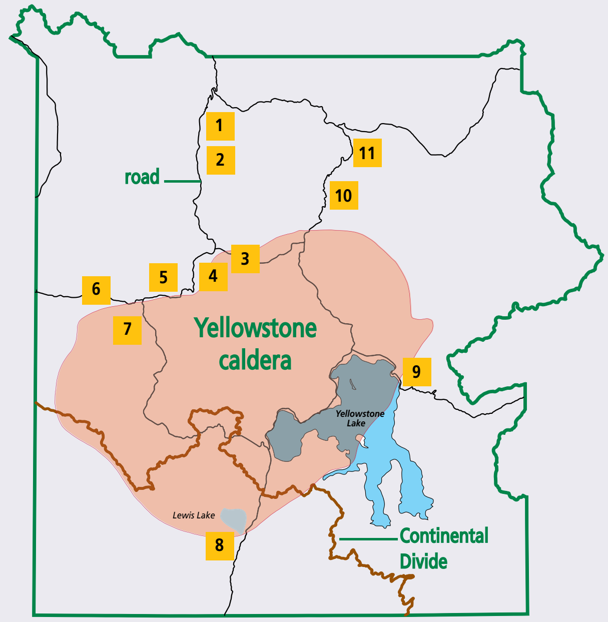
Future volcanic activity

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

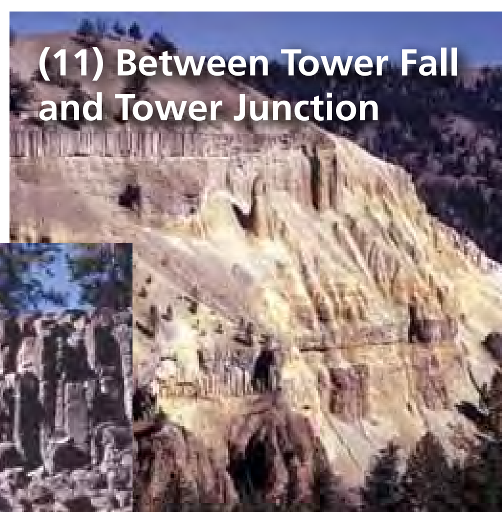
The most likely activity would be lava flows, such as those that occurred after the last major eruption. A lava flow would ooze slowly over months and years, allowing plenty of time for park managers to evaluate the situation and protect people. No scientific evidence indicates such a lava flow will occur soon.

To monitor volcanic and seismic activity in the Yellowstone area, the US Geological Survey, National Park Service, and University of Utah

Where to see volcanic flows



1. Sheepeater Cliff: columnar basalt
2. Obsidian Cliff: lava
3. Virginia Cascades: ash flow
4. Gibbon Falls: Near caldera rim
5. Tuff Cliff: ash flow
6. West Entrance Road, Mt. Haynes and Mt. Jackson: columnar rhyolite, Lava Creek tuff
7. Firehole Canyon: lava
8. Lewis Falls: Near caldera rim
9. Lake Butte: On edge of caldera, overall view of caldera
10. Washburn Hot Springs Overlook: overall view of caldera
11. Between Tower Fall and Tower Junction: columnar basalt


(11) Between Tower Fall and Tower Junction


(1) Sheepeater Cliff


(7) Firehole Canyon

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 in the world. To strengthen the capabilities of scientists to track and respond to changes in Yellowstone's activity, a fifth US volcano observatory was created in 2001, complementing existing ones for Hawaii, Alaska, the Cascades, and Long Valley, California. The Yellowstone Volcano Observatory is supported jointly by the US Geological Survey, the University of Utah, and Yellowstone National Park.

The principal goals of the Yellowstone Volcano Observatory 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.
- 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 in Yellowstone Association bookstores.

established the Yellowstone Volcano Observatory in 2001. The near real-time monitoring network consists of 26 seismic stations, 16 GPS receivers, and 11 stream gauging stations. Information is also collected on temperature, chemistry, and gas concentrations at selected geothermal features and chloride concentrations in major rivers. A monthly activity summary, real-time monitoring of seismicity and water flow, and near real-time monitoring of ground deformation, can be found at the Yellowstone Volcanic Observatory website.

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Staff reviewers

Henry Heasler, Geologist
Cheryl Jaworowski, Geologist

Grand Prismatic Stream is one of more than 10,000 thermal features in Yellowstone. Research on heat-resistant microbes in the park's thermal areas has led to medical, forensic, and commercial uses.

Hydrothermal Systems

Yellowstone was set aside as the world's first national park because of its geothermal wonders. The park contains more than 10,000 thermal features, including the world's greatest concentration of geysers as well as hot springs, mudpots, and steam vents. Research on heat-resistant microbes in the park's thermal areas has led to medical, forensic, and commercial uses. Oil, gas, and groundwater development near the park and drilling in "Known Geothermal Resources Areas" identified by the US Geological Survey in Island Park, Idaho, and Corwin Springs, Montana, could alter the functioning of geothermal systems in the park.

Under the surface

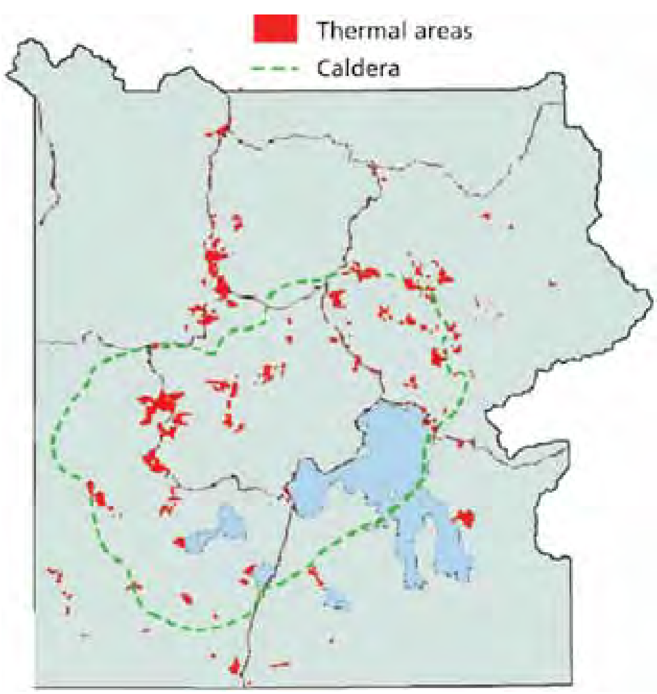
The park's geothermal system is the visible expression of the immense Yellowstone volcano; they would not exist without the underlying magma body that releases tremendous heat. They also depend on sources of water, such as the mountains surrounding the Yellowstone Plateau. There, snow and rain slowly percolate through layers of permeable rock riddled with cracks. 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 and weak areas through rhyolitic lava flows. This upward path is the natural "plumbing" system of the park's hydrothermal features.

As hot water travels through this rock, it dissolves some silica in the rhyolite. This silica can precipitate in the cracks, perhaps increasing the system's ability to withstand the great pressure needed to produce a geyser.

The silica coating on the walls of Old Faithful's geyser tube did not form a pressure-tight seal for the channel of upflow. Lots of water was seen pouring through the "silica-lined" walls after an eruption stopped. Amorphous silica is a lot less strong than the rock it might coat. The pressure in the geyser tube is not contained by the strength of the wall, rather the water pressure in the tube is contained by the greater pressure of colder water outside of the tube.

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.



Geothermal areas in Yellowstone National Park.

Recent activity

No basin-wide changes in geothermal activity have been observed in the park in recent years. The Old Faithful eruption interval is 88 minutes as of January 2013, but remained at 90 to 91 minutes for several years. Steamboat Geyser has not had a major eruption. Echinus Geyser, one of the largest acidwater geyser known, has had a period of limited activity. Work continues on the park's geothermal monitoring program, with progress made in documenting the status and trends of the geothermal system by measuring the total amount of thermal water and the total heat output for selected geyser basins. Aircraft and helicopter thermal infrared images are being used to determine a baseline and document changes in the hydrothermal areas.

The widely dispersed locations of the park's geothermal areas make a systematic monitoring program to protect the features and the public difficult. The most visible changes in individual thermal features receive the most public attention but do not necessarily represent human influences or changes in the entire geothermal system. In order to distinguish human influences from natural changes, the natural variability of the geothermal system must be characterized by gathering reproducible data over many

FREQUENTLY ASKED QUESTIONS:

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.

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, mudpots, and fumaroles. These distinct areas often (but not always) occur in 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 Artists' Paintpots. The largest group of mudpots can be found at Mud Volcano, at the southern end of Hayden Valley.

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

Terrace Mountain, near Mammoth Hot Springs, may be a dormant thermal area dated as 406,000 years old.

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.

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 (237°C) 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.

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.

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

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 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?

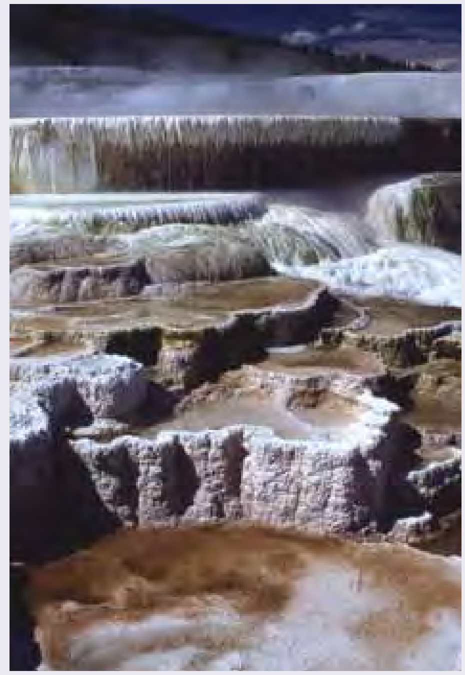
Cigarette butts quickly accumulate where smoking is allowed, and they—like any litter—can clog vents, thus altering or destroying hydrothermal activity. Also, sulfur deposits exist in these areas, and they easily catch fire, producing dangerous and sometimes lethal fumes.

Hydrothermal Features in Yellowstone

Fumaroles or steam vents, are the hottest hydrothermal features in the park. The limited amount of water flashes into steam before reaching the surface. At places like Roaring Mountain (above), the result is a loud hissing of steam and gases.

Mudpots such as Fountain Paint Pot (above) are acidic features 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.

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



Travertine terraces, found at Mammoth Hot Springs (above), 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, forming travertine, the chalky white rock of the terraces. Due to the rapid rate of deposition, these features constantly and quickly change.

Hot springs such as this one at West Thumb (above) 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.

GEOLOGY

Hydrothermal Feature: Geysers

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, similar to 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. 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.

years. The park's geothermal monitoring strategy therefore includes remote sensing, field studies of groundwater flow, measurement of individual geothermal feature temperatures and surface water flow, and collaboration with many researchers from outside the National Park Service.

National Park Service policy generally prohibits any interference with geothermal activity in Yellowstone. New road or other construction through geothermal areas is designed to mitigate impacts. In 1994, the National Park Service and State of Montana established a water rights compact and controlled groundwater area to protect geothermal resources in the park from groundwater or geothermal development that could occur in a designated area north and west of the park in Montana.

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Staff reviewers

Henry Heasler, Geologist
Cheryl Jaworowski, Geologist

The geology below Yellowstone Lake reflects shaping by lava flows where the lake lies within the caldera and shaping by glacial and other processes in the southern half of the lake that lies outside the caldera.

Yellowstone Lake Geology

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. These structures looked similar to hydrothermal structures found in deep ocean areas, such as the Mid-Atlantic Ridge and the Juan de Fuca Ridge. The structures also provided habitat for aquatic species such as fresh-water sponges and algae.

Lake-bottom surveys

From 1999 to 2003, scientists from the US 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 and fissures. The survey 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. For example, hydrothermal

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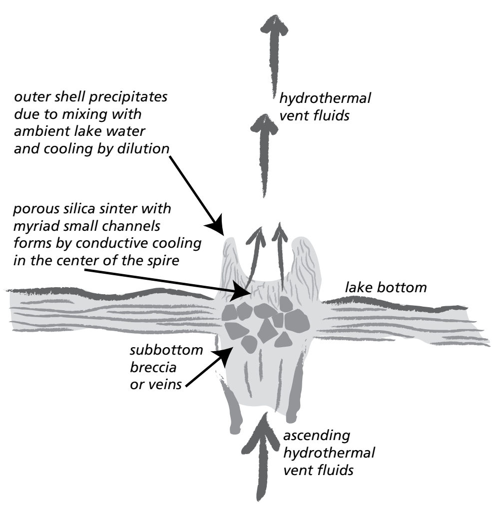
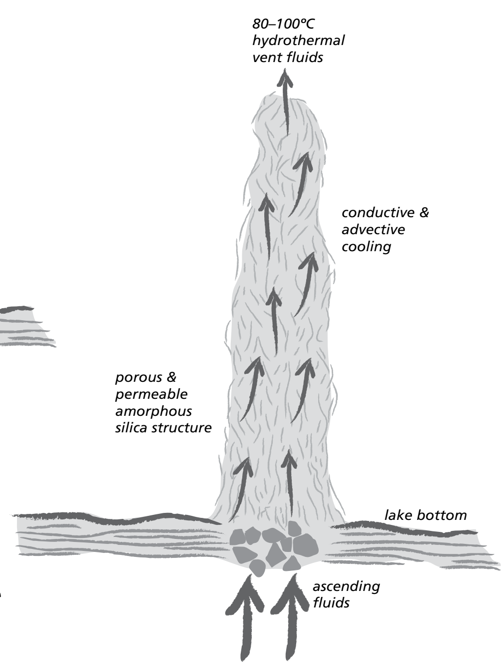
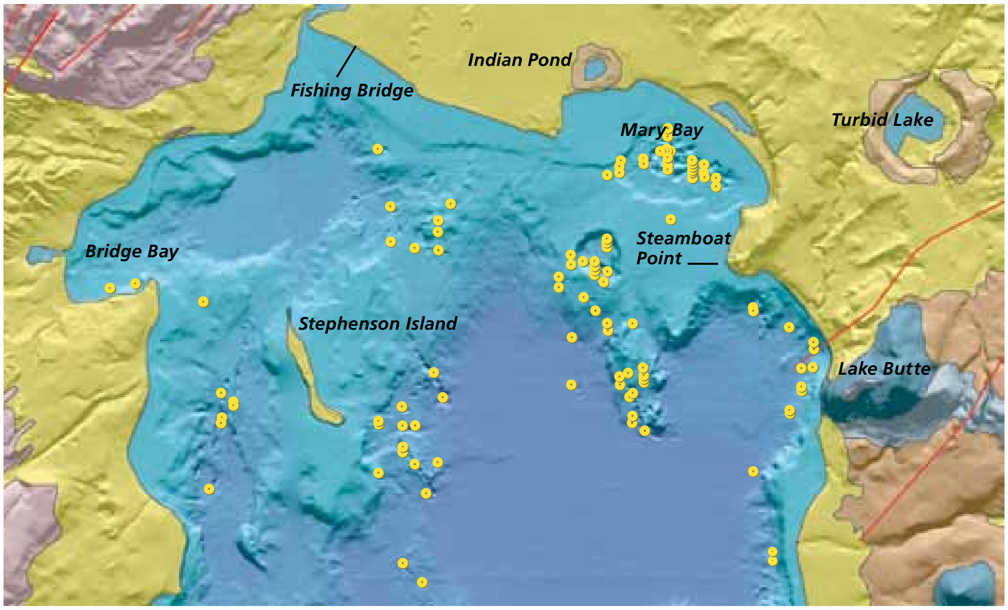
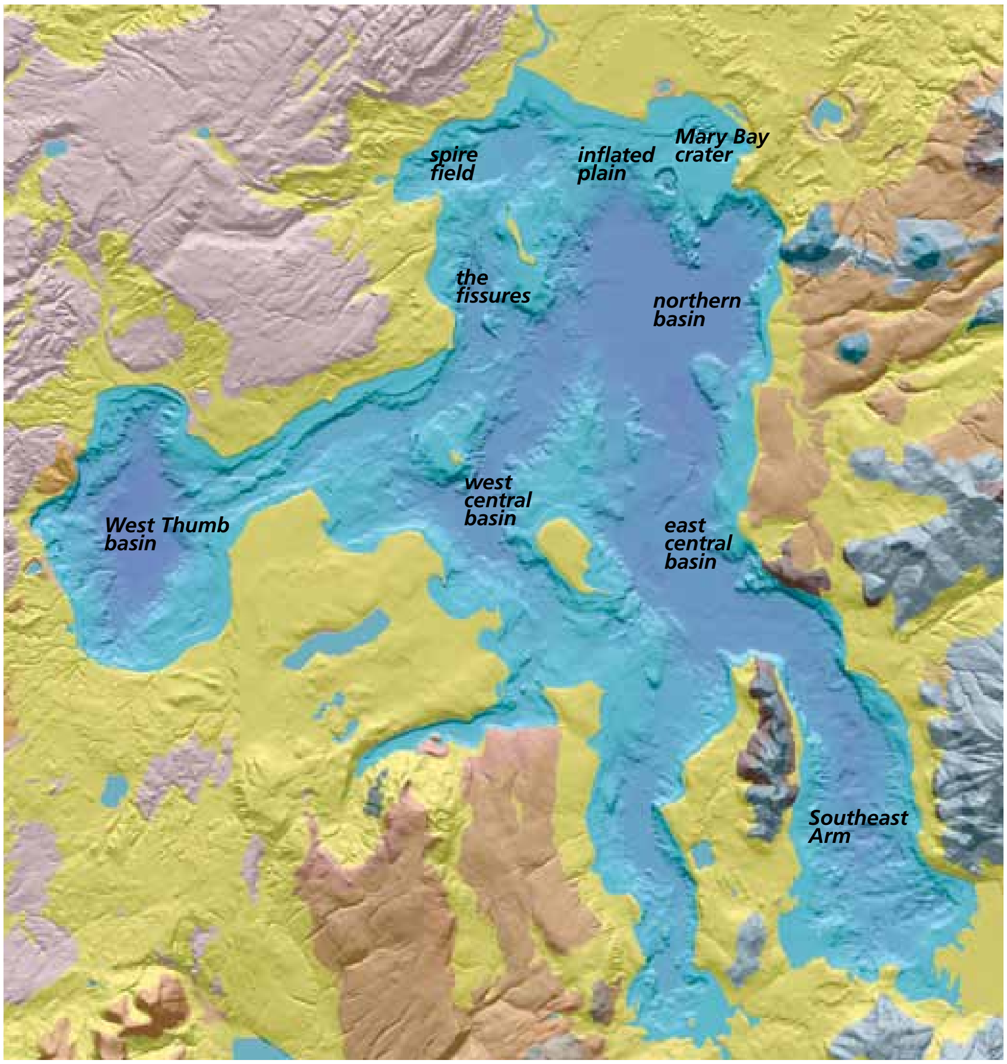




A photo of a Bridge Bay spire, initial spire growth (center), and a mature spire (right). Illustrations adapted from originals by Yellowstone National Park researcher and US Geological Survey research geologist Lisa Morgan.



USGS/ LISA MORGAN



USGS/ LISA MORGAN

GEOLOGY

Yellowstone Lake has existed since the end of the Pinedale glaciation. The lake 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 LeHardy's Rapids, which is considered the northern geologic boundary of the lake. The top map shows locations of hydrothermal vents in northern Yellowstone Lake; the map below shows the geologic features of the lake bottom. Both maps resulted from the five-year survey project.

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 US 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.

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Staff reviewers

Henry Heasler, Geologist
Cheryl Jaworowski, Geologist

Approximately 1,000 to 3,000 earthquakes occur each year in the Yellowstone area; most are not felt. The 1959 Hebgen Lake earthquake caused significant damage to park roads, show here at Gibbon Falls.

Earthquakes

Yellowstone is the most seismically active area in the Intermountain West. Approximately 1,000 to 3,000 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.

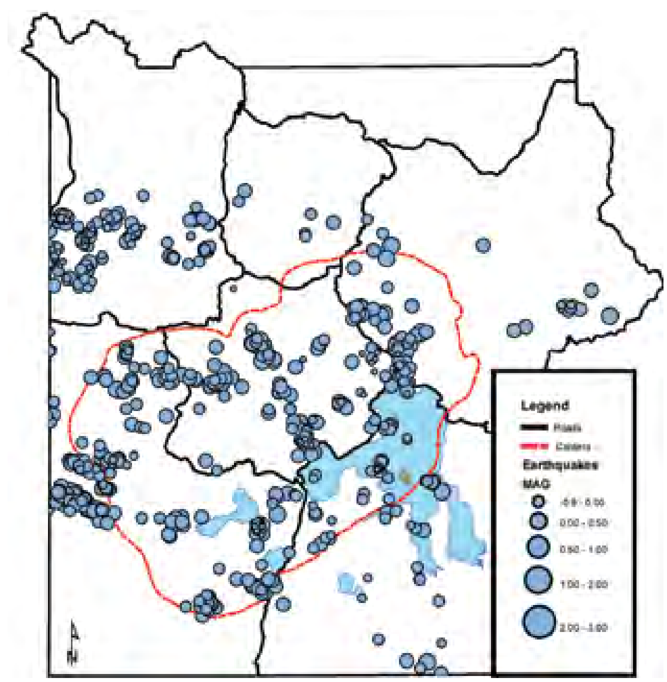
Sometimes Yellowstone experiences an "earthquake swarm"—a series of earthquakes over a short period of time. The largest swarm occurred in 1985, with more than 3,000 earthquakes recorded during three months. Hundreds of quakes were recorded during swarms in 2009 (near Lake Village) and 2010 (between Old Faithful area and West Yellowstone). Scientists are confident these swarms are due to shifting and changing pressures in Earth's crust, not to any change in volcanic activity.

Earthquakes help us understand the sub-surface geology around and beneath Yellowstone. The energy from earthquakes travels through hard and molten rock at different rates. Scientists 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.

More information

volcanoes.usgs.gov/yvo
www.usgs.gov/corecast
www.seis.utah.edu

Staff reviewers
Henry Heasler, Geologist
Cheryl Jaworowski, Geologist



Approximately 698 earthquakes occurred in Yellowstone National Park in 2012. Blue dots = earthquakes. Red line = Yellowstone Caldera. Earthquake data courtesy University of Utah.

GEOLOGY

Much of Yellowstone was shaped by glaciers. Glacial erratics are scattered across Yellowstone's landscape, shown here with a kettle pond in the Lamar Valley..

Glaciers

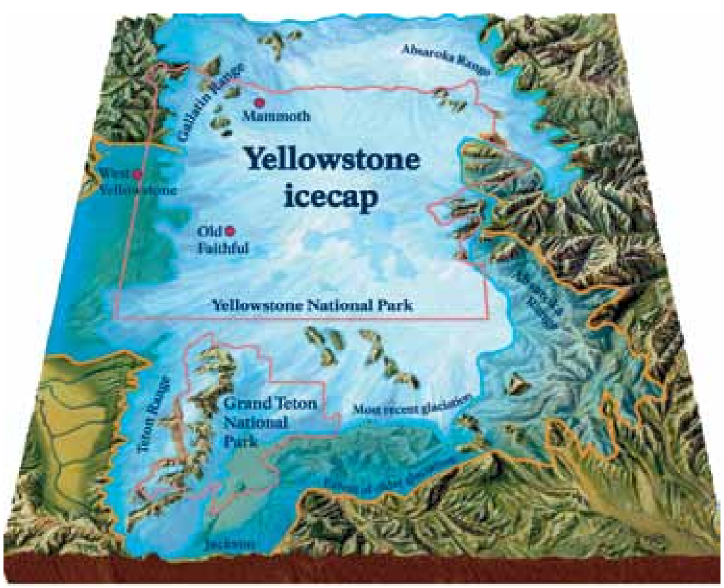
Glaciers result when, for a period of years, more snow falls in an area than melts. Once the snow reaches a certain depth, it turns into ice and begins to move under the force of gravity or the pressure of its own weight. During this movement, rocks are picked up and carried in the ice, and these rocks 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 151,000 to 157,000 years ago. Evidence exists that this glacial episode extended farther south and west of Yellowstone than the subsequent Pinedale Glaciation, 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.

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. Ages of Pinedale maximum vary around the Yellowstone Ice Cap from 20,000 years ago on the east to 16,000 years ago on the north and possibly as young as 14,000 years ago on the south. Other than the Pitchstone Plateau, most of the Yellowstone Plateau was ice free between 13,000 to 14,000 years ago.

During this time, glaciers advanced and retreated from the Beartooth Plateau, altering the present-day northern range and other grassy landscapes. During



The extent of two major glaciations is shown on this map: Bull Lake (orange outline) and Pinedale (blue outline).

FREQUENTLY ASKED QUESTION:

Did glaciers ever cover Yellowstone?

Yes, Yellowstone has experienced glaciers many times. There is physical evidence of the last two major Rocky Mountain glaciations: Bull Lake and Pinedale. Limited evidence exists for pre-Bull Lake glaciations. Most of the Yellowstone Plateau was ice free by 14,000 to 13,000 years ago. Scientists estimate that 18,000 years ago most of the park was under 4,000 feet of ice. During this glacial time, called the Pinedale, ice flowed from high elevations to the low elevation volcanic plateau and an ice cap formed.

glacial retreat, water flowed differently over Hayden Valley and deposited various sediments. Glacial dams also backed up water over Lamar Valley; when the dams lifted, catastrophic floods helped to form 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. 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 Yellowstone's higher elevation volcanic plateau allowed snow to accumulate.

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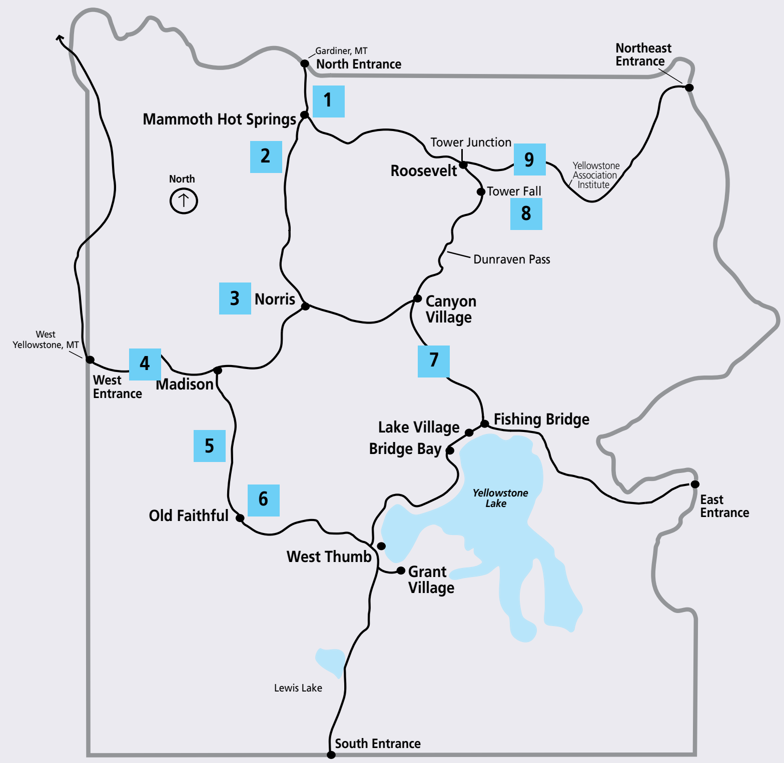
Staff reviewers

Henry Heasler, Geologist
Cheryl Jaworowski, Geologist

Where to See Evidence of Glaciers



1. Mammoth Hot Springs: Thermal kames exist in this area. Mount Everts and Bunsen Peak were both overridden by ice. The top of Sepulcher peaked above the Pinedale ice.
2. Swan Lake Flat: These meadows and wetlands formed after the glaciers retreated. Electric Peak, to the northwest, was also carved by glaciers.
3. Norris Geyser Basin: Several high peaks in the Gallatin Mountains were above the Pinedale ice cap.
4. Madison Valley, west of Seven Mile Bridge: Glacial moraines, glacial outwash, and recent Madison River deposits can be seen.
5. Fountain Flats: The Porcupine Hills and Twin Buttes are thermal kames.
6. Upper Geyser Basin: Volcanic rocks and ice-water contact deposits. 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.
7. Hayden Valley: The valley is covered with glacial till left from the most recent glacial retreat. It also has a variety of glacial and ice-water contact deposits. This glacial till contains many different grain sizes, including clay and a thin layer of lake sediments that do not allow water to percolate quickly into the ground. Thus, Hayden Valley is marshy.
8. Tower Fall area: North of Tower Fall, sediments between layers of basalts may show evidence of the oldest known glaciation in Yellowstone. Plus, huge boulders (known as erratics) from the last major glaciation rest atop the youngest basalt.
9. Lamar Valley: Huge boulders and ponds between the Lamar and Yellowstone rivers were left by glaciers, as were several moraines. Other ponds are within post glacial landslides.

GEOLOGY

Sedimentation and erosion actively shape Yellowstone's landscape. Here, the Lamar River wears at its river banks, depositing the sedimentation elsewhere.

Sedimentation and 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 (approximately 540 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.

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Staff reviewers

Henry Heasler, Geologist
Cheryl Jaworowski, Geologist

Left: The Beartooth Mountains northeast of Yellowstone are actually an uplifted block of Precambrian rock. Right: Mt. Everts, near Mammoth, exposes sedimentary rock, which erodes easily and often tumbles or slides into Gardner Canyon.

Petrified trees in Yellowstone are the result of volcanic eruptions that occurred about 50 million years ago. This piece of petrified wood shows annual rings.

Fossils

Fossil plants, invertebrates, vertebrates, and trace fossils have been identified in Yellowstone National Park from more than 20 stratigraphic units spanning 500 million years, from the Cambrian to the Holocene. Best known are the fossil forests of Specimen Ridge, where the remains of hundreds of 50-million-year-old trees stand exposed on a steep hillside, with trunks up to eight feet in diameter and some more than 20 feet tall. The significance of Yellowstone's paleontological resources is both classic in the value of the specimens collected by early expeditions and promising in the potential they hold for future scientific discoveries.

Although the park's paleontologic resources are extensive and scientifically valuable, it is estimated that only 3 percent of the park's potentially fossil-bearing units have been assessed. Fossils are a nonrenewable resource. Erosion is the key to discovery of nearly all paleontological specimens; however, once exposed, fossils are subjected to physical and chemical forces that can quickly become destructive to them. While the quality of fossil preservation is determined by the depositional environment, the natural process of erosion is a major threat to fossils. Road construction, other infrastructure development, and illegal collecting can also impact fossil-bearing units. Due to the fragility of most fossils, it is necessary to inventory and document fossil localities to evaluate existing fossil material and obtain baseline information so that appropriate management decisions can be made about these areas. Several new paleontological localities were identified in 2001. They are located throughout the park from Mount Everts, the Buffalo Plateau, Top Notch Mountain, Mount Hornaday to the Northeast Entrance.

Yellowstone's petrified trees occur within volcanic rocks approximately 50 million years old. They are the result of rapid burial and silicification, not volcanic eruptions.

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

The fossils of Yellowstone have long been studied and have already contributed to important scientific findings. Research in the park by Charles Walcott on trilobites in the late 1800s provided the foundation for his theory of the "Cambrian Explosion," a term he used to describe the relatively sudden appearance of complex multi-cellular life possessing "hard parts" such as phosphatic or calcitic exoskeletons. The scientific community has become especially interested in studying the Eocene fossil plant material in the park to include in regional studies of the paleoclimate and paleoecology of that period. Much could be gained in understanding current global climate change by studying Eocene times, an episode of rapid and intense warming when our planet was at its hottest.

Paleobotany

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

Most petrified wood and other plant fossils come from Eocene deposits about 50 million years old, which occur in many northern parts of the park.

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."

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.

Additional studies and observations require a modification of Knowlton's original hypothesis. Andesitic volcanic eruptions such as the 1980 eruption of Mount St. Helens showed that trees are uprooted by rapidly flowing volcanic debris flows. The volcanic debris flows not only transported the trees to lower elevations, the trees were also deposited upright. Thus, with increased scientific knowledge, our understanding of Yellowstone's Fossil Forests has changed.

Cretaceous marine and nonmarine sediments are exposed on Mount Everts and other areas in Yellowstone. Similar to Cretaceous rocks throughout the Rocky Mountains, 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.

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Staff reviewers
Henry Heasler, Geologist
Cheryl Jaworowski, Geologist

Thermophiles, or heat-loving microscopic organisms, are nourished by the extreme habitat at hydrothermal features in Yellowstone National Park. They also color hydrothermal features shown here at Clepsydra Geyser.

Life in Extreme Heat

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 is an outstanding example of this dual characteristic. Visitors marvel at its size and brilliant colors. Along the boardwalk 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

Words to Know

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.

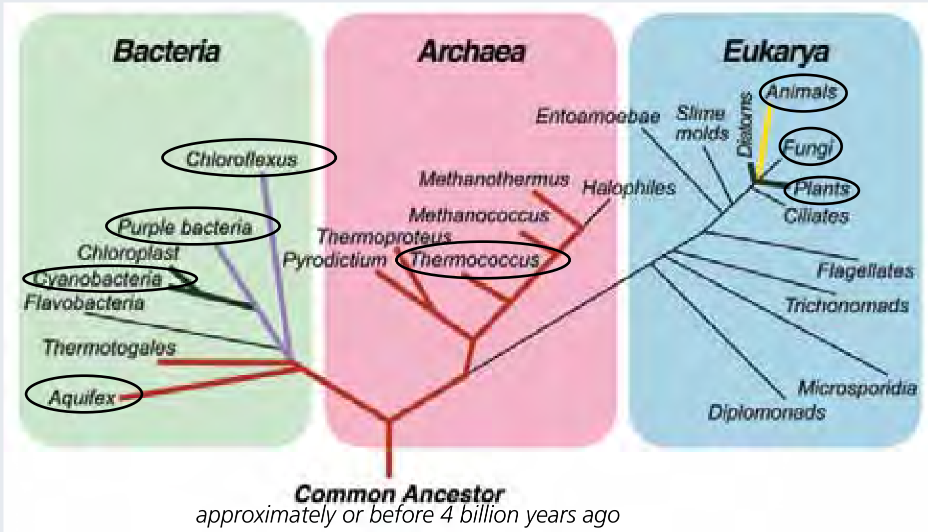
Bacteria (Bacterium): Single-celled microorganisms without nuclei, varying in shape, metabolism, and ability to move.

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.

Thermophiles in the Tree of Life



Yellowstone's hot springs contain species from the circled groups on this Tree of Life. Jack Farmer produced this image of the tree of life, which first appeared in *GSA Today,* July 2000 (used with permission).

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.

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.

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.

About Microbes

Other life forms—the archaea —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.*

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Staff reviewers
Henry Heasler, Geologist
Cheryl Jaworowski, Geologist

Almost every hot spring or geyser in Yellowstone hosts bacteria. The travertine terraces in Mammoth Hot Springs host thermophilic bacteria.

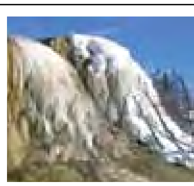
Thermophilic Bacteria

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.

Thermophilic Bacteria in Yellowstone National Park

Name		pH and Temperature	Description	Location
Cyanobacteria: *Calothrix* *Oscillatoria* *Leptolyngbya* *Spirulina* *Synechococcus*		usually alkaline 45–75°C (113–167°F)	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*		usually alkaline 60–80°C (140–176°F)	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.		optimum >70°C >158°C 60–86°C (140–187°F)	Color: black, pink, or gray green, yellow, white Metabolism: chemosynthesis, using hydrogen or sulfur Form: filaments and mats	• Lower Geyser Basin • Mammoth Hot Springs

Note: The cyanobacteria genus *Phormidium* is now *Leptolyngbya*. Cyanobacteria and green nonsulfur bacteria photos by Carolyn Duckworth. Sulfur-oxidizing bacteria photo by Thermal Biology Institute, Montana State University.

Archaea are the most extreme of all extremophiles, and some scientists think they have not changed much from their ancestors. Grand Prismatic Spring at Midway Geyser Basin contains archaea.

Thermophilic Archea

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.

Archaea can be found in the Mud Volcano area, among other places in Yellowstone National Park.

Thermophilic Archea found in Yellowstone National Park

Name	pH and Temperature	Description	Location
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, especially Congress Pool • Roaring Mountain

Unseen, microscopic eukarya live in the extreme environments of Yellowstone. Norris Geyser Basin is one of the best places in Yellowstone to see thermophilic algae.

Thermophilic Eukarya

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.

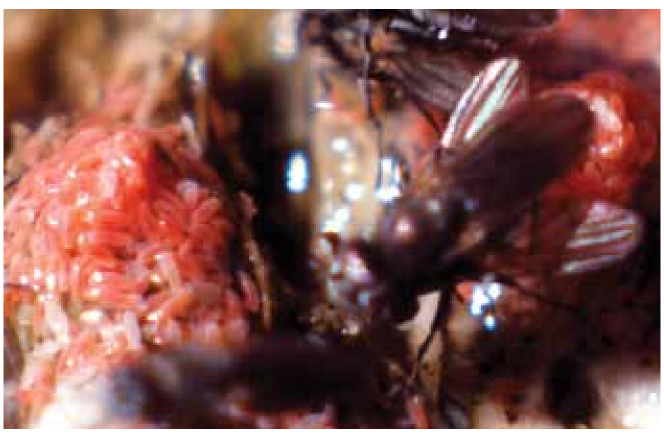
Norris Geyser Basin is one of the best places to see thermophilic algae. Bright green *Cyanidium caldarium* grows on top of orange-red iron deposits around Whirligig and Echinus geysers and their run-off channels. Waving streamers of *Zygogonium* are especially easy to see in Porcelain Basin, where their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

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. 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. This association helps both can survive higher temperatures than when alone. In



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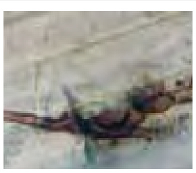
Counterclockwise from top: Ephydrid flies lay eggs in pink-orange mounds, sometimes on the firm surfaces of the mats; Waving streamers of *Zygogonium* are easy to see in Porcelain Basin; The fungi *Curvularia proturberata* lives in the roots of hot springs panic grass.

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.

Thermophilic Eukarya found in Yellowstone National Park

Name		pH and Temperature	Description	Location
Algae				
Cyanidium caldarium		pH 0.5–3 <56°C (133°F)	Color: bright green Metabolism: photosynthetic Form: coating on top of Formations; mats	• Roaring Mountain • Norris, both basins
Zygogonium		pH 2–3 35°C (96°F)	Color: dark brown or purple Metabolism: photosynthetic Form: filaments and mats	• Norris, especially Porcelain Basin
Protozoa				
Naegleria (amoeba)		Warm Alkaline	Predator; can infect humans when ingested through nose	• Huckleberry Hot Springs • Boiling River
Vorticella (ciliate)			Consumer; single-celled ciliate (feathery appendages swirl water, bringing prey)	• 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°)	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; 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

Note: Algae and Warm springs spike rush photos by Carolyn Duckworth. Fungi photo by Russell Rodriguez and Joan Henson. Ross's bentgrass photo by NPS / Jennifer Whipple.

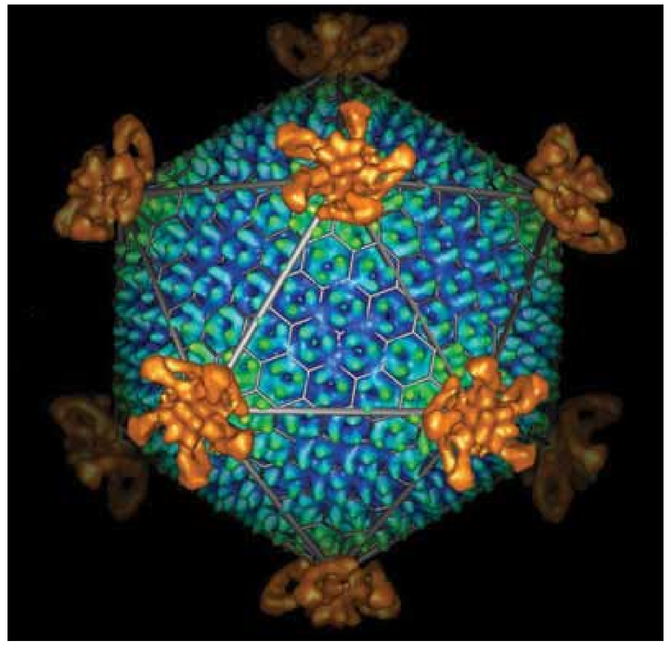
A virus was discovered in Congress Pool, shown here, at Norris Geyser Basin. It was infecting the archaeum *Sulfolobus*.

Thermophilic Viruses

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.



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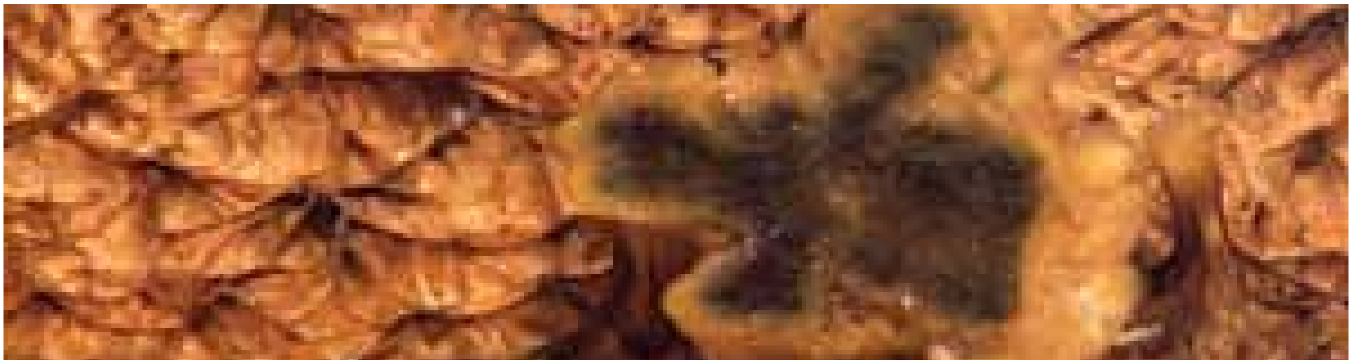
This virus parasitizes *Sulfolobus*.

Thermophilic Viruses found in Yellowstone National Park

Name	pH and Temperature	Description	Location
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



Channels formed with water runoff from geysers create bacterial columns such as this one, located where the runoff channels from Pinwheel and Whirligig geysers meet

Thermophilic Communities

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. Here, we discuss the microbe communities most easily seen in Yellowstone.

Millions of individual microbes can connect into long strands called filaments. Some bacteria 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* forms structures and 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.

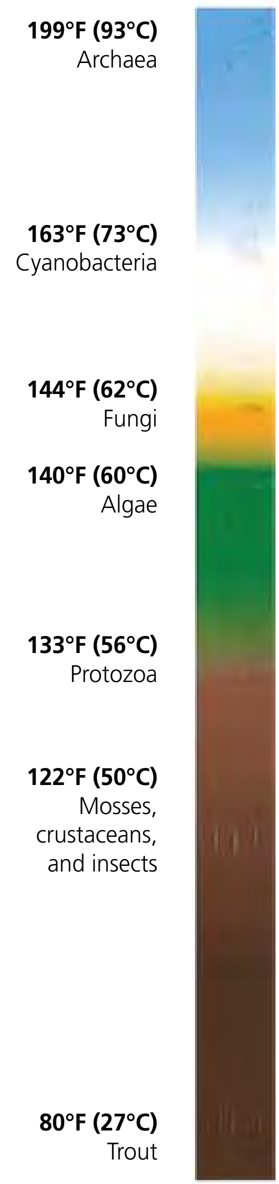
Photosynthetic activity of cyanobacteria such as *Lyptolyngbya* form columns or pedestals. Oxygen bubbles rise in the mat, forcing the microbes upward. The higher formations capture more organic matter and sediment than the lower mats, which help build the columns. Called stromatolites or microbialites,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

Mats can be as thin as tissue paper or as thick as lasagna. Multiple layers of microorganisms make up inch-thick mats. Dozens of types of microbes from all three domains can exist in these layers. Each 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.

Changes in communities

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. 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



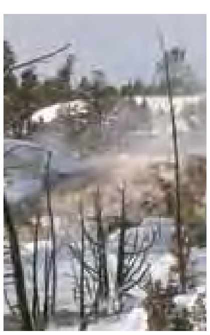
Thermophilic community inhabitants are controlled, in part, by water temperature and pH. The chart provides general guidelines for what lives in each temperature.

iron in the water, forming the orange community. At the Chocolate Pots, which you can see from pullouts along the Gibbon River just north of Gibbon Meadows, iron-rich water flows from the vents. Cyanobacteria—such as *Synechococcus*, 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.

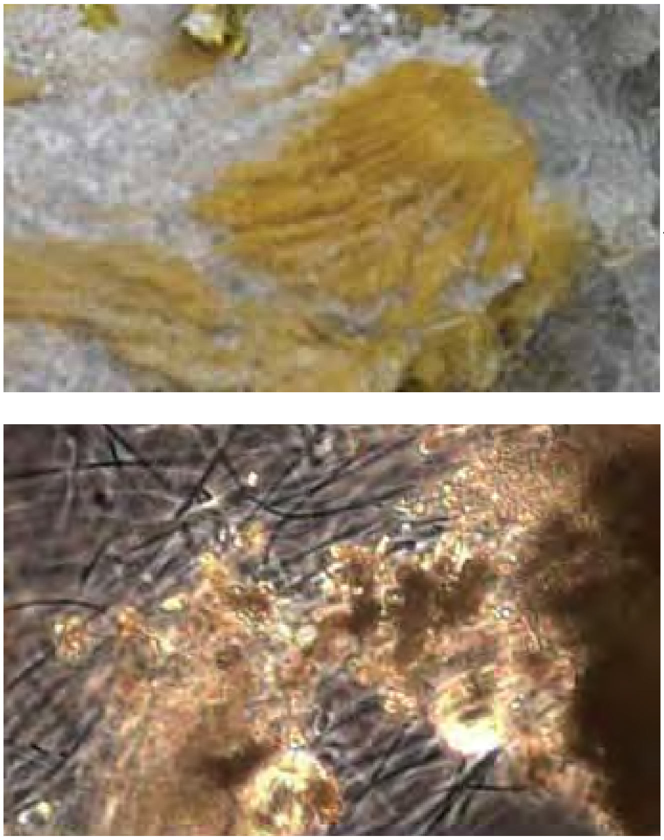
COURTESY / CAROLYN DUCKWORTH

Bison and elk find food and warmth on the less extreme edges of thermophilic environments in winter.

Thermophiles by Place and Color in Yellowstone National Park

Location	Characteristics	Thermophiles by Temperature	Thermophiles by Color
Upper, Middle, and Lower Geyser Basins and West Thumb Geyser Basin			
	• 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 and Mud Volcano Area			
	• 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			
	• 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

Note: Photos by Carolyn Duckworth.



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Top: Structures formed by the bacteria *Thermocrinis.* Bottom: Millions of individual microbes can connect into long strands called filaments, shown here with the help of a microscope.

Communities formed by thermophilic microbes sustain communities of larger organisms within Yellowstone's hydrothermal areas. 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. 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 a shift in 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 follow the threads of these intricate webs.

Thermophiles in Time and Space

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.

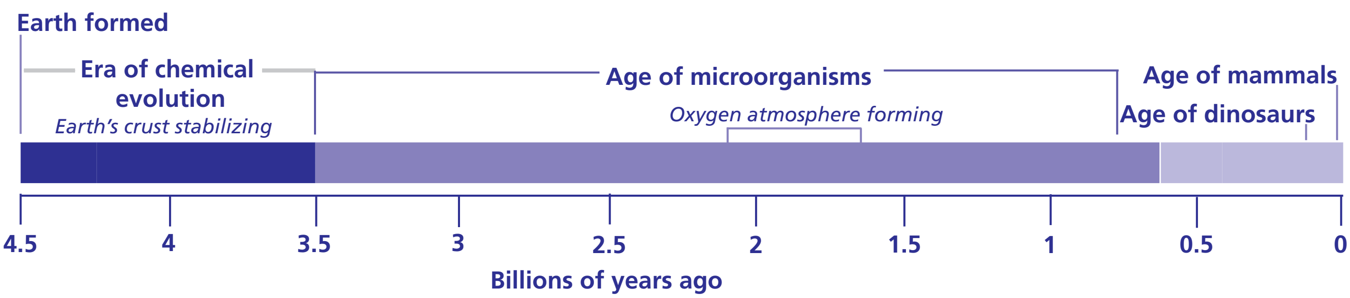
The chemosynthetic microbes that thrive in some of Yellowstone's hot springs do so by metabolizing inorganic chemicals, a source of energy that does not require sunlight. Such chemical energy sources provide the most likely habitable niches for life on Mars or on the moons of Jupiter—Ganymede, Europa, 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.

Similar signatures

Thermophile communities leave behind evidence of their shapes as biological "signatures." For example,

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 life on Earth, the search for life on other planets seems more likely to encounter evidence of microorganisms than of more complex life.



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.

NASA/JPL

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.

More than 1,300 native plant species occur in Yellowstone National Park. The whitebark pine, shown here and found in high elevations in the Greater Yellowstone Ecosystem, is an important native species in decline.

Vegetation

The vegetation communities of Yellowstone National Park include overlapping combinations of species typical of the Rocky Mountains as well as of the Great Plains to the east and the Intermountain region to the west. The exact vegetation community present in any area of the park reflects the consequences of the underlying geology, ongoing climate change, substrates and soils, and disturbances created by fire, floods, landslides, blowdowns, insect infestations, and the arrival of nonnative plants.

Today, the roughly 1,300 native species in the park represent the species able to either persist in the area or recolonize after glaciers, lava flows, and other major disturbances. Yellowstone is home to three endemic plant species, at least two of which depend on the unusual habitat created by the park's thermal features. Most vegetation management in the park is focused on minimizing human-caused impacts on their native plant communities to the extent feasible.

Vegetation Communities

There are several vegetation communities in Yellowstone: higher- and lower-elevation forests and the understory vegetation associated with them, sagebrush-steppe, wetlands, and hydrothermal.

Vegetation in Yellowstone National Park

Number in Yellowstone
Native plant species: more than 1,300:

- 1,150 native flowering species
- Hundreds of wildflowers.
- Trees: seven conifers (lodgepole pine, whitebark pine, Engelmann spruce, subalpine fir, Douglas-fir, Rocky Mountain juniper, limber pine) and some deciduous species, including quaking aspen and cottonwood.
- Shrubs: include common juniper, sagebrush (many species), Rocky Mountain maple.
- Three endemic species (found only in Yellowstone): Ross's bentgrass, Yellowstone sand verbena, Yellowstone sulfur wild buckwheat.

Nonnative plant species: 218.

Characteristics

- 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.
- Hydrothermal areas support unique plant communities and rare species.

Management Issues

- Controlling nonnative species, which threaten native species, especially near developed areas; some are spreading into the backcountry.
- Park partners are monitoring whitebark pine and forest insect pests.
- Biologists survey areas for sensitive or rare vegetation before disturbance such as constructing a new facility.
- Park managers are restoring areas of disturbance.

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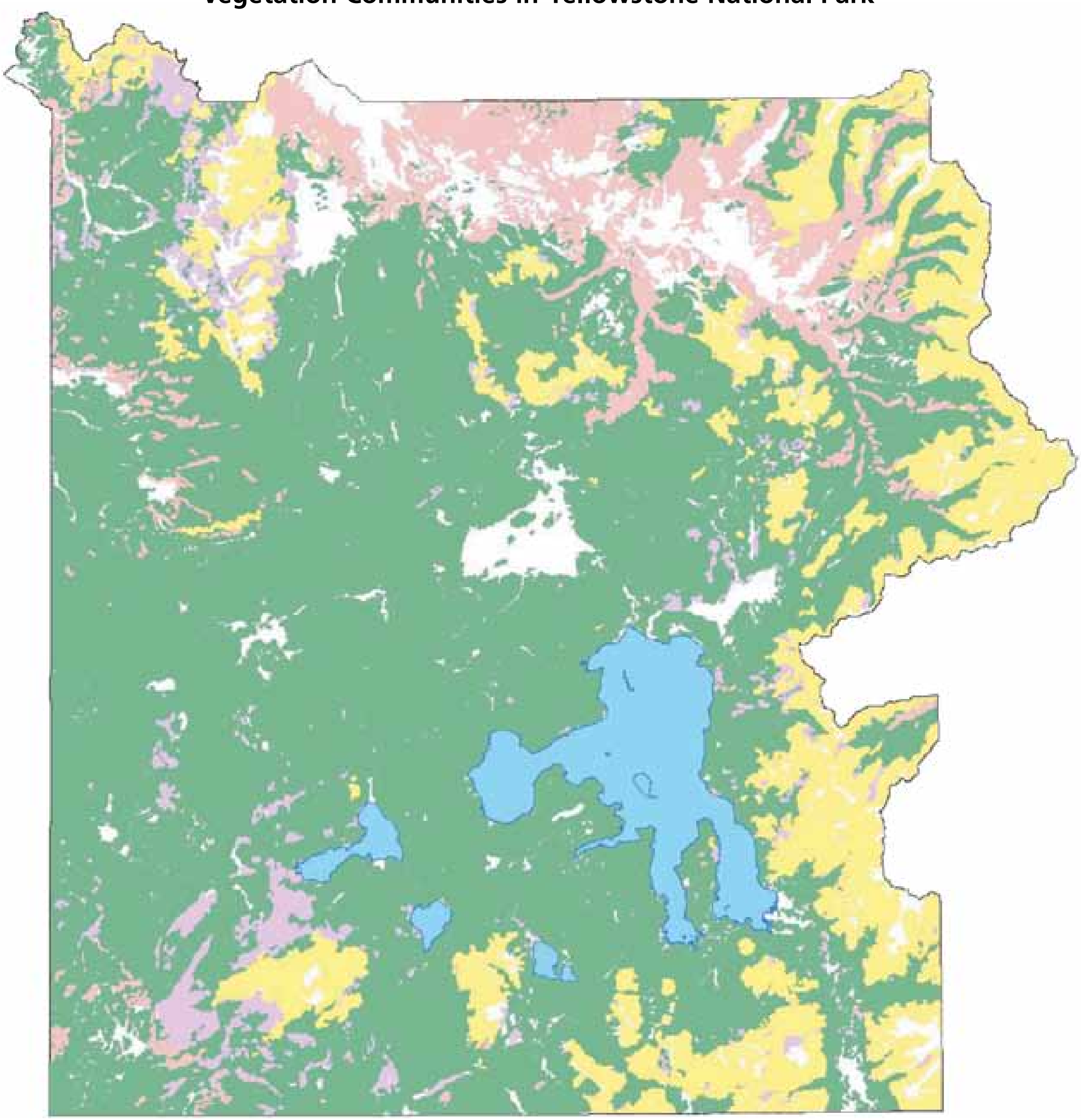
Staff reviewers

Jennifer Whipple, Botanist

Roy Renkin, Vegetation Management Specialist

Vegetation Communities in Yellowstone National Park



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

Douglas-fir forests occur at lower elevations and are associated with the Lamar, Yellowstone, and Madison river drainages in Yellowstone National Park.

Forests

Forests cover roughly 80 percent of the park and lodgepole pine comprises nearly all of that canopy. Lodgepole pine, Engelmann spruce, subalpine fir, whitebark pine, and limber pine are found at higher elevations.

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

At higher elevations, older forest is dominated by Engelmann spruce and subalpine fir, especially in areas that grow on andesite, a volcanic rock, such as the Absaroka Mountains. These forests may have been dominated by lodgepole pine at one time, but have been replaced by Engelmann spruce and subalpine fir in the absence of fire and presence of non-rhyolitic soil (a non-volcanic soil). Engelmann spruce and subalpine fir can also be common in the understory where the canopy is entirely composed of lodgepole pine.

In rhyolitic soils (another volcanic substrate), 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.

Forests in Yellowstone

Higher-Elevation Species

Lodgepole pine (Pinus contorta)
- Most common tree in park, 80 percent of canopy
- Needles in groups of twos
- 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

Limber pine (Pinus flexilis)
- Needles in groups of five
- Young branches are flexible
- Up to 75 feet tall
- Often on calcium-rich soil

Whitebark pine (Pinus albicaulis)
- Grows above 7,000 feet
- Needles in groups of five
- Up to 75 feet tall

Lower-Elevation Species

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 three-pronged bract between scales
- Up to 100 feet tall

Rocky Mountain juniper (Juniperus scopulorum)
- Needles scale-like
- Cones are small and fleshy
- Up to 30 feet tall

Understory vegetation

Understory vegetation differs according to precipitation, the forest type, and the substrate. Lodgepole pine forest is often characterized by a very sparse understory of mostly 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 more moist. 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*).

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*. Some American Indian tribes used this tree to make the frames of their tipis or lodges, hence the name "lodgepole" pine.

Description

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.

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.

Reproduction

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.

Habitat

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.

Lodgepole pine forests are the most common in Yellowstone. A lodgepole's serotinous cones need to be exposed to the high heat of a forest fire for the seeds to be released. The other cones open when the seeds within are mature (end of the second summer).

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.

Whitebark pine

Whitebark pine (*Pinus albicaulis*) is a high-elevation tree of the northern Rocky Mountains and the Pacific Northwest, where it grows in nearly homogeneous stands on harsh, dry terrain but is more often found with other conifers in moister, more protected sites. It often grows in areas with poor soils, high winds, and steep slopes that are inhospitable to other species. It retains snow and reduces erosion, acts as a nurse plant for other subalpine species, and produces seeds that are an important food for grizzly bears and other wildlife.

Whitebark pine is experiencing unprecedented mortality throughout its range. A primary cause is blister rust (*Cronartium ribicola*), an introduced pathogen that increases the trees' vulnerability to infestation by endemic pine beetles. Whitebark pine is also vulnerable to climate change, altered fire regimes, and dwarf mistletoe.

Approximately 20 percent of nearly 4,800 live tagged trees were infected by blister rust when first surveyed by the Greater Yellowstone Network from 2004 to 2007. When they were resurveyed from 2008 to 2011, 20 percent (977) had died, including more than 60 percent of the trees >30 cm in diameter (larger trees), and 301 new trees in the surveyed ares were tall enough to be tagged. The mountain pine beetle prefers larger trees for laying their eggs; the larvae feed on the inner phloem of the bark. The percentage of trees with blister rust has increased in some transects but decreased in others, which could be an artifact of infected trees that have been killed by fire or beetles.

Aerial surveys, which measure the spatial extent of mortality rather than the percentage of individual dead trees counted on the ground, have generally arrived at higher whitebark pine mortality estimates in the Greater Yellowstone Ecosystem. This could be because larger trees, which occupy more of the area in the forest canopy visible from the air, are more likely to be attacked by beetles. Aerial surveys by the US Forest Service and the state of Montana indicate that approximately 7 percent of the 281, 700 acres of whitebark pine stands in Yellowstone National Park were infested with beetles in 2010, down from 15 percent in 2009.

The needles of a whitebark pine are clustered in groups of five.

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Staff reviewer

Roy Renkin, Vegetation Management Specialist

Forest insect pests

The conifer trees of Yellowstone face six major insect and fungal threats. The fungus is an nonnative 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 10 years, all five insects have been extremely active, which may be due to the effects of climate change.

The primary cause of tree mortality in the Yellowstone is native bark beetles. The beetles damage trees in similar ways: their larvae and adults consume the inner bark. If the tree is girdled, it dies. Their feeding activity can girdle a tree in one summer, turning the crown red by the following summer. The needles usually drop within the next year, leaving a standing dead tree. Pockets of red-needled trees are evident throughout the park. Forest structure, tree health, and climate are the major factors determining the extent of an outbreak; drought and warmer temperatures can make forests more vulnerable to infestation.

Pest activity

The severity of insect-caused tree mortality has increased in recent years throughout the West, and the insects have spread to previously unaffected plant communities. Several native bark beetle species in the Scolytidae family are altering extensive areas within Greater Yellowstone. Forest structure, tree health, and climate are the major factors in determining whether an outbreak expands; drought and warmer temperatures can make forests more vulnerable to infestation.

Although activity by both Douglas-fir beetle and Engelmann spruce beetle has declined to endemic (natural to Yellowstone) levels since 2000, other forest insects of ecological significance remain active. Mountain pine beetle activity in 2010 (which will be evident in the mapping of 2011 tree mortality) was largely confined to the northwest portion of the park, in high-elevation whitebark pine and lower elevation lodgepole pine. Defoliation of Douglas-fir and Engelmann spruce by the western spruce budworm is present in the park throughout the lower Lamar and along the Yellowstone and Lamar River valleys, but spread considerably less in 2010 than in recent years. These trends appeared to continue in 2011, when the park was only partially surveyed.

Future of insect outbreaks in Yellowstone

Landscape-scale drought and the availability of suitable host trees have contributed to the initiation and persistence of insect outbreaks. Healthy trees can defend themselves from beetle attack by "pitching out" adult females as they try to bore into the tree. Extreme winter temperatures can kill off overwintering broods and wet summer weather impedes the insects from invading additional trees. Insect activity also decreases as the older and more susceptible

Forest Insect Pests in Yellowstone

Number in Yellowstone
Six forest insect pests

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.

Engelmann spruce beetle (*Dendroctonus rufipenni*)
- 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 (*Dendroctonus 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
- 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.

Management Issues
- Research supported by the National Park Service will investigate the interactions between insect infestations and wildfire.

trees are killed off. Spruce beetles have declined because they have killed almost all of their preferred food source (spruce trees more than 10 inches in diameter).

Research supported by the National Park Service will investigate the interactions between insect infestations and wildfire. Recent and ongoing studies are focusing on how bark beetle epidemics may affect fire behavior in lodgepole-dominated forests and comparing the resulting fire hazard with that in Douglas-fir forests. Research institutions include the University of Wisconsin-Madison and Colorado State University.

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Staff reviewer

Roy Renkin, Vegetation Management Specialist

Other vegetation communities in Yellowstone include sagebrush-steppe, wetlands, and hydrothermal communities. Sagebrush-steppe occurs in the northern range in Yellowstone.

Other Vegetation Communities

Sagebrush-steppe

This vegetation type occurs in the 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 (924 km^2) 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, thermal species, reptiles and amphibians, and for numerous insects, birds and fish.

Wetlands in Yellowstone

Where to See

Some wetlands located 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.

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.

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 cooling, allowing plants to invade a previously inhospitable place.

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 (above), 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 asters indicate the coming of autumn.

Yellowstone is home to three endemic plant species, or species that occur only in Yellowstone and nowhere else in the world. Yellowstone sand verbena, shown here, is only found along the shore of Yellowstone Lake.

Rare Plants

The Greater Yellowstone region has few endemic plant species, or species that occur only in Yellowstone and nowhere else in the world. Endemic species occur in unusual or specialized habitats such as hydrothermal areas. Within Yellowstone, only three endemic species occur: Ross's bentgrass (*Agrostis rossiae*), Yellowstone sand verbena (*Abronia ammophila*), and Yellowstone sulfur wild buckwheat (*Eriogonum umbellatum* var. *cladophorum*).

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.

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Ross's bentgrass

Yellowstone's geothermally influenced plant communities contain species that must be able to tolerate a wide range of conditions. Although most of these species are widespread in range and occur at diverse elevations, not all of them are common. A unique grass of the geyser basins is Ross's bentgrass (*Agrostis rossiae*). This species is highly restricted in range, growing in "vapor dominated" sites in the thermal areas, such as crack systems, the walls of thermal springs, or geothermally influenced depressions. Together, the widespread species and the local endemic form an interesting plant community in the geothermal areas.

Distribution

Ross's bentgrass grows only in the geyser basins in the Firehole River drainage and at Shoshone Geyser Basin. Even within the thermal areas of Yellowstone's geyser basins, the right conditions to support Ross's bentgrass are rare and highly scattered. Thermal habitats are distinguished primarily by their elevated soil temperatures, and heat stress is the primary factor controlling the distribution of plants within them. This species seems to require locations providing the right combination of moisture and warmth that create a natural greenhouse. As a result, this grass is one of the first plants to green up in warm pockets of geyserite—sometimes as early as January.

In the right conditions, Ross's bentgrass can grow profusely, sometimes with several hundred plants in a very small area. Although Ross's bentgrass is considered a poor disperser of seed, this trait may be adapted to thermal habitats that tend to be small and scattered. A seed bank in the thermal area may be more advantageous to a thermal species than dispersing seed into habitat where the plant is unlikely to survive. Most of the known sites of Ross's bentgrass, less than 12 acres of occupied habitat in total, have been mapped using the Global Positioning System (GPS).

Life history

Because the seeds of Ross's bentgrass germinate from December to January, the plants are a conspicuous green presence in the thermal areas by late winter. Flowers are produced in May and early June when the plants reach their maximum size of 1.5–7.8 inches (4–20 cm), after which they dry out and die as the soil temperature rises. 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

Ross's bentgrass is native to the geyser basins along the Firehole River.

the sun's heat from above and the thermal heat from below. Ross's bentgrass is already dead and hard to find by July.

Life in thermal areas

Although the temperature an inch beneath Ross's bentgrass can be 100°F, it does not appear to be especially heat tolerant. It survives only in thermal areas because their lethal summer temperatures impose a short growing season advantageous to annual plants with precocious flowering and prevents competition from slower growing perennials.

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. Nonnative species, such as cheat grass, pose the only known threat; as they spread in thermal areas, they eventually may out-compete Ross's bentgrass.

Research

Recent genetic research indicates that another *Agrostis* found in thermal areas, which was previously considered the same species as the perennial *A. scabra* (ticklegrss), is actually an annual more closely related to *A. rossiae* as well as to *A. scabra* var. *geminata* in Lassen Volcanic National Park and *A. pauzhetica* from the Kamchatka Peninsula of Russia. The thermal *Agrostis* complex needs to be more closely investigated to determine the taxonomy and correct scientific name for this other annual bentgrass in Yellowstone's thermal areas.

Sometimes both of the thermal *Agrostis* occur in the same area, but generally they do not grow directly adjacent to each other. While Ross's bentgrass occurs only along the Firehole River drainage and Shoshone Geyser Basin, the other *Agrostis* is commonly encountered at thermal areas throughout the park. Both *Agrostis* are typically surrounded on cooler ground by non-thermal ticklegrass, which is common in the park interior and reproductively isolated from the thermal plants by its later flowering time. The primary threat to Ross's bentgrass is fast-growing, invasive annual species such as cheat grass, bluegrass, and chickweeds. These species are restricting the presence of *A. rossiae* at several locations in the Upper Geyser Basin.

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Yellowstone sand verbena

Yellowstone sand verbena (*Abronia ammophila*) 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 east of the park.

The presence of a sand verbena at 7,700 feet elevation in the northern Rockies is unexpected, as most members of this North American genus occur in the Southwest or along the Pacific Coast. One speculation by botanists is that the warmth provided by the geothermal activity in the area enabled a genus which had evolved in a warmer climate to gradually adapt to conditions in Yellowstone. Today, Yellowstone sand verbena tolerates the long, cold winters and uses the brief summer to bloom and reproduce.

Distribution

The entire occupied habitat of Yellowstone sand verbena plants is 1.48 acres. Herbarium specimens of Yellowstone sand verbena indicate that the species was previously more widely distributed along the lake shore. These early collections provide evidence that Yellowstone sand verbena has been extirpated at several sites (including near Fishing Bridge museum and the Lake Hotel) since 1900. In the last 30 years, an additional site has been extirpated, suggesting that as much as half of the population has been lost, probably due to trampling.

In 1998 about 8,326 plants were documented along the lake shore. The previous two years had been very wet, resulting in a high level of recruitment with many young plants, some of which would probably not survive drier conditions. In 2010, the population was estimated at 3,600 plants.

Life history

The Yellowstone sand verbena grows close to the sand surface and rarely rises more than three inches from the surface of the sand. 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.

Although it was once thought that the species was an annual, it has a significant taproot that extends at least several feet deep into the sand in mature plants. Sand verbenas as a group are known to be sensitive

Yellowstone sand verbena in the park is isolated from other populations.

to disturbance, suggesting that increased activity on the lake shore may have contributed to the species' decline as the result of wildlife and humans walking across the area. An increase in visitor use of the area could lead to trampling, erosion, and the introduction of nonnative plants.

Research has shown that the plants are capable of self-pollination as well as out-crossing using insect pollinators. Self pollination may sustain Yellowstone sand verbena in the absence of pollinators but it may lead to inbreeding depression. Many types of insects visit the flowers, but pollination occurs primarily from moths and bumblebees. Insect visitation is sporadic and adversely impacted by precipitation and turbulent winds. Genetic exchange among the sites is unlikely due to the significant distance between them and the low numbers at three of the sites. The location of nearly all of the plants on the lake's north shore places the species at risk of extinction due to random events affecting the population.

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VEGETATION

Yellowstone sulfur buckwheat

Approximately 250 species of wild buckwheat are found in the world, with most of the species occurring in arid regions of the western United States. The group has undergone rapid evolution, leading to numerous closely related taxa. The sulfur buckwheats (*Eriogonum umbellatum*), of which there are 41 recognized varieties in the West, exemplify this rapid speciation. Several varieties of sulfur buckwheat live in the park, but the variety endemic to the park, Yellowstone sulfur wild buckwheat (*Eriogonum umbellatum* var. *cladophorum*), in only found in the Firehole River drainage.

Description

Yellowstone sulfur buckwheat differs from the more common varieties with its bright yellow flowers and very hairy, somewhat gray looking leaves. The other bright yellow sulfur buckwheat in the area blooms early in the summer, well before Yellowstone sulfur buckwheat, and on close examination the flowers are hairy on the exterior.

The close relative of Yellowstone sulphur buckwheat has creamy yellow flowers without hairs, greenish leaves, and blooms before Yellowstone sulfur buckwheat. Even though these two taxa are considered members of the same species, there has been no sign of interbreeding or hybridization. Growing on mildly influenced geothermal ground, this plant community includes several species that are more commonly encountered at lower elevations or as components of the Great Basin flora. Superficially, these areas in the vicinity of the park's geyser basins look relatively barren, but the plant species representing different areas of the West form a unique plant community that can be found nowhere else.

Yellowstone sulfur buckwheat is only found in Yellowstone National Park.

Distribution

Yellowstone sulfur buckwheat is adapted to survive on barren, slightly geothermally influenced open areas. It apparently does not tolerate any shading, so it is a conspicuous component of relatively dry plant communities adjacent to the park's thermal areas. The geographic range of this variety is highly restricted, having been found only from the Upper, Midway, and Lower geyser basins to the vicinity of Madison Junction. Adaptation to life in a geothermal setting means that this taxon has to be able to move with changes in the geothermal system. Yellowstone sulfur buckwheat is capable of recolonizing disturbed areas, as demonstrated by its presence near the Old Faithful Inn and Visitor Education Center, and other locations in the Upper Geyser Basin.

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Yellowstone works to prevent the spread of invasive plant species, which can displace native species, change vegetation communities, affect fire frequency, and impact food for wildlife.

Invasive Plants

Invasive nonnative plants can displace native plant species, including some endemic to the park's geothermal habitats, change the nature of vegetation communities and affect fire frequency and the distribution, foraging activity, and abundance of wildlife. These changes can profoundly affect the entire ecosystem. For example, nonnatives unpalatable to wildlife may replace preferred native plants, leading to changes in grazing activity. In turn, this stresses plants not adapted to grazing.

They have altered views of the park's cultural landscapes and historic districts. Seeds may be spread by people and their vehicles, wild and domestic animals, and sand and gravel used for construction and maintenance work. The most vulnerable areas are where the ground has been most disturbed by human use: along the roads, trails, and rivers; and in developed areas and backcountry campsites. Restoring the native plant community in an area that has become infested is extremely difficult.

Managing invasive plants

In addition to about 1,300 native plant species, 218 nonnative species have been documented in the park through ongoing survey efforts over the years. Not all of these nonnative species are necessarily still present in the park, but most of them are. They are prioritized according to the threat they pose to native plant communities and the prospects

Invasive Plants in Yellowstone

Number in Yellowstone
218 species

Canada thistle (*Cirsium arvense*)
- Throughout the park and adjacent national forests.
- Airborne seeds enable it to spread widely throughout the park, invading wetlands.
- Forms dense monocultures, thus radically changing vegetation.

Dalmatian toadflax (*Linaria dalmatica*)
- Northern portions of the park, especially around Mammoth.
- Highly invasive, replacing native plants.

Houndstongue (*Cynoglossum officinale*)
- Primarily Mammoth and East Entrance.
- May have been introduced by contaminated hay used by both the National Park Service and concessioners in their horse operations.
- Highly invasive.
- 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.

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.

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.

Management Issues
- Resource managers target the most invasive species for control or removal.

for successful treatment. Some infestations can be eradicated if the species is treated when the outbreak is still small; other species such as spotted knapweed (*Centaurea maculosa*) are so common that stopping them from spreading is the primary goal. This strategy has helped prevent high priority invasive species from moving into backcountry areas where control is more difficult.

Many grow in disturbed areas such as developments, road corridors, and thermal basins; they also are spreading into the backcountry. Several nonnatives, such as the common dandelion, have spread throughout the park.

Nonnative vegetation was found on about 4,600 acres of the 20,429 acres surveyed on foot in 2011. Based on treatment priorities, 114 acres were selected for treatment, of which 4 acres were treated twice. Plants were manually pulled or clipped on about four acres; the rest were treated using herbicides. Most of the 40 species targeted for treatment are listed by the states of Idaho, Montana, and/or Wyoming as "noxious weeds," which means that they are considered detrimental to agriculture, aquatic navigation, fish and wildlife, or public health. Roadways and developed areas comprised 77 percent of the treatment acres and the remaining 23 percent occurred along the park's trails and in the backcountry.

Preventing the spread of invasive plants

Prevention efforts include control of construction materials entering the park, equipment inspections at park entrances, allowing only certified weed-free hay to be transported through the park, restrictions on the use of hay in the backcountry, and planting native species where ground disturbance has occurred. But staff time is largely spent on control efforts, where staff have increasingly relied on use of herbicides and manual control. Controlling all the nonnative 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. Physical removal is the preferred method when feasible, but pulling or cutting of some perennial species serves to stimulate growth, and the use of herbicides on individual plants is necessary to control aggressive species and cover large areas.

To improve nonnative plant management throughout the region, park staff work with land managers from other government agencies, the Greater Yellowstone Coordinating Committee's Weed Subcommittee, and the National Park Service's Rocky Mountain Exotic Plant Management Team. The park uses Integrated Pest Management—chemical, biological, sociological, and mechanical methods—to control some of the nonnative plants. The park also cooperates with adjacent state and county Weed Control Boards to share knowledge and technology related to nonnative plant detection and control.

Each year, park staff use herbicides and pull or cut plants by hand to control nonnative species that most seriously threaten native species or are most likely to be controlled.

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Staff reviewers

Roy Renkin, Vegetation Management Specialist
Pat Perrotti, Resource Management Specialist

Park managers sometimes restore disturbed areas infested by invasive nonnative plants to native vegetation. The area enclosed by this sturdy fence was an irrigated field; park managers are restoring native plants

Restoring Native Plants

In 1932, President Hoover added more than 7,000 acres of land to Yellowstone National Park to provide low-elevation winter wildlife habitat near Gardiner, Montana. The addition included 700 acres of irrigated agricultural fields.

Park managers stopped irrigating the fields and planted an nonnative 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, nonnative 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 nonnative plants with herbicides and growing cover crops to increase soil organic matter and moisture-holding capacity and restore soil microbial communities. After two to three 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, Montana.

Greater Yellowstone is a fire-adapted ecosystem. Smoke may be visible from ongoing fires during the fire season, typically mid-June through September.

Fire

Fire has been a key factor in shaping the ecology of the Greater Yellowstone Ecosystem. Native plant species evolved adaptations so they survive and in some cases flourish after periodic fires. Fire influences ecosystem processes and patterns, such as nutrient cycling and plant community composition and structure. Fire regimes in the western United States changed with the arrival of European and American settlers, whose livestock removed grassy fuels that carried fires and whose roads fragmented the continuity of fire-carrying fuels. Most naturally occurring fires were suppressed to the extent possible. The National Park Service aims to restore fire's role as a natural process in parks when and where this is feasible.

Lightning may ignite dozens of forest fires during a single summer, but most of them go out naturally after burning less than half an acre. Others torch isolated or small groups of trees, become smoldering ground fires, and eventually go out on their own. On rare occasions, wind-driven fires have burned through large areas of forest, as in 1988, when multiple fires crossed more than one million acres in Yellowstone and on surrounding federal lands despite massive efforts to extinguish them. Without frequent small and occasional large fires to create a mosaic of plant communities in different growth stages, biodiversity declines and leaf litter and deadfall accumulate much faster than they can return nutrients to the soil through decay.

FREQUENTLY ASKED QUESTIONS:

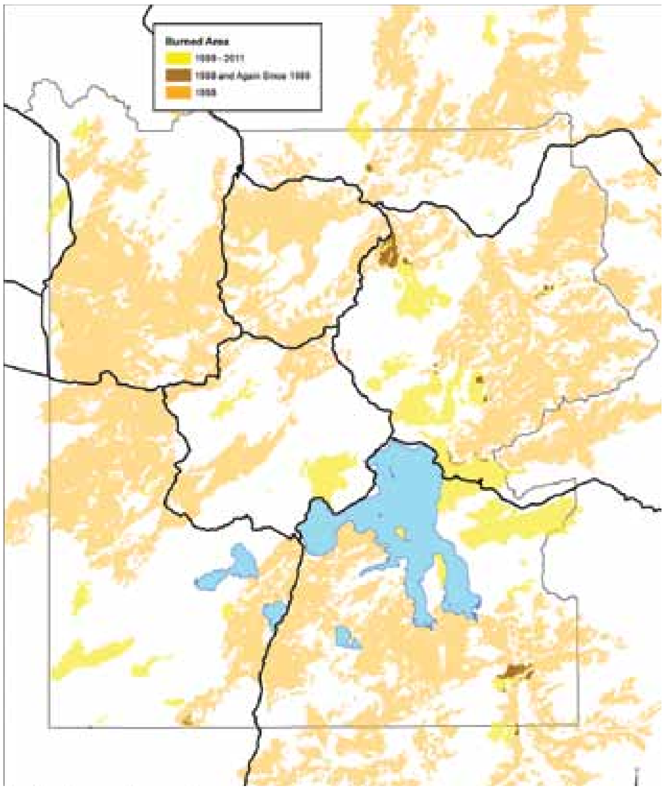
How does fire benefit Yellowstone?

Fires are a natural part of the Greater Yellowstone Ecosystem and vegetation 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. Additionally, the fires of 1988 provided an opportunity 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.

Evidence of fires that burned before the park was established in 1872 can be found in soil profiles, charcoal found in lake sediments, landslides, and old-growth trees. Research shows large fires have been occurring in Yellowstone since forests became established following the last glacial retreat 14,000 years ago. Yellowstone's fire season typically lasts from mid-June to the end of September. The number and extent of fires that occur each year depend on what efforts are made to suppress the fires, as well as environmental conditions such as the number and timing of lightning storms and the amount and timing of precipitation.



Burned areas in Yellowstone from 1988 to 2010. So far, the large fires of the 2000s 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.

Ignition

Afternoon thunderstorms that release little precipitation occur frequently in the northern Rockies. Yellowstone receives thousands of lightning strikes in a typical summer, but most do not result in fires. A snag may smolder for several days and then burn out because fuels are too moist to sustain combustion or too sparse to permit the fire to spread. The park's forests have few shrubs; understory fuels are predominantly young trees. The moisture content of both live and dead vegetation tends to drop as summer progresses, temperatures increase, and relative humidity decreases. Fuels have often dried out enough to ignite the first wildland fire of the year by early July.

A forested area that has burned recently enough to contain only young stands of trees usually doesn't have enough combustible fuel to carry a fire. But as the years pass, trees that don't survive the competition for light and other resources die and eventually fall over. On living trees, older branches die and fall off as they are shaded by new foliage growing above. As a stand grows older and taller, the canopy becomes more broken. This allows enough light to reach the forest floor for a shade-tolerant understory to be established. The accumulation of fuel on the forest floor and the continuity of fuels between the ground, understory, and canopy make older stands more vulnerable to fire. Some forests in Yellowstone may not have burned in at least 300 years and may be particularly prone to lightning ignition.

Fire in Yellowstone

Number in Yellowstone

- In 2011, 2,038 acres burned from 21 known wildland fire starts, four were considered human-caused.
- Six of the fires quickly went out on their own, nine of the fires were suppressed, and six, including the largest (2,000 acres), were allowed to burn while being monitored for public safety.
- Since 1988, the number of fires has ranged from 1 to 77 each year.
- The most active fire year was 2003, when nearly 29,000 acres in Yellowstone burned, including the largest fire since 1988, which burned 18,000 acres.
- From 1989 through 2011, about 142,000 acres burned in Yellowstone, nearly all the result of lightning ignitions rather than human causes.

Characteristics

- Yellowstone's landscape has been shaped by naturally caused fire for 14,000 years.
- Factors affecting size and severity of a fire include: 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; and wind.
- Lightning starts many fires each year that go out on their own. Since 1931, an average of 22 fires each year have been ignited by lightning in Yellowstone.

Management Issues

- The park is required to protect human life as well as the approximately 2 percent of Yellowstone's 2.2 million acres that are considered developed (e.g., roads, buildings, and other infrastructure) from the threat of fire while at the same time letting fire carry out its ecological role in the landscape as much as possible.

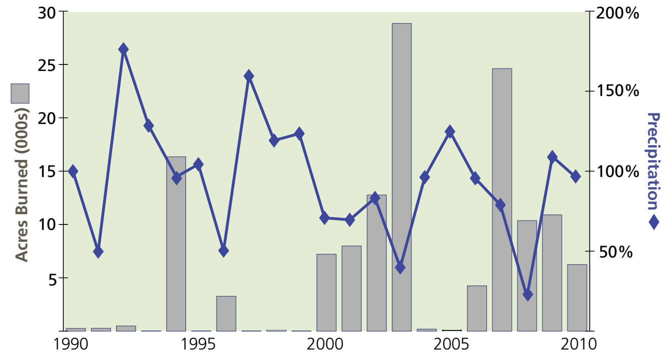
Fire Behavior

Nearly all of Yellowstone's plant communities have burned at one time or another, but their varied characteristics cause fires to behave differently in them. To quickly assess a fire start and its potential to spread, park staff use different vegetation communities as indicators of fuel load, dominant vegetation, and time since the last fire or other disturbance.

The moisture content of dead and down woody debris 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 1,000-hour fuel moistures fall below 13 percent, fires can grow quickly. If extreme drought continues, all forest types and ages are more likely to burn.

To determine how much water is in the fuel, Yellowstone fire monitoring staff weigh and oven dry fuel samples to determine the moisture content. In a normal fire season, 1,000-hour fuels within the park may average 14–18 percent fuel moisture. (Dead fuels are classified according to size, class, and how long they take to dry out when completely soaked; "1,000-hour fuel moisture" refers to the moisture in large fuels such as downed timber that would generally dry out within 42 days. Kiln-dried lumber is 12 percent.)

Active fire behavior is generally not observed until 1,000-hour fuel moisture contents are less than 18 percent, and only minimal areas are burned until moisture levels drop to 13 percent. At that point a fuel moisture threshold is crossed; lightning strikes



Acres burned in Yellowstone and summer precipitation as a percentage of the 1970–2000 average. Although many factors contribute to fire size, more acres are likely to burn when precipitation is below average.

in forested areas at 13 percent fuel moisture quickly result in observable smoke columns and, if fuel and vegetation conditions are right, the fire spreads. Below 12 percent, younger and more varied forest types burn readily, especially when influenced by high winds. During extreme drought years, 1,000-hour fuel moistures may drop as low as 5 percent.

Depending on the forest type, fuel moisture, weather, and topography, fires can grow in size by isolated or frequent torching and spotting (transport of burning material by wind and convection currents), or by spreading from tree crown to crown. Fires in Yellowstone's subalpine forests seldom spread significantly through ground fuels only. Like weather, terrain can be either an ally or adversary in suppressing unwanted fire. A few natural barriers such as the ridge from Electric Peak south to Mt. Holmes; Yellowstone Lake; and the Absaroka Mountains along the eastern boundary of the park are likely to prevent the spread of a low-to-moderate

Of the fires that occur in Yellowstone National Park, 72 percent 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.

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 10 percent of the time.

intensity fire, but fire may cross these features by spotting, covering a distance of two to three miles.

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 early 2000s.

Ongoing research in Yellowstone is also showing that forests experiencing stand-replacing fires can then affect fire behavior for up to 200 years. When a fire encounters a 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.

Frequency of Fire

Fire return intervals since European American settlement have ranged from 20–25 years for shrub and grasslands on the northern range to 300 years or more for lodgepole pine forests on the central plateau and subalpine whitebark pine stands. Fire scars on old Douglas-fir trees in the Lamar River valley indicate an average frequency of one fire every 25–60 years.

Until 1900, written records on fires in Yellowstone were sketchy, with generally only large fires reported. From 1900 through 1930, approximately 374 fires burned 11,670 acres. Since 1931, when fire statistics began to be kept more methodically, 1,609 fires have been lightning-caused and 720 were considered human-caused, including those caused by power lines.

The largest fire in the park's written history prior to 1988 occurred when about 18,000 acres burned at Heart Lake in 1931. In 1989, fire ecologists William Romme and Don Despain suggested that without the fire suppression efforts that began in the 1880s, large fires might have occurred during the dry summers of 1949, 1953, 1960, or 1961. They believe that fire behavior in 1988, in terms of heat release, flame height, and rate of spread, was probably similar to that of the large fires that burned in Yellowstone in the early- to mid-1700s.

In 1988, 50 fires burned a mosaic covering about 800,000 acres in Yellowstone as a result of extremely warm, dry, and windy weather combined with an extensive forest cover of highly flammable fuels. (This estimate was based on satellite imagery taken during October 1988; subsequent GIS mapping of fire perimeters indicates that approximately 1.1 million acres were affected by the 1988 fires.) Some of the largest fires originated outside the park, and a total of about 1.4 million acres burned in the Greater Yellowstone Ecosystem.

Some of the areas that burned in 1988 have burned again during the drought conditions of subsequent years, although unique conditions are required for such areas to reburn. Rare, extremely high wind events (greater than 40 mph), or more than 80 percent ground cover of cured elk sedge (*Carex* spp.) during very dry conditions, seem required for fires to again carry through areas burned in 1988. Fire behavior of previously burned areas is generally of a very high intensity—probably because of the high fuel load due to dead and fallen trees. Understanding the conditions necessary for recently burned areas (less than 50 years old) to reburn and modeling for the type of fire behavior seen in these areas will be a challenge for fire managers in Yellowstone during the next few years.

Consequences of Fire

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, decades 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.

Vegetation and Watersheds

The vegetation in the Greater Yellowstone Ecosystem has adapted to fire and in some cases is dependent on

In 1988, fires burned a mosaic covering approximately 1.1 million acres in the Greater Yellowstone Ecosystem as a result of extremely warm, dry, and windy weather combined with an extensive, highly flammable forest cover.

it. Some plant communities depend on the removal of the forest canopy 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 canopy. Fire creates a landscape more diverse in age, which reduces the probability of disease or fire spreading through large areas.

One of the two types of cones produced by lodgepole pines, which make up nearly 80 percent of the park's forests, is serotinous, which means they will not release their seeds until the resin sealing them melts, requiring a temperature of at least 113°F (45°C). This adaptation helps ensure that the seeds do not disperse until fire creates conditions that favor the establishment of lodgepole pine seedlings: diminished litter on the forest floor and plenty of sunlight through an open canopy.

Fire can limit trees in the grasslands of Yellowstone, such as the Lamar and Hayden valleys. For example, 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.

Mature Douglas-fir trees have 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

Trees in Greater Yellowstone are adapted to fire. This serotinous cone from a lodgepole pine tree was opened by fire, allowing it to release its seeds.

Some soils respond quickly after fires, but others may continue to support little vegetation.

some of the dense Douglas-fir stands in the northern range are probably remnants of these communities.

Although Engelmann spruce and subalpine fir are thin-barked, they grow in cool, moist habitats where conditions that enable fires to burn are infrequent. In 1988, 28 percent of the park's whitebark pine burned, though it grows in open, cold, high-altitude habitats that accumulate fuel very slowly and have only a short season between snowmelt and snowfall during which fires can ignite and carry. Caches of whitebark pine seeds collected by red squirrels and Clark's nutcrackers 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 60 years old before reaching full cone production, and young trees may die before reproducing if the interval between fires is too short or if faster-growing conifers overtake them.

Tree seedlings sprout and grow at variable rates between the surviving trees and the fallen and standing snags. As root systems of standing dead trees decay and lose their grip on the soil, the trees fall—sometimes hundreds at once in the presence of a strong wind. However, many trees remain upright for more than a decade after dying by fire or other cause.

Fires may stimulate regeneration of sagebrush, aspen, and willows, but their growth is also affected by other influences such as climate and wildlife browsing. Aspen has thin bark, but the clones are connected by a network of underground roots that can survive even very hot surface and crown fires. Although the above-ground stems may be killed, fire stimulates the sprouting of suckers from the roots, and fire leaves bare mineral soil suitable for the establishment of aspen seedlings.

Soils in Yellowstone that support little vegetation have been largely unaffected by fire. Soils that have dense, diverse vegetation before a fire are likely to respond quickly after the fire with a variety of species and nearly complete cover. Though above-ground parts of grasses and forbs are consumed by flames, the below-ground root systems typically remain unharmed, and for a few years after fire these plants commonly increase in productivity because fire rapidly releases nutrients from wood and forest litter. The regrowth of plant communities begins as soon as moisture is available, which may be within days at some sites.

Plant growth was unusually lush in the first years after the 1988 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.

The amount of soil loss and sediment deposits in streams after the 1988 fires varied greatly. Although extensive erosion and mudslides occurred along the Gibbon River after heavy rains in the summer of 1989, it is not known how much the fires contributed to this. Vegetation regrowth slowed this erosion by 1991. About a quarter of the Yellowstone Lake and Lewis Lake watersheds and half of the Heart Lake watershed burned to some extent, but no significant changes have been detected in stream bank erosion, substrate composition, channel morphology, nutrient enrichment, or plankton production, nor have any discernible fire-related effects been observed in the fish populations in the six rivers that have been monitored regularly since 1988.

Wildlife

Wildland fires do not significantly affect the abundance of most wildlife species in Yellowstone. Relatively few animals died as a direct result of the large fires in 1988, and most of those deaths were caused by smoke inhalation. Of Yellowstone's seven native ungulate species, only the moose has experienced a population decline that appears to have persisted since 1988. Although moose population estimates have been imprecise, it appears that with less willow and subalpine fir available for winter browse, and snow accumulating more deeply with many forest canopies gone, moose winter mortality increased. Mortality in all ungulate species was unusually high in the winter after the fires, but it is difficult to know how much of that was the result of burned forage rather than drought, large herd sizes, and the relatively severe winter. Elk, bison, and deer populations soon rebounded.

Wildlife continue to use burned areas after fires.

Of the 38 grizzly bears wearing radio transmitters when the fires began, 21 had home ranges burned by one or more of the fires. Thirteen of those bears moved into burned areas after the fire front had passed, three adult females without young stayed within active burns as the fire progressed, three bears remained outside the fire perimeters, one adult female was not located for another two years, and another adult female was never located again at all. 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 substantially, the fires had no discernible impact on the number of grizzly bears in Greater Yellowstone.

Rodents probably had the highest fire-related mortality of any mammals. Although many could escape the fires in burrows, others died of suffocation as the fires came through. They also were more exposed to predators because they temporarily 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. 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.

Managing a Natural Process

The National Park Service allows lightning-ignited fires to carry out their ecological role in Yellowstone as much as is possible without risking human life and property. The park is required to protect human life as well as the approximately 2 percent of Yellowstone's 2.2 million acres that are considered developed (e.g., roads, buildings, and other infrastructure) from the threat of fire while at the same time letting fire carry out its ecological role in the landscape as much as possible.

Yellowstone National Park operates under the 2009 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 Antelope Fire of 2010 was an example of managing a fire for multiple objectives. It was suppressed on its west flank to protect people using the roads, and other values at risk. It was monitored, but not suppressed, as it moved south and east away from developed areas. A similar strategy was used in the 2009 Arnica Fire, which burned in 300-year-old lodgepole pine forests but threatened visitor travel, power lines, and Lake Village.

Working across boundaries

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 in the park. For example, the National Park Service sometimes relies on Forest Service smokejumpers to monitor or fight the park's remote fires. In return, the National Park Service 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. Since 2009, the park's wildland engine has been staffed by both National Park Service and Forest Service firefighters. Programmable radios ensure communication between National Park Service and Forest Service dispatch, which improves firefighter safety. The National Park Service is also working with its partners to develop Community Wildfire Protection Plans to help plan and prepare for a wildland fire that may threaten homes.

History of Fire Management

Fire suppression in Yellowstone National Park began with the arrival of the US Army, which was placed in charge of protecting the park in 1886. The Army, which was in Yellowstone until 1918, successfully extinguished some fires in the belief that suppression would help save the forests. However, it is difficult to determine how much effect a small group of men could have had on overall fire frequency or the extent of fires in a large park without motorized vehicles or good roads. Fire suppression was most successful on the grasslands of the northern range, which were relatively accessible from the park headquarters in Mammoth Hot Springs.

More effective firefighting techniques and airplanes became available after World War II, but even then, fire suppression did not result in a significant increase in fuel loads except perhaps on the northern range. Records indicate fire was almost completely excluded from the Douglas-fir, sagebrush steppe, and aspen communities on the northern range from 1886 until 1987.

By the 1940s, ecologists recognized fire was a natural and unavoidable change agent in many ecosystems, including relatively arid portions of the Rocky Mountains. In the 1950s and 1960s, other parks and forests began to experiment with controlled burns. In 1972, Yellowstone became one of several national parks to initiate programs that allowed some natural fires to burn. Two backcountry areas in the park totaling 340,000 acres, Mirror Plateau and Two Ocean Plateau, were designated as locations where natural fires could burn.

After three years, during which 10 fires burned a total of 831 acres in the natural fire zones, the nonsuppression area was expanded to include most of the park, except for developed areas and a buffer zone at the park boundary. Starting with Yellowstone and Bridger-Teton National Forest in 1976, cooperative agreements were adopted among all Greater Yellowstone federal lands that by 1986 allowed natural fires to burn across shared public land boundaries.

From 1972 to 1987, 235 fires were allowed to burn 33,759 acres in Yellowstone. The summers of 1982–1987 were wetter than average, which may have contributed to the relatively low fire activity during that period. 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

FIRE

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 hazard fuels. It was in the final stages of approval in spring 1988.

However, Yellowstone's "new" fire management plan was suspended in July 1988 as a consequence of the large fires that occurred that summer. After the fires of that summer, a national policy review team examined the national fire policy again and reaffirmed the importance of natural fire policies in national parks and wilderness areas. However, the report also offered recommendations, including the establishment of more specific criteria to determine under what circumstances fires are permitted to burn and more reduction of hazard fuels near developed areas. These recommendations were incorporated into Yellowstone's 1992 fire management plan. Other major revisions occurred to the park's fire management plan in 2004.

The 1988 Fires

The Yellowstone fires of 1988 have been described as being instrumental in the public's understanding of the role of fire in ecosystems, history-making, and career-building. In June of 1988, park managers and fire behavior specialists 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. The spring of 1988 was wet until the month of June, when hardly any rain fell. Park managers and fire behavior specialists expected that July would be wet, though, as it had been historically.

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.

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 (recall that when fuel moisture falls below 13 percent, fires can grow quickly). In addition, a series of unusually high winds fanned flames that, even in dry conditions, would not have moved with great speed.

Because of the extremely dry conditions, no new natural fires were allowed to burn after July 15 except those started adjacent to existing fires and that were

History of Fire Management in Yellowstone

The Issue

For the first 100 years of the park's existence, managers believed fires had to be extinguished to preserve park resources. Subsequent 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 park managers want to preserve, and
- suppressing fires alters the natural landscape and diminishes diversity.

History

- 1886–1918: US Army suppresses fire in Yellowstone
- 1940s: More effective firefighting techniques become available after World War II. Around the same time, ecologists recognize fire is a natural and unavoidable change agent in many ecosystems.
- 1972: Yellowstone begins allowing some natural fires
- 1972–2005: 397 natural, unsuppressed fires burned 66,354 acres—mostly in three dry years: 1979, 1981, 1988. (In 1988, natural fires were allowed to burn in early summer.)
- Spring 1988: A new fire management policy for Yellowstone is in the final approval stages
- 1988: Fires burn 1.1 million acres in Yellowstone, sparking an increase in the public understanding and acceptance of the role of fire in wildland areas.
- 1989: A national policy review team reaffirms the importance of natural fire policies in national parks and wilderness areas and makes other recommendations
- 1992: Yellowstone issues a new fire management plan incorporating the 1989 review team's recommendations
- 2004: Major revisions to Yellowstone's fire management plan.
- 2009: Yellowstone begins operating under the 2009 Federal Wildland Fire Policy, which allows firefighters to manage fires for multiple objectives.

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.

Fighting the fires

An extensive interagency fire suppression effort was initiated in mid-July in the Greater Yellowstone Ecosystem 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

Significant Events during the 1988 Fires

Date	Event
June 14	Storm Creek Fire begins
June 23	Shoshone Fire begins
June 25	Fan Fire begins
June 30	Red Fire begins
July 5	Lava Fire begins
July 11	Mink and Clover fires begin
July 14	On a backcountry fishing trip near the eastern border of Yellowstone National Park, Vice President George H.W. Bush must leave early when fire comes close to camp.
July 21	Yellowstone National Park begins suppressing all fires.
July 22	North Fork Fire begins
July 25	Fire camp crew jumps into West Thumb Bay to escape flames.
August 20	"Black Saturday": Fires double to more than 480,000 acres
September 3	Storm Creek Fire burns over Silver Tip Ranch, north of Yellowstone National Park; the historic ranch survives.
September 7	Fire storm blasts Old Faithful area; Old Faithful Inn is saved and no one is injured.
September 10	Residents of Mammoth Hot Springs evacuated as fire moves across Bunsen Peak toward the area.
September 11	Rain and snow fall.

More than $120 million was spent fighting the fires in the Greater Yellowstone Ecosystem. Rain and snow in September finally stopped the advance of the fires.

FREQUENTLY ASKED QUESTIONS:

How much of the park burned in 1988?

The 1988 fires affected approximately 1.1 million acres 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.

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 at that time 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.

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 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 firefighting 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, 42 lightning-caused fires had occurred in or burned into the park, but only eight were still burning. More than $120 million had been spent in control efforts on fires in the Greater Yellowstone Ecosystem, 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, 10,000 people were involved. This was the largest such cooperative effort undertaken to that date in the United States.

The Yellowstone fires of 1988 received more media attention than any other event in the history of national parks up to that time.

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

1988 Fires in Yellowstone

Numbers in Yellowstone

- 9 fires caused by humans.
- 42 fires caused by lightning.
- 36 percent (793,880 acres) of the park was affected.
- Fires which began outside of the park burned 63 percent 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.

Management Issues

- 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 firefighting 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.

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.

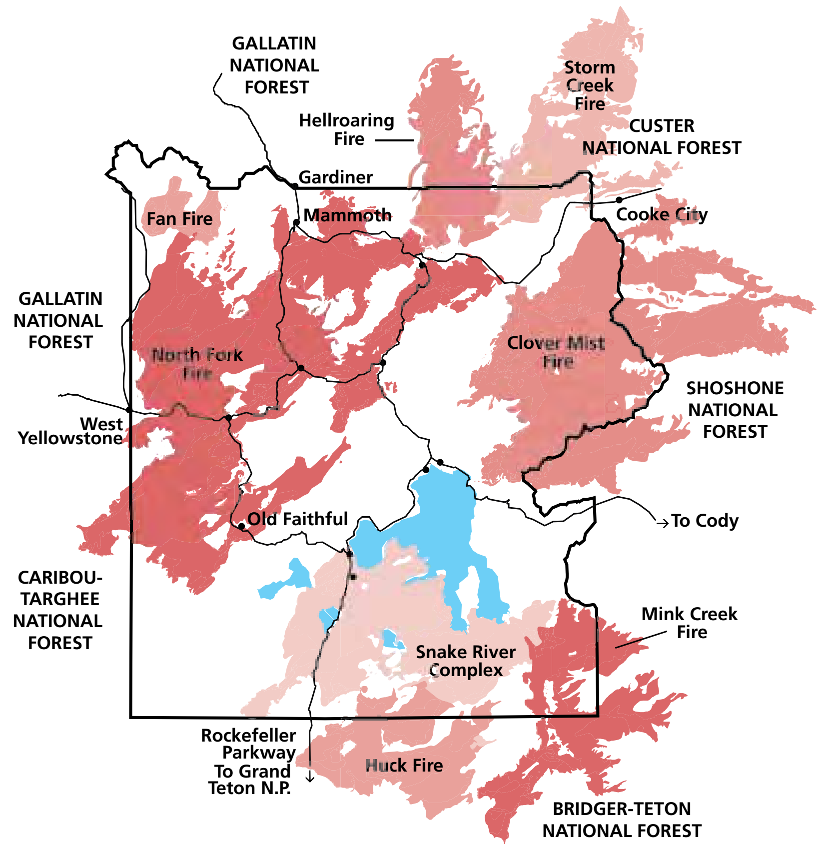
Additional confusion resulted from the mistaken belief that managers in the Yellowstone area let park fires continue burning unchecked because of the natural fire plan—long after such fires were being fought. Confusion was probably heightened by misunderstandings about how fires are fought: if crews were observed not taking action on a fire, casual observers might think the fire 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 over-emphasized. 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.

Firefighters worked to prevent historic structures like the Old Faithful Inn from burning.

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. Education rangers developed programs to interpret



This map of fires from 1988 uses colors only to help you see fire boundaries. Colors do not indicate anything else.

Burned Areas within Yellowstone National Park in 1988

Burn Type	Acres	% 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 Spatial Analysis Center, Yellowstone National Park, 1989. Table adapted from *Yellowstone in the Afterglow: Lessons From the Fires*, Mary Ann Franke, 2000.

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 on the Greater Yellowstone Ecosystem, "The '88 Fires: Yellowstone and Beyond"

the fires and their effects for visitors and for the general public. Other education 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 actually began while the fires were still burning.

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 0.1 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.

Consequences of the 1988 Fires

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 hazard fuels around developed areas.

Recent research was presented September 2008 at the 9th Biennial Scientific Conference on the Greater Yellowstone Ecosystem, "The '88 Fires: Yellowstone and Beyond." Proceedings at www.nps.gov/yell/naturescience/upload/'88fires.pdf. Volume 17, issue 2 of *Yellowstone Science* dedicated to the conference is available at www.nps.gov/yell/planyourvisit/yellsci-issues.htm.

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:

- **X** A long-term drop in park visitation.
- **X** Flooding downstream of the park because of increased runoff on bare slopes.
- **X** A decline in fish populations because increased erosion silted up the water.
- **X** An increase in fish populations in smaller streams where deforestation and loss of shade could result in warmer water and higher nutrient levels.
- **X** More rapid invasion of nonnative plants into burned areas and corridors cleared as fire breaks.
- **X** An increase in lynx following a boom in snowshoe hares as a result of changes in forest structure.
- **X** An increase in the elk population because of improved forage.
- **X** A decline in the grizzly bear population because of smaller whitebark pine seed crops.
- **X** Another big fire season in Yellowstone because of all the fuel provided by so many dead and downed trees.

Yellowstone National Park's 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 (left) and 1989 (right).

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.

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Staff Reviewers

Becky Smith, Fire Ecologist

Roy Renkin, Vegetation Specialist

Yellowstone National Park has abundant and diverse wildlife. Surrounded by ravens, a bald eagle, and a golden eagle land on an elk carcass killed by the Slough Creek wolf pack near the Lamar River as a coyote watches.

Wildlife

Yellowstone's abundant and diverse wildlife are as famous as its geysers. Habitat preferences and seasonal cycles of movement determine, in a general sense, where a particular animal may be at a particular time. Early morning and evening hours are when animals tend to be feeding and are more easily seen. But remember that the numbers and variety of animals you see are largely a matter of luck and coincidence.

Wild animals, especially females with young, are unpredictable and dangerous. Keep a safe distance from all wildlife. Each year a number of park visitors are injured by wildlife when approaching too closely. Approaching on foot within 100 yards (91 m) of bears or wolves or within 25 yards (23 m) of other wildlife is prohibited. Please use roadside pullouts when viewing wildlife. Use binoculars or telephoto lenses for safe viewing and to avoid disturbing wildlife.

By being sensitive to its needs, you will see more of an animal's natural behavior and activity. If you cause an animal to move, you are too close. It is illegal to willfully remain near or approach wildlife, including birds, within any distance that disturbs or displaces the animal.

FREQUENTLY ASKED QUESTION:

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 where wildlife have been seen recently.

Yellowstone is home to the largest concentration of mammals in the lower 48 states. Here, bison and elk graze on the northern range.

WILDLIFE

Mammals

Yellowstone is home to the largest concentration of mammals in the lower 48 states. In addition to having a diversity of small animals, Yellowstone is notable for its predator–prey complex of large mammals, including eight ungulate species (bighorn sheep, bison, elk, moose, mountain goats, mule deer, pronghorn, and white-tailed deer) and seven predators (black bears, Canadian lynx, coyotes, grizzly bears, mountain lions, wolverines, and wolves).

The National Park Service's goal is to maintain the ecological processes that sustain these mammals and their habitats while monitoring the changes taking place in their populations. Seasonal or migratory movements take many species across the park boundary where they are subject to different management policies and uses of land by humans.

Mammals in Yellowstone

Yellowstone is home to the largest concentration of mammals in the lower 48 states.

- 67 different mammals live here, including many small mammals.
- As of 2011, 593 grizzly bears live in the Greater Yellowstone Ecosystem.
- Black bears are common.
- Gray wolves were restored in 1995. As of December 2012, 79 live in the park now.
- Wolverine and lynx, which require large expanses of undisturbed habitat, live here.
- Seven native ungulate species—elk, mule deer, bison, moose, bighorn sheep, pronghorn, and white-tailed deer—live here.
- Nonnative mountain goats have colonized northern portions of the park.

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Bears

Yellowstone is home to two species of bears: grizzly bears and black bears. Of the two species, black bears have a much larger range across the United States. The grizzly bear is typically larger than the black bear and has a large muscle mass above its shoulders; a concave, rather than straight or convex, facial profile; and its behavior is much more aggressive. The grizzly bear 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. In coastal Alaska and Eurasia, the grizzly bear is known as the brown bear.

Visitors should be aware that all bears are potentially dangerous. Park regulations require that people stay at least 100 yards (91 m) from bears (unless safely in your car as a bear moves by). Bears need your concern not your food; it is against the law to feed any park wildlife, especially bears.

Yellowstone is home to both grizzly bears (above) and black bears. Safe traveling in bear country begins before you get on the trail. Learning about bears before you come to the park can help you avoid a confrontation.

Grizzly bears

The Greater Yellowstone Ecosystem and northwest Montana are the only areas south of Canada that still have large grizzly bear (*Ursus arctos horribilis*) populations. Grizzly bears were federally listed in the lower 48 states as a threatened species in 1975 due to unsustainable levels of human-caused mortality, habitat loss, and significant habitat alteration. Grizzly bears may range over hundreds of square miles, and the potential for conflicts with human activities, especially when human food is present, will make the presence of a viable grizzly population a continuing challenge for its human neighbors in the Greater Yellowstone Ecosystem.

Population

The estimated Greater Yellowstone Ecosystem grizzly bear population increased from 136 in 1975 to 593 in 2011, and the bears have gradually expanded their occupied habitat by more than 50 percent. As monitored by the Interagency Grizzly Bear Study Team, the criteria used to determine whether the population within the Greater Yellowstone Ecosystem has recovered include estimated population size, distribution of females with cubs, and mortality rates. An estimated 150 grizzly bears occupy ranges that lie

Grizzly Bears in Yellowstone

Number in Yellowstone
Approximately 150 with home ranges wholly or partially in park.

As of 2011, 593 in Greater Yellowstone

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.

Size and Behavior
- Males weigh 200–700 pounds, females weigh 200–400 pounds; adults stand about 3½ feet at the shoulder.
- May live 15–30 years.
- Grizzly bears are generally 1½ to 2 times larger than black bears of the same sex and age class within the same geographic region, and they have longer, more curved claws.
- Lifetime home range: male, 800–2,000 square miles, female, 300–550 square miles.
- Agile; can run up to 45 mph.
- Can climb trees but curved claws and weight make this difficult. Can also swim and run up and downhill.
- 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, implantation is delayed until fall; gives birth in the winter; typically 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 has been 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. Currently, they occupy 22,095 square miles in the Greater Yellowstone Ecosystem.

partly or entirely within Yellowstone. The number of females producing cubs in the park has remained relatively stable since 1996, suggesting that the park may be at or near ecological carrying capacity for grizzly bears.

The estimated adult grizzly bear male mortality rate was 13 percent in 2009, 29 percent (26 bears) in 2010, and 15.3 percent (24 bears) in 2011. If the rate exceeds 15 percent for three consecutive years, this failure to meet one of the recovery criteria will trigger a biology and monitoring review by the Interagency Grizzly Bear Study Team to identify the cause of the problem and potential corrective action.

Two human fatalities occurred in the park's backcountry during the summer of 2011. In one case a man was known to be killed by a sow with cubs. No one witnessed the second attack. Although DNA evidence indicated several bears had been at the scene, it did not conclusively prove which bear was responsible for the victim's death. An adult female and two cubs were captured and removed (the adult was euthanized and her cubs sent to a zoo) after the second fatality. Six total conflicts with grizzly bears occurred in the park in 2011 compared to an average of seven a year during 1990–2010. Four of the conflicts involved human food and two involved human fatalities. (See "Your safety in bear country" at the end of this chapter.)

There were 44 known and probable grizzly mortalities in the Greater Yellowstone Ecosystem in 2011. Seven of these occurred in Yellowstone National Park: four management removals (1 adult female and 2 cubs, 1 subadult male) and three natural deaths.

FREQUENTLY ASKED QUESTIONS:

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 people or bears. 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.

Bears are still sometimes seen near roads and they may be seen 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 has effectively remained re-listed since 2009. Regardless of its listing status, scientists will continue to monitor the long-term recovery goals for grizzly bears.

Description

The grizzly bear's color varies from blond to black, often with pale-tipped guard hairs. In the Greater Yellowstone Ecosystem, many grizzly bears have a light brown girth band. However, the coloration of black and grizzly bears is so variable that it is not a reliable means of distinguishing the two species.

Bears are generally solitary, although they may tolerate other bears when food is plentiful. Grizzlies have a social hierarchy in which adult male bears dominate the best habitats and food sources, generally followed by mature females with cubs, then by other single adult bears. Subadult bears, who are just learning to live on their own away from mother's protection, are 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.

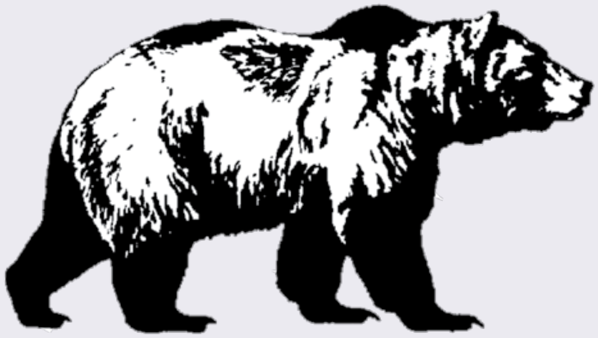
Diet

Bears are omnivores that can only poorly digest parts of plants. They typically forage for plants when they have the highest nutrient availability and digestibility. Although grizzly bears make substantial use of forested areas, they make more use of large, non-forested meadows and valleys than black bears. The longer, less curved claws and larger shoulder muscle mass of the grizzly bear makes it better suited to dig plants from the soil, and rodents from their caches.

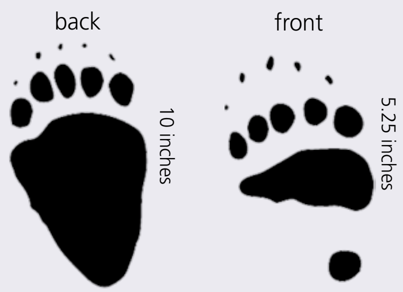
Grizzly bear food consumption is influenced by annual and seasonal variations in available foods, but over the course of a year, army cutworm moths, whitebark pine nuts, ungulates, and cutthroat trout are the highest-quality food items available to them in the Greater Yellowstone Ecosystem. They also eat a wide variety of plant foods, prey on small mammals, and scavenge meat when available from winter-killed

Identify Grizzly Bears and Black Bears

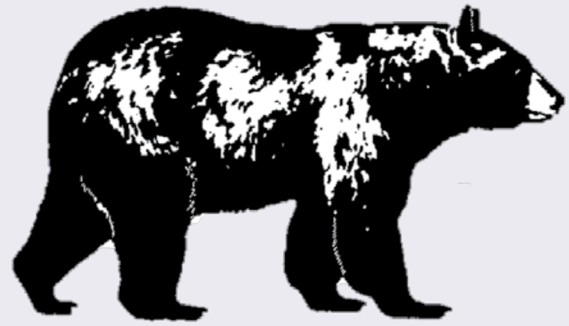
Grizzly Bear



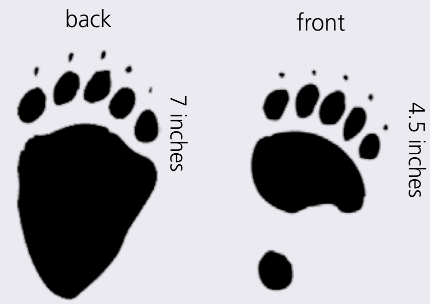
- Rump lower than shoulders.
- Shoulder hump present.



Black Bear



- Rump higher than shoulders.
- No shoulder hump.



carcasses, road-killed wildlife, and animals killed by other predators. 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 coexist in Greater Yellowstone.

Bears spend most of their time feeding, especially during "hyperphagia," the period in autumn when they may put on more than three pounds of weight a day until they enter their dens to hibernate. In years when whitebark pine nuts are available, they are the most important bear food from September through October. Fall foods also include pondweed root, sweet cicely root, grasses and sedges, bistort, yampa, strawberry, globe huckleberry, grouse whortleberry, buffaloberry, clover, horsetail, dandelion, ungulates, ants, false truffles, and army cutworm moths.

From late March to early May, when they come out of hibernation, until mid May, a grizzly bear's diet primarily consists of elk, bison, and other ungulates. These ungulates are primarily winter-killed carrion (already dead and decaying animals), and elk calves killed by predation. Grizzly bears dig up caches made by pocket gophers. Other items consumed during spring include grasses and sedges, dandelion, clover, spring-beauty, horsetail, and ants. When there is an

When combined with other characteristics, a grizzly bear's shoulder hump can help distinguish it from a black bear.

abundance of whitebark seeds left from the previous fall, grizzly bears will feed on seeds that red squirrels have stored in middens.

From June through August, grizzly bears consume thistle, biscuitroot, fireweed, and army cutworm moths in addition to grasses and sedges, dandelion, clover, spring-beauty, whitebark pine nuts, horsetail, and ants. Grizzly bears are rarely able to catch them elk calves after mid-July. Starting around mid-summer, grizzly bears begin feeding on strawberry, globe huckleberry, grouse whortleberry, and buffaloberry. By late summer, false truffles, bistort, and yampa are included in the diet as grasses, sedges, and dandelion become less prominent.

Hibernation

Bears' annual denning behavior probably evolved in response to seasonal food shortages and cold weather. Bears hibernate during the winter months in most of the world. The length of denning depends on latitude, and varies from a few days or weeks in Mexico to six months or more in Alaska. Pregnant females tend to den earlier and longer than other bears. Grizzly bear females without cubs in Greater Yellowstone den on average for about five months.

Dens created by digging (opposed to natural cavities like rock shelters) in Greater Yellowstone usually cannot be reused because runoff causes them to collapse in the spring; however, grizzly bears will occasionally re-use a den, especially those located in natural cavities. Greater Yellowstone dens are typically dug in sandy soils and located on the mid to upper one-third of mildly steep slopes (30–60°) at 6,562–10,000 feet (2,000–3,048 m) in elevation. Grizzly bears often excavate dens at the base of a large tree on densely vegetated, north-facing slopes. This is desireable in Greater Yellowstone because prevailing southwest winds accumulate snow on the northerly slopes and insulate dens from sub-zero temperatures.

The excavation of a den is typically completed in 3–7 days, during which a bear may move up to one ton of material. The den includes an entrance, a short tunnel, and a chamber. To minimize heat loss, the den entrance and chamber is usually just large enough for the bear to squeeze through and settle; a smaller opening will be covered with snow more quickly than a large opening. After excavation is complete, the bear covers the chamber floor with bedding material such as spruce boughs or duff, depending on what is available at the den site. The bedding material has many air pockets that trap body heat.

The body temperature of a hibernating bear, remains within 12°F of their normal body temperature. This enables bears to react more quickly to danger than hibernators who have to warm up first. Because of their well-insulated pelts and their lower surface area-to-mass ratio compared to smaller hibernators, bears lose body heat more slowly, which enables them to cut their metabolic rate by 50–60 percent. Respiration in bears, normally 6–10 breaths per minute, decreases to 1 breath every 45 seconds during hibernation, and their heart rate drops from 40–50 beats per minute during the summer to 8–19 beats per minute during hibernation.

Bears sometimes awaken and leave their dens during the winter, but they generally do not eat, drink, defecate, or urinate during hibernation. They live off of a layer of fat built up prior to hibernation. The urea produced from fat metabolism (which is fatal at high levels) is broken down, and the resulting nitrogen is used by the bear to build protein that allows it to maintain muscle mass and organ tissues. Bears may lose 15–30 percent of their body weight but increase lean body mass during hibernation.

Bears emerge from their dens when temperatures warm up and food is available in the form of winter-killed ungulates or early spring vegetation. Greater Yellowstone grizzly bears begin to emerge from their den in early February, and most bears have left their dens by early May. Males are likely to emerge before females. Most bears usually leave the vicinity of their dens within a week of emergence, while females with cubs typically remain within 1.86 miles (3 km) of their dens until late May.

Life cycle

Grizzly bears reproduce slowly compared to other land mammals. Females rarely breed before age four, and typically become pregnant once every three years. Grizzly and black bears breed from May through July, and bears may mate with multiple partners during a single season. Because implantation of a fertilized egg in the uterus is delayed, the embryo does not begin to develop until late November or December, about one month after the mother has denned. This appears to allow her to conserve energy until she enters her den, where in late January or early February she gives birth to one or two cubs, sometimes three, rarely four. At birth the cubs are hairless and blind, are about eight inches (20 cm) long, and weigh from 8 to 12 ounces (224–336 g). The cubs do not hibernate. They sleep next to the sow, nurse, and grow rapidly. At ten weeks, grizzly bear cubs weigh about 10–20 pounds (4.5–9.0 kg). Male bears take no part in raising cubs, and may actually pose a threat to younger bears. Grizzly bear cubs usually spend 2½, and sometimes 3½ years with their mother before she or a prospective suitor chases them away so that she can mate again. Females frequently establish their home range in the vicinity of their mother, but male cubs disperse farther.

Grizzly bears, black bears, and wolves

Grizzly bears are more aggressive than black bears, and more likely to rely on their size and aggressiveness to protect themselves and their cubs from predators and other perceived threats. Grizzly bears, black bears, and gray wolves have historically coexisted in much of the same range throughout a large portion of North America. The behavior of bears and wolves during interactions with each other are dependent upon many variables such as age, sex, reproductive status, prey availability, hunger, aggressiveness, numbers of animals, and previous experience in interacting with the other species. Most interactions between the species involve food, and they are usually characterized by avoiding each other. Few instances of bears and wolves killing each other have been documented. Wolves sometimes kill bears, but usually only cubs.

Wolves prey on ungulates year-round. Bears feed on ungulates primarily as winter-killed carcasses, ungulate calves in spring, wolf-killed carcasses in spring through fall, and weakened or injured male ungulates during the fall rut. Bears may benefit from the presence of wolves by taking carcasses that wolves have killed, making carcasses more available to bears throughout the year. If a bear wants a wolf-killed animal, the wolves will try to defend it; wolves usually fail to chase the bear away, although female grizzlies with cubs are seldom successful in taking a wolf-kill.

Grizzly bears and the Endangered Species Act

On July 28, 1975, under the authority of the Endangered Species Act, the US Fish and Wildlife Service listed the grizzly bear in the lower 48 states as "threatened," in part, because the species was reduced to only about 2 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 an Endangered Species Act 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, national forests surrounding Yellowstone, Bureau of Land Management lands, and state and private land in Idaho, Montana, and Wyoming).
- Created the Interagency Grizzly Bear Study Team 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 to increase communication and cooperation among managers in all recovery areas, and to supervise public education programs, sanitation initiatives, and research studies.

The Grizzly Bear Recovery Plan was established in 1993 and revised in 2006. It has four demographic and sustainable mortality goals for grizzly bears in the Greater Yellowstone Ecosystem. This plan guides management when the grizzly is on the threatened species list. Bear managers use the Grizzly 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

A grizzly bear sow with three cubs defends a carcass from wolves on Alum Creek in Hayden Valley, 2010. Most interactions between the grizzly bears, black bears, and wolves involve food. The species usually avoid each other.

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 the 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. The strategy has built-in flexibility:

- Grizzly–human conflict management and bear habitat management are high priorities in the recovery zone, which is known as the Primary Conservation Area. 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 Primary Conservation Area, states develop management plans, with input from affected groups and individuals, that define where grizzly bears are acceptable.

Legal status of the population

Scientists and managers believe the grizzly bear population has grown robustly since 1983. Grizzlies are raising cubs in all portions of the recovery zone, and cub survival is high. They are also dispersing into new habitat well outside of the recovery zone. Of the estimated 593 grizzlies living 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 Absaroka Mountains onto the Plains.

For these reasons and because the grizzly bear population in the Greater Yellowstone Ecosystem was determined to be a distinct population segment that met all the population criteria for delisting, the Greater Yellowstone grizzly population was removed from the threatened species list in 2007 by the US Fish and Wildlife Service. Several bear advocacy groups filed lawsuits challenging the decision and some cases are still pending.

In September 2009, a federal district judge overturned the delisting ruling, placing grizzly bears back on the threatened species list because: (1) the Conservation Strategy that guides management after delisting was unenforceable and non-binding on state and federal agencies, and (2) that the US Fish and Wildlife Service did not adequately consider the

Management to Conserve Grizzly Bears

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; 16,794 comments received.
- 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 US Fish and Wildlife Service 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 Greater Yellowstone grizzly bear population 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.
- 2010: The US Fish and Wildlife Service appeals the decision to keep the grizzly bear on the threatened species list.
- 2011: An appeals court rules the grizzly bear remains on the threatened species list.

Grizzly Bear Recovery Plan: New Population Monitoring Criteria

Population Objectives	Was the objective achieved?					
	2006	2007	2008	2009	2010	2011
Estimated % of total mortality of independent aged females not to exceed 9%.	✓	✓		✓	✓	
Estimated % of total mortality of independent aged males not to exceed 15%.	✓	✓		✓		
Estimated % of mortality from human causes for dependent young not to exceed 9%.	✓	✓	✓	✓	✓	✓
Demographic objective of 48 females producing cubs annually.	✓	✓	✓	✓	✓	✓

✓ = Objective was achieved.

impacts of the potential loss of whitebark pine nuts, a grizzly bear food source.

In January 2010, the Department of Justice and the US Fish and Wildlife Service filed an appeal of the judge's decision in the Ninth Circuit Court in San Francisco. The primary points made in the appeal were that: (1) the judge's decision that the Conservation Strategy was unenforceable and therefore did not prove "Adequate Regulatory Mechanisms were in Place" made the Endangered Species Act unworkable; and (2) the judge was wrong on the whitebark pine issue, did not take into account information on whitebark pine provided in the US Fish and Wildlife Service legal briefing, and should have deferred to the opinion of federal experts because it is not the judge's job to interpret biology.

In November 2011, the Ninth Circuit Court of Appeals ruled against the US Fish and Wildlife Service on the whitebark pine issue, resulting in the Greater Yellowstone Ecosystem grizzly bear population remaining on the threatened species list. The panel ruled in favor of the US Fish and Wildlife Service on the issue of the Conservation Strategy providing adequate regulatory mechanisms to conserve bears after delisting.

Meanwhile, management of the bears in the Greater Yellowstone Ecosystem 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.

Black bears

The black bear (*Ursus americanus*) is the most common and widely distributed bear species in North America. However, the Greater Yellowstone Ecosystem is one of the few areas south of Canada where black bears coexist with the grizzly bear (*Ursus arctos*). From 1910 to the 1960s, park managers allowed visitors to feed black bears along park roads, although the National Park Service officially frowned on this activity. During this time, along with Old Faithful, black bears became the symbol of Yellowstone for many people, and are still what some people think of when Yellowstone bears are mentioned. Since 1960, park staff have sought to deter bears from becoming conditioned to human foods.

Population

Little is known about the black bear population in Yellowstone or whether it has been affected by the increase in grizzly bear numbers and distribution since the 1970s. Black bears are commonly observed in the park, especially on the northern range and in the Bechler area of the park. Black bears have few natural predators, although both cubs and adults are occasionally killed by their own kind or by the other large carnivores with which they compete for food—wolves, cougars, and grizzly bears. Vehicle collisions (average = 1 per year) and removals of nuisance bears (average = 1 every 5 years) are not common either. Most black bear mortality in the park is likely attributed to old age or other natural causes. Outside the park, some black bears are killed during state regulated hunting seasons. As their access to human foods has been reduced, human injuries from black bears in the park have decreased from an average of 45 per year during the 1930s–1960s to approximately

In Yellowstone, about 50 percent of black bears are black in color, others are brown, blond, and cinnamon.

one injury every five years since 1980. Black bears are occasionally radio-collared for management and scientific reasons, with the latter focusing on research on habitat selection and multi-carnivore interactions.

Description

In Yellowstone, about 50 percent of black bears are black in color, others are brown, blond, and cinnamon. 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.

The life cycle of a black bear is similar to grizzly bears. Like grizzly bears, black bears spend most of their time during fall and winter feeding during hyperphagia. In November they locate or excavate a den on north-facing slopes between 5,800–8,600 feet (1,768–2,621 m) where they hibernate until late March.

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. Like grizzly bears, black bears also experience delayed implantation. Total gestation time is 200 to 220 days, but only during the last half of this period does fetal development occur.

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 nurse and sleep.

Bear management

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 and 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; installing bear-proof garbage cans; strictly prohibiting feeding of bears; and removing

In the early days of National Park Service management in Yellowstone, black bears could be fed along roadsides and at garbage dumps. Today, black bears in the park are wild.

Black Bears in Yellowstone

Number in Yellowstone
Common

Where to See
Tower and Mammoth areas, most often.

Size and Behavior
- 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.
- Have fair eyesight and an exceptional sense of smell.

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
- Study began in 2000 to find out how black bears fit into the mix of northern range predators; 12 black bears have been radio-collared.

potentially dangerous bears, habituated bears, and bears that damaged property in search of food. The open-pit garbage dumps remained open.

After 10 years, the number of bear-caused human injuries decreased slightly to an average of 45 each year. In 1970, Yellowstone initiated a more intensive program that included eliminating open-pit garbage dumps inside the park with the intention of returning bears to a natural diet of plant and animal foods.

Bear researchers and brothers John and Frank Craighead predicted bears would range more widely and come into more conflict with humans as the bears were weaned off of human food. This prediction was realized in the first years of the revised management program: 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. However, the number of bear-human conflicts decreased to an annual average of 10 each year after 1972. 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.

Your safety in bear country

On average, bears injure one person each year within Yellowstone National Park. In 2011, in separate incidents, two visitors were killed by bears inside the park. Hiking in bear country takes appropriate preparation. Before you set out, ask about area closures, advisories, and seasonal food habits of local bears. Know what to do if you encounter a bear unexpectedly. Resources are available at visitor centers—where public bear spray demonstrations are offered in summer programs—and on the park website (http://go.nps.gov/ynp-bear).

Statistically, you're most likely to have an encounter with bears at park roadsides. If you see a bear while driving, do not stop. Regardless of what other people may do, keep moving to the next paved pullout and park safely. If the bear is within 100 yards, watch and take pictures from inside your car. Always comply with instructions of park staff on scene.

As you venture beyond developed areas, stay clear of animal carcasses. Bears are very protective of carcasses as a food source. A single dead animal can attract and hold more than a dozen bears. Many may

Bear spray is proven to be highly successful at stopping aggressive behavior in bears.

Bear Management in Yellowstone

Early Interactions

- 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 occur annually.

Changes in Management in 1970

- 1970: Yellowstone implements a new bear management program to restore bears to a diet of 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.

Recent Progress

- 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 humans 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.

be bedded down nearby. Watch for gatherings of ravens, magpies, and coyotes. They can be good first indicators that a carcass is nearby. Leave the area immediately by the same route you used to get there.

Bears don't like surprises. Be vigilant about alerting unseen bears to your presence. Some trail conditions make it hard for bears to see, hear, or smell approaching hikers. Make noise by calling out and clapping your hands loudly at regular intervals. Bells are not enough. If you see a bear that hasn't noticed you, leave the area.

Know how to react. If you have a surprise encounter with a bear, do not run. Face the bear and slowly back away. If a bear charges you, stand your ground and use your bear spray. Do not drop your pack. It can help to protect your back from injury. If a bear makes contact with you, fall to the ground onto your stomach and play dead.

A sow protecting her cubs is one of the most dangerous situations you can face in nature. As cute and charismatic as cubs can be, no photograph of them is ever worth risking personal injury. Always assume mother is nearby and ready to protect her young. For the safety of others, please report all bear incidents and wildlife encounters to a park ranger immediately. As you enjoy park trails:

- Hike with a group of three or more people.
- Make yourself heard in areas where you can't see far around you.
- Watch for bears and be alert for fresh tracks or scat.
- Carry bear spray and know how to use it.
- Do not run.

Stay clear of animal carcasses. Ravens can be a good indicator that an animal carcass is nearby.

Watch for fresh tracks and scat.

Two Human Fatalities from Bear Encounters Occurred in Yellowstone During Summer 2011

In separate incidents, two park visitors were killed in bear encounters in Yellowstone during summer of 2011.

In October, park staff captured and euthanized a 250-pound, 6 to 7 year-old sow after genetic (DNA) tests obtained from bear hair and scat samples determined that it was present at the scene of the mauling death of a 59-year-old man from Michigan in late August along the Mary Mountain Trail, about five miles west of the Hayden Valley trailhead.

The same bear was responsible for the July 6 death of a 57-year-old California man during a defensive attack on the Wapiti Lake Trail near Canyon Village. Rangers and an Interagency Board of Review determined the man's death resulted from a defensive attack by the sow protecting her cubs. The bear did not have a history of aggression or human interaction.

"We will more than likely never know what role, if any, the sow might have played (in the second death) due to the lack of witnesses and presence of multiple bears at the incident scene," said Superintendent Dan Wenk. "But because the DNA analysis indicates the same bear was present at the scene of both fatalities, we euthanized her to eliminate the risk of future interaction with Yellowstone visitors and staff."

The sow's two cubs were captured and placed at the Grizzly and Wolf Discovery Center in West Yellowstone, Montana. Adult bears that are removed from the wild do not adapt well to captivity; cubs typically adapt successfully to captivity.

Attacks by bears are considered extremely rare. These were the first bear-caused human fatalities in Yellowstone since 1986. A total of seven people have been killed by bears in the park since it was founded in 1872.

Hikers are encouraged to travel in groups of three or more, make noise on the trail, and carry bear spray. Under no circumstances should anyone run from a bear. Visitors are reminded that park regulations require them to stay at least 100 yards away from bears and wolves and at least 25 yards away from all other large animals.

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Staff reviewer

Kerry Gunther, Bear Management Biologist

Bison

Yellowstone is the only place in the United States where bison (*Bison bison*) have lived continuously since prehistoric times. This is the nation's largest bison population on public land and among the few bison herds that have not been hybridized through interbreeding with cattle. However, some Yellowstone bison are infected with brucellosis, a livestock disease that can be transmitted to wild bison and elk as well as cattle through contact with infected fetal tissue. To prevent conflicts with ranching activities outside the park, the National Park Service works with other federal and state agencies to manage and develop policies for bison access to winter range there.

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.

Description

The bison is the largest land mammal in North America. Bulls are more massive in appearance than cows, and more bearded. Bison are sexually mature at age two. Although female bison may breed at these younger ages, older males (>7 years) participate in most of the breeding. Both sexes have horns, those of the cow being slightly more curved and slender than the bull's.

Bison are animals of the grasslands; they eat primarily grasses and sedges. Their massive hump supports strong muscles that allow the bison to use its head as a snowplow in winter, swinging side to side to sweep aside the snow.

Cows, calves, and some younger bulls comprise a herd. Mature bulls, however, spend most of the year alone or with other bulls. The exception is during the rut, or mating season. At this time, in late July and August, bulls seek out females. They display their dominance by bellowing, wallowing, and engaging in fights with other bulls. Once a bull has found a female who is close to estrus, he will stay by her side until she is ready to mate. Then he moves on to another female.

After a gestation period of 9 to 9 ½ months, single reddish-brown calves are born in late April and May. Calves can keep up with the herds in 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 kill bison calves when they wander too far.

Wolves and grizzly bears are the only large predators of adult bison. Dead bison provide an important

Bison in Yellowstone

Number in Yellowstone
Estimated at 4,200 in August 2012. There are two sub-populations in Yellowstone: Northern Range and Hayden Valley.

Where to see
- Year-round: Hayden and Lamar valleys.
- Summer: grasslands.
- Winter: hydrothermal areas and along the Madison River.

Size and Behavior
- Male (bull) weighs up to 2,000 pounds, female (cow) weighs up to 1,000 pounds.
- May live 12–15 years, a few live as long as 20 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 agile, and can run up to 30 miles per hour.

History
- Yellowstone National Park is the only place in the lower 48 states to have a continuously free-ranging bison population since prehistoric times.
- In the 1800s, market hunting, sport hunting, and the US Army nearly caused the extinction of the bison.
- By 1902, poachers reduced Yellowstone's small herd to about two dozen animals.
- The US 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.

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 Ecosystem, 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 snowpack. 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.

History

From 30 to 60 million bison may have roamed North America before the mid 1800s. Their historical 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 American Indian 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.

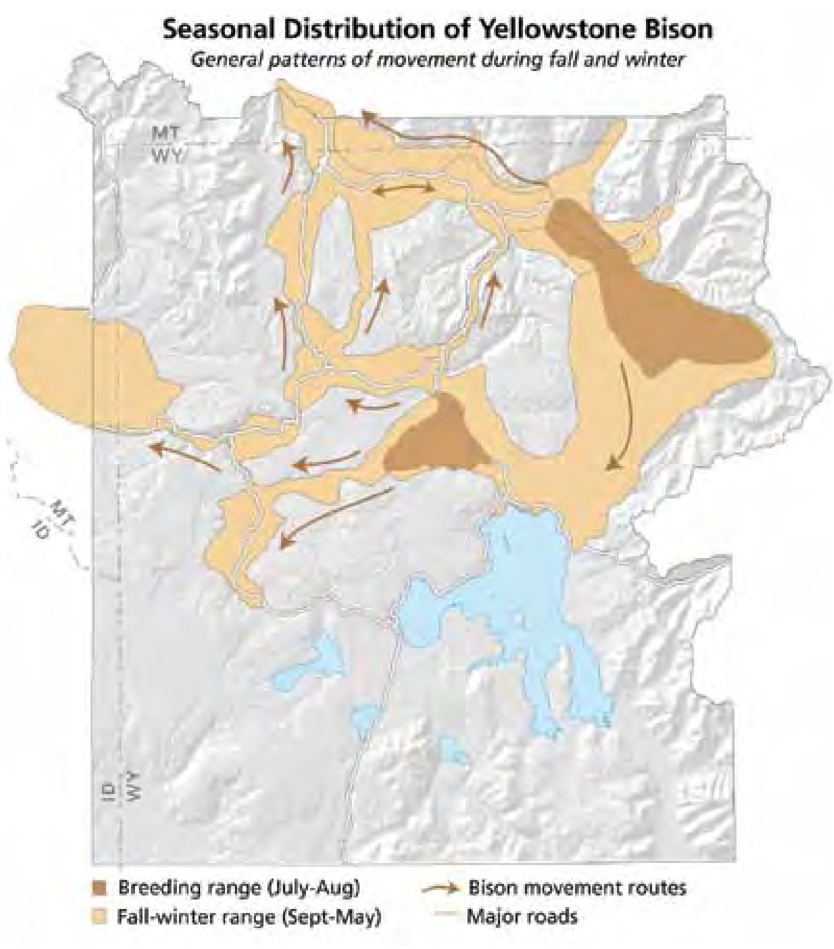
European American settlers moving west during the 1800s changed the balance. Market hunting, sport hunting, and a US Army campaign in the late 1800s nearly eliminated bison. Yellowstone was the only place in the contiguous 48 states where wild, free-ranging bison persisted. The US Army, which administered 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.

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 US 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

FREQUENTLY ASKED QUESTION:

What is the difference between a bison and a buffalo?

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. 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. In this book, we use "bison."



WILDLIFE

1917–1995

1917		1985	1989	1990	1995
Brucellosis found in bison that live in Yellowstone.	Husbandry and active restoration until 1950. Buffalo Ranch stands down as park treats bison like other wildlife. Policy shifts in 1966 to end brucellosis eradication effort in park interior.	Montana receives brucellosis-free status; begins public hunts for bison.	Bison routinely migrate to boundary in years of heavy snowfall. Park begins collaborative planning to develop management plan.	Montana ends hunt due to public outcry. The National Park Service prepares EA enabling staff to haze and shoot bison outside park.	Montana files lawsuit against the National Park Service to keep bison out of the state; settlement requires EIS preparation.

also slowly increased. In the 1930s, the introduced bison were allowed to move freely and intermingle with the native bison. The park's bison population 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.

Bison management

In 1968, managers stopped manipulating bison populations and allowed natural ecological processes to operate. The Yellowstone bison population grew to more than 2,000 by the 1980s and expanded its use of lower elevation winter range outside the park where shallower snow makes foraging easier and spring greenup occurs earlier. 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.

Brucellosis, cattle, bison, and elk

Brucellosis, caused by the bacterium *Brucella abortus*, can cause pregnant cattle, elk, and bison to abort their calves. It is transmitted primarily when susceptible animals directly contact infected birth material. No cure exists for brucellosis in wild animals. All cattle that use overlapping ranges with bison are vaccinated for brucellosis when they are calves. Cattle brought this nonnative disease to the region when pioneers settled the West. The disease was subsequently transmitted to local wildlife populations. Many bison and elk in the Greater Yellowstone Ecosystem have been exposed to the bacterium that causes brucellosis. It does not appear to have had substantial population-level impacts in wildlife, but infected females may abort their first calf, and the disease can be transmitted between all three species if they have contact with infected birth materials.

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 pasteurization, people in developed countries have virtually no risk of contracting the disease. And if they do, they can be treated with a series of antibiotic injections.

Presence in Yellowstone

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

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.

1996–2000

1996	1997	1998	1999	2000
Interim Bison Management Plan begins. Stephens Creek facility is constructed as part of settlement agreement with state of Montana.	Unusually severe winter. More than 1,000 bison shot or shipped to slaughter.	94 bison died in management actions; Draft EIS released. Receives 67,500+ public comments.	Almost 8,000 acres of winter habitat along north boundary is protected in partnership with Rocky Mountain Elk Foundation. Federal agencies withdraw from agreement with Montana to produce an EIS. Devil's Slide conservation agreement enacted.	February: Federal judge orders state and federal agencies into mediation to work out differences; August: Final EIS released; December: Records of Decision signed by federal and state governments.

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 because management strategies prevent bison from commingling with cattle.

Brucellosis management in cattle

Federal and state agencies and the livestock industry have spent much time and money to eradicate

Bison Management in the Greater Yellowstone Ecosystem

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 and Background

- 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, bison, and elk 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 US
- Bison have not been known to transmit brucellosis to cattle under natural conditions although transmission is biologically feasible and has occurred in captivity.
- The state of Montana, like other states, has spent much time, effort, and money to successfully 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.
- A vaccine used in cattle, RB51, is being used for Yellowstone bison.
- Untested bison are now tolerated outside the west boundary Nov. 1–May 15 and the northern boundary Nov. 1–May 1.
- Yellowstone bison have access to 75,000 acres of additional habitat in the Gardiner Basin of Montana (State decision Feb 2012).
- Fewer cattle graze lands near park than in 2000.
- The state of Montana is managing a bison hunt on public lands outside the park.
- Four tribes are conducting bison hunts on unclaimed federal lands outside the park by authority of their respective treaties with the United States.

Objectives

- Maintain genetic integrity of the bison population.
- Prevent dispersal beyond conservation area.
- 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.

Interagency Management Partnership

- National Park Service (NPS)
- Animal Plant Health Inspection Service (APHIS)
- US Forest Service (FS)
- Montana Department of Livestock (DOL)
- Montana Department of Fish, Wildlife and Parks (FWP)
- InterTribal Buffalo Council (ITBC)
- Confederated Salish Kootenai Tribes
- Nez Perce Tribe

WILDLIFE

2001–present

2002–2005	2005	2006	2008	2010
During years 2–5 of the Bison Management Plan, approximately 840 bison are shipped to slaughter or killed.	FWP and APHIS open quarantine facility; 14 bison calves taken from Yellowstone for project. DOL and APHIS begin vaccinating captured bison. FWP begins bison hunt on November 15.	Approximately 1,000 bison removed from the park via management actions, transfer to quarantine, or hunting.	Approximately 1,700 bison removed by hunting and capture operations. More than 500 die due to winter conditions. State and federal agencies revise the management plan: more bison will be tolerated outside the park boundary in winter.	DEIS for remote vaccination released for public comment. APHIS proposes management of brucellosis in livestock focused on a designated surveillance area and changing downgrade of brucellosis class-free status to a case-by-case basis.

brucellosis from cattle. States accomplishing this task receive "brucellosis class-free" status and can export livestock without restrictions and costly disease testing. Until recently the rules governing this status were strict—one cow infected among one herd meant the entire herd had to be quarantined or slaughtered; two herds in two years in one state meant the entire state would lose its brucellosis class-free status. There was a minimum one-year time period before a state can regain class-free status.

The Animal and Plant Health Inspection Service implemented an interim rule in 2010 that allows detections (or outbreaks) of brucellosis in domestic livestock to be dealt with on a case-by-case (or herd-by-herd) basis. The interim rule removes the provision for automatic reclassification of any Class Free State or area to a lower status if two or more herds are found to have brucellosis within a two-year period or if a single brucellosis-affected herd is not depopulated within 60 days. As long as outbreaks are investigated and contained by removing all cattle testing positive for exposure, then corrective regulations are not imposed on the rest of the cattle producers in the state. In fact, brucellosis was detected in several domestic bison and cattle herds in Idaho, Montana, and Wyoming from 2009 to present, without any state-wide corrective actions being implemented. Thus, the interim rule eliminates many economic barriers created by the brucellosis class status system and should increase tolerance for bison and the potential for expansion of the conservation area for wild bison.

Decades of Lawsuits

- 1984: Fund For Animals sues the National Park Service (NPS) to stop bison from crossing the park boundary into Montana, where they are shot. (Suit dismissed.)
- 1989: Memorandum of Understanding (MOU): the state of Montana, NPS, and US Forest Service (FS) agree to develop a long-term management plan to cooperatively manage bison.
- 1992: Another MOU between Montana, NPS, Forest Service, and Animal Plant Health Inspection Service (APHIS) defines each party's roles and responsibilities in developing a long-term bison management plan.
- 1995: Montana files lawsuit against NPS and APHIS because the federal agencies are asking the state to implement conflicting management actions. The settlement includes preparing an interim bison management plan to be in effect until the EIS for long-term management is completed.
- 1996: Sierra Club Legal Defense Fund sues NPS to stop capturing bison inside the park.
- 1997: Fund For Animals files lawsuit to stop all road grooming in the park unless scientific evidence shows that it does not harm wildlife. (Settled.)
- For the next few years, bison-related lawsuits become more about winter-use management, which is discussed later in this chapter.
- 1999: Federal agencies withdraw from 1992 MOU with Montana to produce an EIS. Soon thereafter, the state of Montana sues the federal government.
- 2000: Federal judge orders state and federal agencies into mediation to work out differences. In August, the final EIS is released; federal and state governments issue separate Records of Decision.
- 2003: Several groups file a lawsuit against the state of Montana and the federal government to stop using helicopters to haze bison outside the west boundary as it is disrupting nesting bald eagles. (Rejected.)
- 2009: Several groups file a lawsuit against NPS and FS to stop their participation in the IBMP, to stop "lethal bison removals," and to begin the process for a new management plan. Montana District Court ruled in favor of federal agencies. Appeals court ruled in favor of federal agencies.
- 2010: Several groups sue to stop the state of Montana from moving quarantined bison to private lands.

Nevertheless, the state of Montana remains concerned that bison migrating outside of Yellowstone National Park present a risk to cattle.

Interagency Bison Management Plan

Developing a long-term management plan took twelve years because of a wide variety of agency perspectives and missions. Interim plans were used to manage bison as various lawsuits, environmental assessments, and environmental impact statements proceeded. Through court-appointed mediation, the state and federal agencies found common ground in managing bison.

The resulting *Final Environmental Impact Statement for the Interagency Bison Management Plan (IBMP) for the State of Montana and Yellowstone National Park* was released in August 2000; the federal government and the state of Montana released separate Records of Decision in December 2000 describing the negotiated settlement. The IBMP identified two common goals:

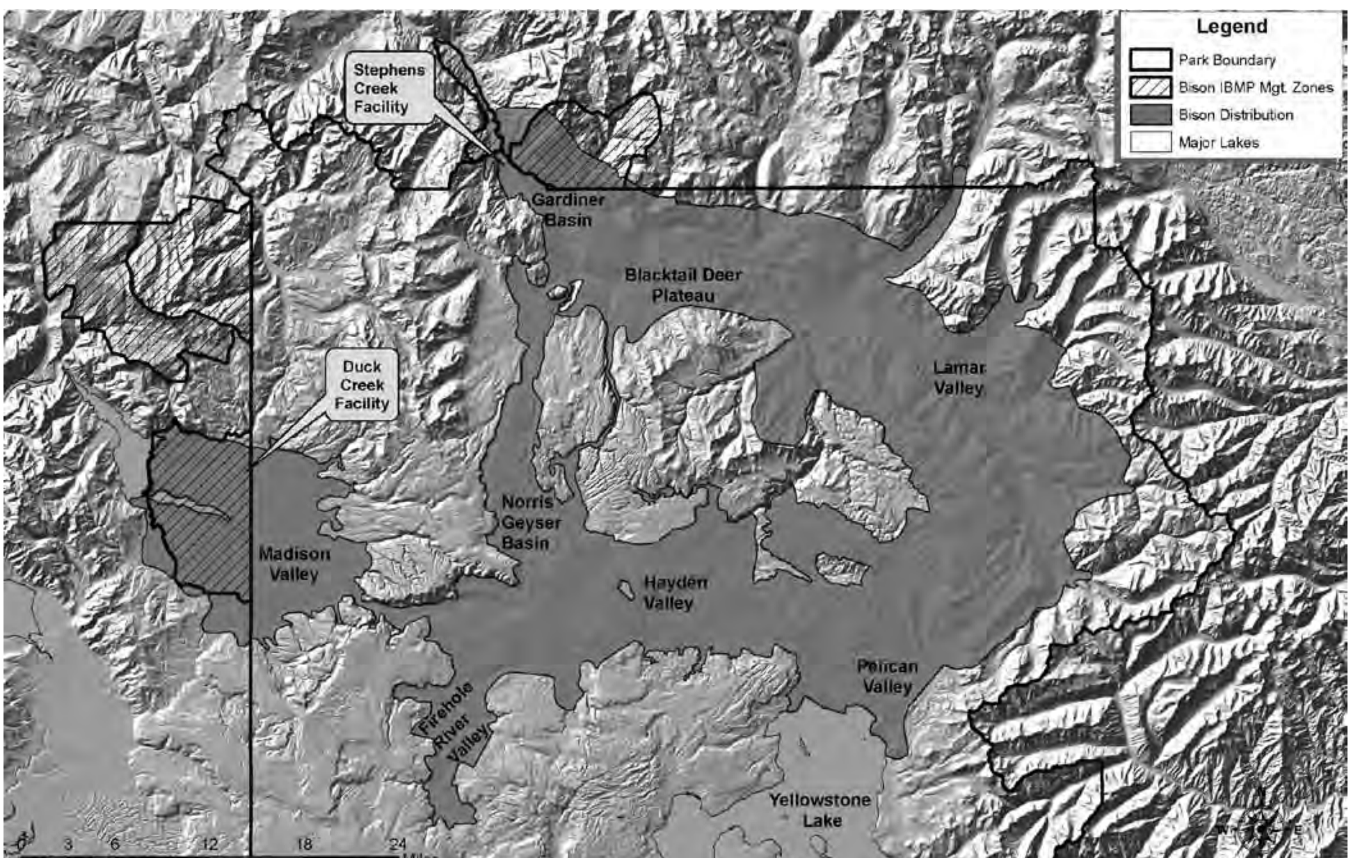
- maintain a wild, free-ranging bison population
- prevent transmission of brucellosis from bison to cattle surrounding Yellowstone National Park.

It also envisioned progressively greater tolerance for bison outside Yellowstone. Some areas outside park boundary provide habitat for unlimited bison year-round: the Eagle Creek/Bear Creek area outside the north boundary and the Lee Metcalf Wilderness and Cabin Creek Wildlife Management Area outside the west boundary.

To achieve these goals, the IBMP uses adaptive management to modify the plan as scientists and managers learn more about bison behavior and migration, and about brucellosis.

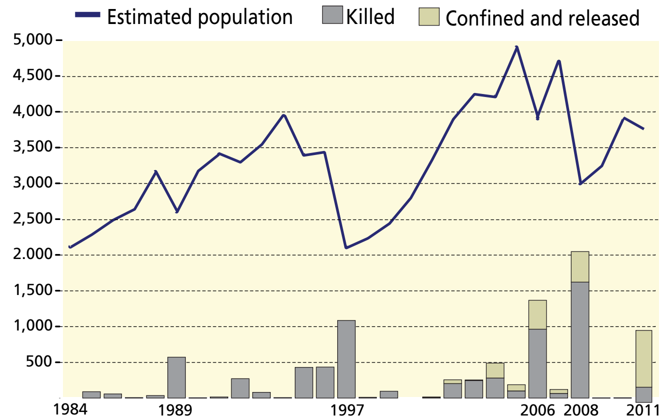
The IBMP also allows natural processes to occur throughout most of the bison conservation area and accounts for the migratory nature of bison. But as bison approach the park boundary, more intensive management actions can occur to keep bison from commingling with cattle.

The IBMP was in use without major changes until the end of winter in 2008. Under the plan, more than 3,600 bison were removed from the population for risk management purposes from 2001 to 2011, with more than 1,000 bison and 1,700 bison culled during the winters 2006 and 2008, respectively. These culls differentially affected breeding herds, altered gender structure, created reduced female cohorts, and



The bison conservation area, including capture facilities and management zones outside Yellowstone National Park. Map produced by the Yellowstone National Park Spacial Analysis Lab.

The migration of bison outside of Yellowstone National Park (the boundary is marked here with the 1903 arch at the northern entrance) is a hot issue for the Greater Yellowstone Area.



Estimated summer population and the number of bison killed the preceding winter, including those harvested by hunters, 1984–2011.

dampened productivity of bison. Thus, there was a need to adjust the management plan to better protect migratory bison and facilitate their conservation. Since more than 1,400 bison were sent to slaughter in 2008, the National Park Service has worked with other federal and state agencies toward greater population stability and fewer boundary removals by increasing the area outside the park available to bison as winter range and confining bison in fenced pastures where they are fed until spring when necessary.

Bison movements are influenced by winter conditions and population size. During the unusually high snowpack of the 2010–11 winter, half of the population approached the boundary. To avoid sending bison to slaughter, nearly 800 were herded into fenced pastures and hundreds of others were allowed to remain on public and private land outside the park until greenup when they were hazed into the park. Of the confined bison, 53 were transferred to a research project and the others were released into the park in May after 150 had been vaccinated against brucellosis. Since bison hunting was authorized outside the park in 2006, a total of 481 have been harvested, including 211 in the winter of 2010–11.

Revising the plan

Between August and December 2008, the agencies met seven times to revise the IBMP. Their adjustments included:

- 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 an additional, 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 outside the national park as a tool to help create separation between cattle and bison.

These adaptive adjustments to the IBMP allowed for greater tolerance of untested bison on the Horse Butte peninsula outside the western boundary of the park because cattle were no longer present. Also, in April 2011 the federal, state, and tribal agencies involved with bison management agreed to allow bison on 75,000 acres of US Forest Service and other lands north of the park boundary and south of Yankee Jim Canyon until May 1 each winter. This agreement greatly expanded the tolerance area for bison north of the park during winter, but was controversial due to public safety and property damage concerns. This led to a lawsuit by ranching interests to prevent the expansion of the conservation area. In May 2011, the Montana Sixth Judicial District Court enjoined Montana from implementing increased tolerance for bison north of Yellowstone and court proceedings are underway.

Evaluation of the plan

Overall, the National Park Service considers the IBMP successful at preventing brucellosis transmission from wild Yellowstone bison to domestic cattle. Scientists have learned that the bison population grows faster than they estimated ten years ago. This balances the fact that management actions reduce adult female survival by about 10 percent. They have also seen that bison migration is being restored to this landscape. This will benefit long-term herd survival by providing a way for bison to pioneer suitable habitats and respond to environmental changes, human management needs, and evolutionary processes that function at time scales of centuries. While brucellosis prevalence has not declined in this time period, managers now can reach disease management goals using the IBMP as an effective risk management program.

Other management actions and issues

Bison hunting

Since 2005, approximately 500 bison have been killed during the winter hunt in Montana. Several of the winters have been mild and bison have had good forage inside the park. The hunt continues to generate revenue for the state. In addition, four tribal groups—Nez Perce, Confederated Salish and Kootenai, Shoshone-Bannock, Umatilla—hunt bison on public lands outside the park in accordance with their 1855 treaties with the United States. In 2012, the Montana State Veterinarian, Confederated Salish and Kootenai Tribes, and Nez Perce Tribe recommended an adaptive management change to hunt in Yellowstone National Park.

Vaccination

The overall goal of a bison vaccination plan is to increase the number of bison not infected with the bacteria by decreasing transmission. Since 2004, as part of capture operations, calves and yearlings that tested negative for brucellosis have been vaccinated.

In 2010, the National Park Service released the draft environmental impact statement (DEIS), *Remote Vaccination Program for Bison in Yellowstone National Park*. It evaluates vaccinating bison in the field, using remote delivery methods that do not require handling individual bison. The National Park Service remains committed to the suppression of brucellosis in a manner aligned with bison conservation. Currently, managers struggle with the suite of issues that surround brucellosis suppression practices in free-ranging wildlife. To develop a lasting solution, Yellowstone's superintendent invited an independent professional review of this conflict through a brucellosis science workshop in February 2013 to evaluate whether substantial brucellosis suppression is feasible and sustainable without significantly affecting bison behavior or visitor experience. Release of the EIS is on hold until recommendations from this panel are received and evaluated. The National Park Service is evaluating public comments and expects to release the final EIS in late 2013.

Quarantine

Montana Fish, Wildlife and Parks and APHIS have conducted a bison quarantine feasibility study. Bison calves that would otherwise be sent to slaughter have been used to develop and test a protocol to certify disease-free bison. A total of 87 adults and offspring cleared the protocol and were relocated to a private ranch in 2010. They will be monitored for five more years (assurance testing). The second, and last, group of bison (39 adults plus calves) are expected to complete the quarantine protocol and be relocated in 2012. In 2012, around 62 bison that successfully completed the quarantine procedures were transferred to the Assiniboine and Sioux tribes of the Fort Peck Reservation to be managed as wild bison. The State of Montana initially planned to transfer half of these bison to the Gros Ventre and Assiniboine tribes of the Fort Belknap Reservations, but plaintiffs in the State of Montana blocked this action. A court hearing was conducted and the judge's opinion is pending.

Thus far the quarantine protocol has proven successful because calves have been born in quarantine for three years and they and their mothers have remained free of brucellosis. If the five-year assurance testing proves successful, quarantine could provide a way for Yellowstone bison to be a part of bison conservation in other places.

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. State and federal agencies will continue to work together using the IBMP as their primary tool to prevent bison to livestock transmission. Each agency plays a separate role in managing this population that now has approximately 60,000 acres of suitable habitat dispersed throughout 350,000 acres of Montana.

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Staff reviewer

Rick Wallen, Bison Ecology and Management.

Bighorn Sheep

Although widely distributed across the Rocky Mountains, bighorn sheep (*Ovis canadensis*) persist chiefly in small, fragmented populations that are vulnerable to sudden declines as a result of disease, habitat loss, and disruption of their migratory routes roads and other human activities. About 10 to 13 interbreeding bands of bighorn sheep occupy steep terrain in the upper Yellowstone River drainage, including habitat that extends more than 20 miles north of the park. These sheep provide visitor enjoyment as well as revenue to local economies through tourism, guiding, and sport hunting. Mount Everts receives the most concentrated use by bighorn sheep year-round.

All bighorn sheep have horns. The rings on horns can be used to determine age, though it is easier to count the rings on a ram (above).

Population

From the 1890s to the mid-1960s, this bighorn sheep population fluctuated between 100 and 400. Given the vagaries of weather and disease, bighorn sheep populations of at least 300 are desirable to increase the probability of long-term persistence with minimal loss of genetic diversity. The count reached a high of 487 in 1981, but a pinkeye epidemic caused by *Chlamydia* reduced the population by 60 percent the following winter and the population has been slow to recover. Although the temporary vision impairment caused by the infection is rarely fatal for domestic sheep that are fenced and fed, it can result in death for a sheep that must find its forage in steep places.

After dropping to a low of 134 sheep following the severe winter of 1996–97, the overall trend has been upward. The 2012 count by the Northern Yellowstone Cooperative Wildlife Working Group

Bighorn Sheep in Yellowstone

Number in Yellowstone
379 in 2012

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
- Average life span: males, 9–12 years; females 10–14 years.
- Adult male (ram): 174–319 pounds, including horns that can weigh 40 pounds. The horns of an adult ram can make up 8–12% of his total body weight.
- Adult female (ewe): up to 130 pounds.
- Horn growth is greatest during the summer and early in life. Female horns grow very little after 4–5 years, likely due to reproductive costs.
- The horn size of bighorn sheep rams can influence dominance and rank, which affects social relationships within herds.
- Older ram horns may be "broomed" or broken at the horn tip, which can take off 1–2 years of growth.
- Mating season begins in November.
- Ram skulls have two layers of bone above the brain that function as a shock absorber, an adaptation for the collision of head-on fighting that is used to establish dominance between rams of equal horn size, especially during mating.
- One to two lambs born in May or June.

Habitat
- Feed primarily on grasses; forage on shrubby plants in fall and winter.
- Rocky Mountain bighorn sheep, found in greater Yellowstone, differ from other currently recognized subspecies in the United States: Desert bighorn sheep, which is currently listed as an endangered species, Dall sheep found in Alaska and northwestern Canada, and Stone's sheep, which are a subspecies of Dall sheep.

Management
- 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 1981–1982 reduced the northern herd by 60%.
- Other unknown factors may be limiting the population now.

WILDLIFE

Most bighorn sheep in Yellowstone are migratory, wintering in lower-elevation areas along the Yellowstone, Lamar, and Gardner rivers, and moving to higher-elevation ranges from May through October.

Bighorn sheep exhibit some habituation to humans. Be alert to them along the road and never feed them.

was 378, with 39 lambs per 100 ewes, which is above average for this population.

Competition with other species

Bighorn sheep populations that winter at high elevations are often small, slow growing, and low in productivity. Competition with elk as a result of dietary and habitat overlaps may have hindered the recovery of this relatively isolated population after the pinkeye epidemic. Rams may be hunted north of the park, but the state of Montana has granted few permits in recent years because of the small population size.

Although wolves occasionally prey on bighorn sheep, the population has increased since wolf reintroduction began in 1995. Longer-term data are needed to show whether sheep abundance may be inversely related to elk abundance on the northern range. The Wyoming Game and Fish Department, Montana Fish, Wildlife and Parks, the Idaho Department of Fish and Game, Montana State University, the US Forest Service, and several nongovernmental organizations are cooperating with the National Park Service to study how competition with nonnative mountain goats, which were introduced in the Absaroka Mountains in the 1950s, could affect bighorn sheep there.

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Staff reviewer

P.J. White, Chief, Wildlife and Aquatic Resources

Mountain Goats

Descendants of mountain goats (*Oreamnos americanus*) introduced in Montana during the 1940s and 1950s established a population in the park in the 1990s and have reached a relatively high abundance in the northeastern and northwestern portions via the Absaroka and Gallatin mountain ranges. Investigations of paleontological, archeological, and historical records have not found evidence that the mountain goat is native to Greater Yellowstone. Many people consider the goats a charismatic component of the ecosystem, including those who value the challenge of hunting them outside the park. But the colonization has raised concerns about the goats' effects on alpine habitats. Competition with high densities of mountain goats could also negatively affect bighorn sheep, whose range overlaps that of mountain goats.

Habitat

Mountain goats live in alpine habitats. Studies of alpine vegetation in the northeast portion of the park during 2002 and 2003 suggest that ridge top vegetation cover is lower, and barren areas along alpine ridges are more prevalent in areas that have received relatively high goat use. Competition with high densities of mountain goats could negatively affect bighorn sheep, whose range overlaps with mountain goats.

Studies by Idaho State University and the National Park Service during 2008–2010 suggest goats are affecting the soil chemistry of sites they inhabit by increasing the availability of soil nitrogen through deposition of urine and feces. Soil rockiness may be increasing slightly over time at sites with high goat presence, but no large-scale effects have been detected so far with respect to vegetation (species, community structure).

In 2010, the National Park Service began a long-term research program with Montana State University and other federal and state agencies on mountain goat ecology and the potential for competition with bighorn sheep.

Mountain goats are not native to the Greater Yellowstone Ecosystem.

Mountain Goats in Yellowstone

Nonnative species

Number in Yellowstone

200–300 in and adjacent to Yellowstone

Where to See

- Infrequently seen; northeastern and northwestern portions of the park in alpine habitat
- Winter: steep, south-facing slopes, windblown ridgetops; Spring: south- and west-facing cliffs; Summer: meadows, cliffs, ravines, and forests.

Behavior and Size

- Mature male (billy) weighs 300 or more pounds; female (nanny) weighs 150 pounds.
- Young (kids) born in late May–June.
- Females usually begin to breed at 2½ years.
- Live in precipitous terrain.
- Both sexes have horns; females curve less and are thinner and sometimes longer than males.

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Elk

Yellowstone provides summer range for an estimated 10,000–20,000 elk (*Cervus elaphus*) from 6–7 herds, most of which winter at lower elevations outside the park. These herds provide visitor enjoyment as well as revenue to local economies through hunting outside the park. As Yellowstone's most abundant ungulate, elk comprise approximately 90 percent of winter wolf kills and are an important food for bears, mountain lions, and at least 12 scavenger species, including bald eagles and coyotes. Competition with elk can influence the diet, habitat selection, and demography of bighorn sheep, bison, moose, mule deer, and pronghorn. Elk browsing and nitrogen deposition can affect vegetative production, soil fertility, and plant diversity. Thus, changes in elk abundance over space and time can alter plant and animal communities in Yellowstone.


Bull elk grow antlers for the fall mating season and keep them through the winter, they fall off for the new year's growth.

WILDLIFE

Description

Elk 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 one of 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 two-thirds 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.

Elk in Yellowstone

Number in Yellowstone

- Summer: 10,000–20,000 elk in 6–7 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 north to the northern range and around Gardiner, Montana; <100 year-round along the Firehole and Madison rivers; south to the Jackson Hole Elk Refuge in Jackson, Wyoming.

Size and Behavior

- 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.
- 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.

Elk Antlers

Antlers are usually symmetrical and can occur on females.

- The average, healthy, mature bull has 6 tines on each antler, and is known as a "six point" or "six by six."
- 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.

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.

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.

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.

Elk calves can walk within an hour of birth, but they spend much of their first week to ten days bedded down between nursings.

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.

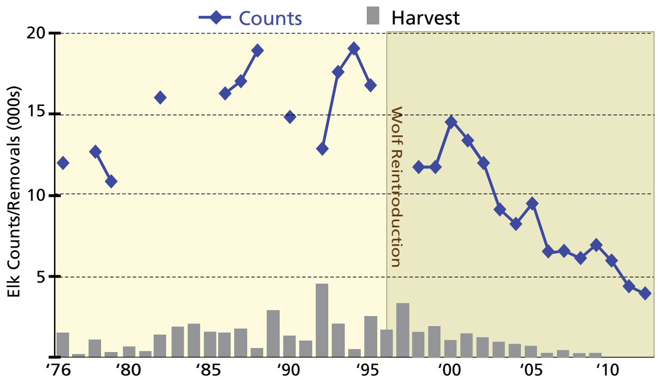
Population

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.

Elk on the northern range

Yellowstone's largest elk herd winters along and north of the park's winter boundary. With more moderate temperatures and less snowfall than the park interior, this area can support large numbers of wintering elk. 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.

After decades of debate over whether this range was overgrazed by too many elk, public concern has



Winter counts and hunting harvests of the northern elk herd in Yellowstone National Park and adjacent areas of Montana, 1976–2012. Counts were not adjusted for sightability.

shifted to the herd's small size. The winter count, which was approximately 17,000 when wolf reintroduction began in 1995, fell below 10,000 in 2003. It fluctuated between 6,000 and 7,000 as the wolf population on the park's northern range declined from 94 in 2007 to 38 in 2010. The elk count dropped to 3,915 in early 2013, the lowest since culling ended in the park in the 1960s. The decrease has been attributed to predation by reintroduced wolves and a large bear population, hunter harvest, and drought-related effects on pregnancy and survival. The State of Montana has reduced the permits issued for this herd so that hunting of females now has little impact on population size.

There are some indications that elk–wolf interactions are contributing to a release of willows and other woody vegetation from the effects of herbivory on the northern range. Wolves have altered the group sizes, habitat selection, movements, distribution, and vigilance of elk while the proportion of browsed aspen, cottonwood, and willow leaders has decreased in some areas during recent years, and cottonwood and willow heights have increased significantly. Research is underway to determine how climate, hydrology, wolf predation/avoidance, and herbivory interact in their effects on these woody species.

Elk in the interior

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.

Elk in the Greater Yellowstone Ecosystem

The Greater Yellowstone Ecosystem is home to approximately 30,000–40,000 elk. For most of the last two decades, the Jackson herd, which currently numbers about 12,000, has been larger than the northern Yellowstone herd. Some ranges and migratory routes overlap, and some interchange occurs among the herds. Summer range in the southern part of Yellowstone National Park is used by part of the Jackson herd as well as by elk from the North Fork Shoshone and northern Yellowstone herds. Because the wildlife responsibilities of the National Park Service, the US Fish and Wildlife Service, the US Forest Service, and state wildlife agencies also coincide, elk management in Greater Yellowstone requires substantial coordination among government agencies with different priorities.

Elk in areas burned by wildfire

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.

Disease in Greater Yellowstone

Brucellosis

Many elk and bison in the Greater Yellowstone Ecosystem have been exposed to the bacterium that causes brucellosis. Brucellosis is a contagious bacterial disease that originated in livestock and often causes infected cows to abort their first calves. It is transmitted primarily when susceptible animals directly contact infected birth material. No cure exists for brucellosis in wild animals. For more information about brucellosis, see "Bison."

The prevalence of brucellosis in Yellowstone elk is low; the rate of exposure to brucellosis in 100 adult female elk captured on the park's northern range during the winters of 2000 to 2005 was 2 percent; it was 3 percent in 130 neonatal elk on the park's northern range during the summers of 2003–2005; and it was 3 percent in 73 adult female elk captured in the park's Madison–Firehole drainages during winters of 1996–1998. Elk are commonly observed within 100 yards of bison during late winter and spring when brucellosis-induced abortion or calving occurs in Yellowstone.

Because of their high densities, elk that are fed in winter have sustained high levels of brucellosis; winter feeding on the northern range stopped more than 50 years ago. Elk are fed during the winter at the National Elk Refuge in Jackson, Wyoming, in addition to 22 Wyoming-run feedgrounds. The feedgrounds were created in the 1900s to maintain Wyoming's elk herds and limit depredation as migratory routes from summer range to lower elevation winter ranges became blocked by settlement in the Jackson area. Transmission of brucellosis from feedground elk, where an average of 30 percent have tested positive for exposure to the bacteria, was the apparent source of infection in Wyoming cattle in 2004.

Chronic wasting disease

Elk, deer, and moose in Greater Yellowstone are at moderate risk for exposure to chronic wasting disease (CWD). This fatal infection, transmitted by animal contact or through the environment, has spread to within 130 miles of the park. National Park Service staff and partners will continue surveillance and, if necessary, take action to minimize both transmission of the disease and the effects of intervention on the elk population and other park resources.

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Staff reviewer

P.J. White, Chief, Wildlife and Aquatic Resources

Moose

Moose in Yellowstone are one of four subspecies of moose (*Alces alces shirasi*) in North America, and are found in forested areas and willow flats from southeastern British Columbia to northern Colorado. They are better adapted to survival in deep snow than other ungulates in Greater Yellowstone. Although some moose in Yellowstone migrate to lower elevations in winter, others move to higher elevations where they can browse beneath a mature forest canopy that reduces snow accumulation. Except during the rut, moose are usually found alone or in small family groups. This behavior, and their use of habitat where they are often well concealed, impedes accurate estimates of population size and distribution.

Description

Moose are the largest members of the deer family in Yellowstone. 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. The weaker animal usually gives up before any serious damage is done; occasionally the opponent's antlers inflict a mortal wound.

Bulls usually shed their antlers in late November or December, although young bulls may retain their antlers as late as March. Shedding their heavy antlers

Bull moose usually shed their antlers in the beginning of winter to help conserve energy and survive the winter.

Moose in Yellowstone

Number in Yellowstone
- Fewer than 100
- Population has declined in last 40 years due to loss of old growth forests surrounding the park, hunting outside the park, burning of habitat, and predators.

Where to See
- Marshy areas of meadows, lake shores, and along rivers.

Behavior and Size
- Adult male (bull) weighs close to 1,000 pounds; female (cow) weighs up to 900 pounds; 5½to 7½ feet at the shoulder. Young weigh 25–35 pounds at birth.
- 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.

WILDLIFE

Like many ungulates, a moose calf can walk 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.

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 five 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 to give birth in.

Population

Moose appear to have been scarce in Yellowstone until the latter half of the 1800s and in Jackson Hole until early in the 1900s. Forest fire suppression, restrictions on moose hunting, and moose transplantations contributed to their subsequent range expansion and increased numbers.

Forest fire suppression was probably the most important factor in their population increase because moose in Greater Yellowstone depend on mature fir forests for winter survival, unlike other North American moose populations that prefer shrubland that has been disturbed by events like fires.

The moose population declined following the fires of 1988 that burned mature fir forests. 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.

Although some Rocky Mountain moose populations have continued to grow and spread into new habitat, those in Yellowstone have declined since the 1980s. Estimated at roughly 1,000 in the 1970s, the current Yellowstone moose population is believed to be less than 200, with the northern range population down by at least 75 percent since the 1980s. Predation of moose calves by bear and wolf populations may be continuing to limit population growth, but the low pregnancy rates of Greater Yellowstone moose suggest limits set by food availability. Long-term studies suggest that North American moose populations tend to erupt, crash, and then stabilize for awhile at a density that depends on current ecological conditions and hunting pressure.

The state of Montana has limited moose hunting in the districts immediately north of Yellowstone to antlered bulls since 1996 and reduced permits to 15 a year. Eight bulls were harvested in 2008, when Montana Fish, Wildlife and Parks estimated that the population in those districts was 150.

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.

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Staff reviewer

P.J. White, Chief, Wildlife and Aquatic Resources

WILDLIFE

Deer

The Greater Yellowstone Ecosystem is home to both mule deer (*Odocoileus hemionus*) and white-tailed deer (*Odocoileus virginianus*). The mule deer is an exclusively western species commonly seen in open-brush country throughout the western states. Widely dispersed throughout Yellowstone National Park during the summer, mule deer migrate seasonally and most of the population winters outside of the park. Although the white-tailed deer is the most common deer species throughout North America, it has never been abundant in Yellowstone. This may be due to habitat and elevation constraints on the northern range or competition from other ungulates that are better suited to park habitat. The two species are differentiated by their antler shape and tail size and appearance.

Behavior

All species of deer use their hearing, smell, and sight to detect predators such as coyotes, cougars, or wolves. 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.

Population

While the relative distribution of mule deer across their winter range has remained similar over the last two decades, the population appears to have increased in recent years. Mule deer populations may decline during severe winters, when deep snow and extremely cold temperatures make foraging difficult.

Mule deer (above) are common in Yellowstone, living throughout the park in almost all habitats; white-tailed deer are scarce and generally occur along streams and water in the northern range.

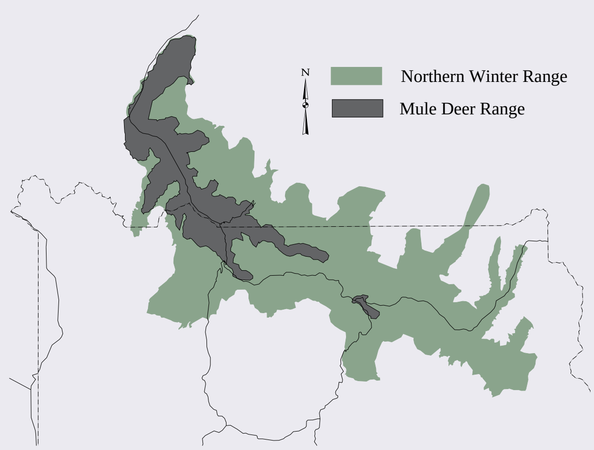
Mule Deer in Yellowstone

Number in Yellowstone
Summer: 1,000–1,300; winter: less than 400

Where to See
Summer: throughout the park; Winter: North Entrance area.

Size and Behavior

- 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 wolves, coyotes, cougars, and bears.



Mule deer winter range lies primarily north of the park boundary.

Although researchers estimate that northern Yellowstone has a summer mule deer population of 1,000 to 1,300, fewer than several hundred stay in the park all winter. Unlike elk and bison, many of which remain in the park throughout the year, mule deer are preyed upon by wolves, coyotes, cougars, and bears in the park mostly in the summer. Because of the mule deer's seasonal distribution, the relative scarcity of white-tailed deer, and the abundance of elk, which are the main prey of wolves, wolf recovery in Yellowstone is believed to have had little effect on deer populations and recruitment.

Although the primary causes of deer mortality are winter kill and predation, mule deer and white-tailed deer outside the park are subject to state-regulated harvesting in the fall. Because of their scarcity, little is known about the white-tailed deer that inhabit the northern range, and the population within the park is not monitored.

White-tailed Deer in Yellowstone

Number in Yellowstone
Scarce, not monitored

Where to See
Along streams and rivers in the northern range.

Size and Behavior
- 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 wolves, coyotes, cougars, and bears.

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Staff reviewer
P.J. White, Chief, Wildlife and Aquatic Resources

Pronghorn

The North American pronghorn (*Antilocapra americana*) is the surviving member of a group of animals that evolved in North America during the past 20 million years. It is not a true antelope, which is found in Africa and southeast Asia. The 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.

Pronghorn evolved in North America 20 million years ago. They can run sprints at 45–50 miles per hour, an adaptation to outrun an extinct cheetah.

Description

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 typically have 10–16 inch horns that are curved at the tips. About 70 percent of the females 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.

Behavior

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 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,

Pronghorn in Yellowstone

Number in Yellowstone
200–300

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 sustain sprints of 45–50 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 1800s, 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 1900s due to overgrazing concerns.

Management Concerns
- Pronghorn are a species of special concern in the park.
- This small population could face extirpation from random catastrophic events such as a severe winter or disease outbreak.

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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.

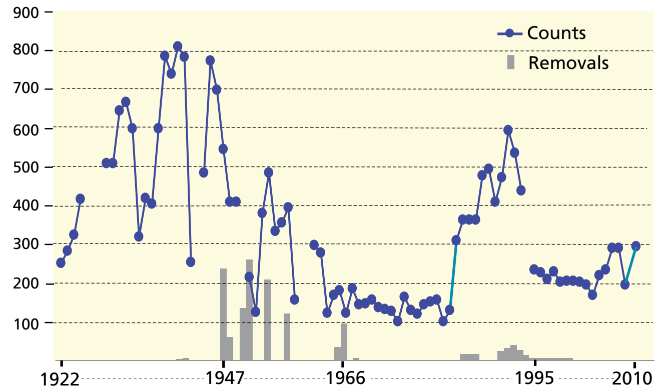
The pronghorn breeding season begins mid-September and extends through early October. During the rut the older males "defend" groups of females (called a harem). They warn any intruding males with loud snorts and wheezing coughs. If this behavior does not scare off the opponent, a fight may erupt. The 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.

Population

During the early part of the 1800s, 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 roam the sagebrush prairies in herds totaling nearly 500 thousand animals.



Pronghorn removals and spring counts in Yellowstone and adjacent areas of Montana, 1918–2010.

The pronghorn's population fluctuations on the northern range show the effects of management interventions as well as natural shifts in forage availability, competition with elk, and predation. Efforts to keep pronghorn in the park with fences and winter feeding reduced their abundance and use of migratory routes by the 1920s, and about 1,200 pronghorn were removed from 1947 to 1967 to address perceived sagebrush degradation. Although hunting has not been allowed north of the park since the 1970s, complaints about crop depredation led to the removal of about 190 pronghorn on private land from 1985 to 2002. The reason for the sudden population decline in the early 1990s remains unclear, but fawn survival is low due to coyote predation, and development of private land north of the park has reduced available winter range. The pronghorn winter range in the park is former agricultural land infested with nonnative vegetation of low nutritional quality.

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.

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Staff reviewer

P.J. White, Chief, Wildlife and Aquatic Resources

Wolves

Although wolf packs once roamed from the Arctic tundra to Mexico, loss of habitat and extermination programs led to their demise throughout most of the United States by early in the 1900s. In 1973, the US Fish and Wildlife Service listed the northern Rocky Mountain wolf (*Canis lupus*) as an endangered species and designated Greater Yellowstone as one of three recovery areas. From 1995 to 1997, 41 wild wolves from Canada and northwest Montana were released in Yellowstone National Park. As expected, wolves from the growing population dispersed to establish territories outside the park where they are less protected from human-caused mortalities. The park helps ensure the species' long-term viability in Greater Yellowstone and has provided a place for research on how wolves may affect many aspects of the ecosystem.

Description

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 range from 2 to 11 individuals. Pack size varies based on the size of its main prey and adequate food. 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 howling, and defend against intrusion by other wolves (individuals or packs).

The Blacktail pack, with 15 wolves, was the largest pack on the northern range in 2011.

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; 10–15 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

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Wolves in Yellowstone

Number in Yellowstone

- 400–450 wolves in the Greater Yellowstone Ecosystem.
- As of December 2012, there were 79 wolves counted in the park, 34 in the northern range, and 45 in the interior. Nine packs were noted.
- As of January 2013, 22% of wolves in the park wear a radio collar.

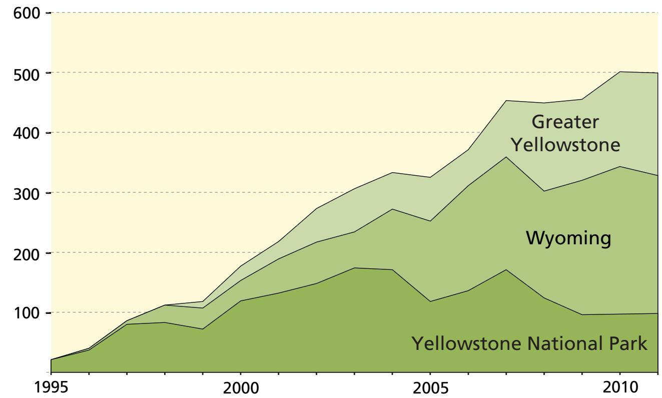
Where to See

- They inhabit most of the park now, look at dawn and dusk.
- The Lamar Valley is one of the best places in the world to watch wolves.

Size and Behavior

- 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 within park ranges from 185 to 310 square miles (300 to 500 square kilometers); 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.
- Researchers are studying the impact of wolf restoration on cougars, coyotes, bears, and elk.

Historical and current range of gray wolves.



Greater Yellowstone wolf population, 1995–2010.

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 this "food stress" occurs, it can lead to increased wolf mortality—which was seen in 2008.

Population

In the first years after restoration began in Yellowstone in 1995, the wolf population grew rapidly as the newly formed packs spread out to establish territories with sufficient prey, primarily elk. The wolves have expanded their population and range, and now are found throughout the Greater Yellowstone Ecosystem.

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, when all but 22 of the pups died. This shortened interval concerns scientists. Infectious canine hepatitis, canine parvovirus, and sarcoptic 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.

The park's wolf population has dropped substantially since 2007, when the count was 171. Most of the decrease has been in packs on the northern range, where it has been attributed primarily to the decline in the elk population there. Disease, primarily distemper and possibly mange, have also been factors in the population decline. In most years, park staff attempt to fit enough wolves in the park with radio collars to keep track of each pack for research and management purposes. Though the number varies each year depending on population size, typically 30 percent of the population is collared by the end of the collaring season.

Wolves in the Northern Rocky Mountains have met the US Fish and Wildlife Service's criteria for a recovered wolf population since 2002. The US Fish and Wildlife Service in 2011 estimated about 1,650 wolves, 244 packs, and 110 breeding pairs in the Northern Rocky Mountain Distinct Population Segment including areas of Idaho, Montana, and Wyoming.

The gray wolf was removed from the endangered species list in 2011 in Idaho and Montana. Wolves are now delisted throughout the northern US Rocky Mountains, including Wyoming. For the first time since restoration, wolves are hunted in each state surrounding Yellowstone.

Interesting Wolf Behavior

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.

Wolves arrived in Yellowstone National Park via truck on January 12, 1995.

Wolf restoration

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 historical range. Predator control, including poisoning, was practiced here in the late 1800s and early 1900s. Other predators such as bears, cougars, and coyotes were also killed to protect livestock and "more desirable" wildlife species, such as deer and elk.

The gray wolf was present in Yellowstone when the park was established in 1872. 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

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Wolf Restoration in Yellowstone

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: 10 wolves from northwestern Montana relocated to Yellowstone National Park; US District Court judge orders the removal of the reintroduced wolves in Yellowstone, but stays his order, pending appeal. (Decision reversed in 2000.)
- 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, and Wyoming removed from the endangered species list, then returned to the list.
- 2009: The US Fish and Wildlife Service again delisted wolf populations in Montana and Idaho, but not in Wyoming. A legal challenge resulted in the Northern Rocky Mountain wolf population being returned to the federal endangered species list.
- 2011: Wolf populations were again delisted in Montana and Idaho by action of Congress within the previous year, and the US Fish and Wildlife Service proposed delisting wolves in Wyoming.
- 2012: Based on a Congressional directive, wolves were delisted in Wyoming and the Northern Rocky Mountain Distinct Population is no longer listed.

Current Status

- Wolves are now delisted throughout the northern US Rocky Mountains, including Wyoming. The US Fish and Wildlife Service will monitor the delisted wolf populations for a minimum of five years to ensure that they continue to sustain their recovery.

136 wolves were killed in the park; by the 1940s, wolf packs were rarely reported. By the mid-1900s, wolves had been almost entirely eliminated from the 48 states.

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.

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 US Fish and Wildlife Service is required by this law to restore endangered species that have been eliminated, if possible. By 1978, all wolf subspecies were on the federal list of endangered species for the lower 48 states except Minnesota. (National Park Service policy also calls for restoration of native species where possible.)

Restoration proposed

National Park Service 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 US Fish and Wildlife Service 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

A wolf is released from its cage into the pen in 1995. 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.

the decline of coyotes and increase of red foxes.

In 1991, Congress provided funds to the US Fish and Wildlife Service to prepare, in consultation with the National Park Service and the US Forest Service, an environmental impact statement (EIS) on restoration of wolves. In June 1994, after several years and a near-record number of public comments, the Secretary of the Interior signed the Record of Decision for the final EIS for reintroduction of gray wolves to Yellowstone National Park and central Idaho.

Staff from Yellowstone, the US Fish and Wildlife Service, and participating states prepared for wolf restoration to the park and central Idaho. The US Fish and Wildlife Service 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 and release

In late 1994 and early 1995, and again in 1996, US Fish and Wildlife Service 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 eight wolves on January 12 and the second six 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 six 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.

Results of the restoration

Preliminary data from studies indicate that wolf recovery will likely lead to greater biodiversity throughout the Greater Yellowstone Ecosystem. 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 Greater Yellowstone Ecosystem. 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 Greater Yellowstone Ecosystem. Results to date indicate the effects of wolf predation on elk population dynamics range from substantial to quite modest.

Canadian and American wildlife biologists captured wolves in Canada and relocated and released them in both Yellowstone and central Idaho. Wolves were temporarily penned before their release.

Current Wolf Management

As a recovered population, wolves are now managed by the appropriate state, tribal, or federal agencies.

Within Yellowstone National Park, no hunting of wolves is allowed. Outside the park, regulated hunting is allowed and managed by the respective states where wolves occur. Because wolves do not recognize political boundaries, and often move between different jurisdictions, the harvest of some wolves that live within the park for most of the year, but at times move outside the park, occurs.

For current information about management of wolves in Yellowstone and the 2012 wolf hunt, visit http://www.nps.gov/yell/naturescience/wolves.htm.

The role of the courts

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.

Legal status of a recovered population

The biological requirements for removing the wolf from the endangered species list have been achieved: at least 300 wolves and three consecutive years of at least 30 breeding pairs across three recovery areas. The US Fish and Wildlife Service approved wolf management plans in Idaho and Montana, and in 2008 it delisted wolves in these two states and in Yellowstone and Grand Teton national parks. Several environmental groups sued to stop the delisting, however. They successfully argued that the Wyoming wolf management plan was flawed and that genetic connectivity had not been established between the Greater Yellowstone Ecosystem and the other recovery areas. A court decision required the wolf to be listed again as an endangered species. In 2009, the US Fish and Wildlife Service again delisted wolf populations in Montana and Idaho, but not in Wyoming. A legal challenge resulted in the Northern Rocky Mountain wolf population being returned to the federal endangered species list.

In 2011, wolf populations were again delisted in Montana and Idaho by an action of Congress, and a proposal by the US Fish and Wildlife Service to delist wolves in Wyoming was still pending. In 2012, a Congressional directive required the US Fish and Wildlife Service to reissue its 2009 delisting, which stated that "if Wyoming were to develop a Service-approved regulatory framework it would be delisted in a separate rule" (74 FR 15123, April 2, 2009, p. 15155).

On September 30, 2012, wolves in Wyoming began to be managed by the State under an approved management plan, as they are in the states of Idaho and Montana. The US Fish and Wildlife Service will continue to monitor the delisted wolf populations in all three states for at least five years to ensure that they continue to sustain their recovery. The US Fish and Wildlife Service may consider relisting the species, and even emergency relisting, if the available data demonstrates such an action is needed, as it does with all recovered species.

Wolves are now managed by the appropriate state, tribal, or federal agencies; management in national parks and national wildlife refuges continue to be guided by existing authorizing and management legislation and regulations.

Your safety in wolf country

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.

Wolf watchers at Slough Creek, one of the best places in the world to observe wild wolves.

Like coyotes, wolves can quickly learn to associate campgrounds, picnic areas, and roads with food. This can lead 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.

Outlook

The future of wolves in Greater Yellowstone will depend on how livestock depredation and hunting of wolves outside the park are handled. Wolf populations will also continue to be affected by the availability of elk, deer, and bison, which fluctuates in response to hunting quotas, winter severity, and disease. To what extent wolves may have contributed to the decline in the northern Yellowstone elk population since the mid-1990s or the possibly related resurgence of willow in some areas is an ongoing topic of debate.

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Staff reviewer

Doug Smith, Senior Wildlife Biologist

Coyotes

Coyotes (*Canis latrans*) are intelligent and adaptable. They can be found throughout North and Central America, thriving in major urban areas as well as in remote wilderness. This adaptability helped coyotes resist widespread efforts early in the 1900s to exterminate them in the West, including Yellowstone National Park, where other mid-size and large carnivores such as cougars and wolves were eradicated. The coyote is a common predator in Greater Yellowstone, often seen traveling through open meadows and valleys, alone or in packs.

Description

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 1900s, 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 seven 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 mark with their scent (urine and feces) to communicate their location, breeding status, and territorial boundaries.

Coyotes in Yellowstone

Number in Yellowstone
Abundant

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

Size and Behavior
- 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 voles, mice, rabbits, other small animals, and carrion—and only the very young elk calves in the spring.
- 4–8 pups are born in April in dens; emerge in May.

History
- Like other predators, coyotes were often destroyed in the early part of the 1900s 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.

Coyotes are abundant throughout the park, and pup survival has increased. Coyotes may be killed by disease and vehicle-collisions as well as by other carnivores like wolves and cougars.

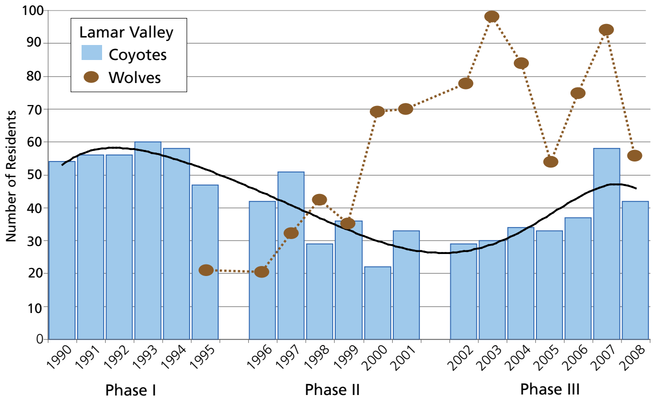
Population

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 killed by wolves—primarily when feeding on other animals killed by wolves. On the northern range, the coyote population decreased as much as 50 percent after wolves were restored as a result of competition with wolves for food, attacks by wolves, and loss of territory to them. More recent trends in the Lamar Valley, however, indicate that the coyote population has increased.

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 coyotes from visitor-use areas and becoming habituated to humans with cracker-shell rounds, bear pepper spray, or other negative stimuli. Animals that continue to pose a threat to themselves

WILDLIFE



Mid-winter coyote counts from the Yellowstone Ecological Research Center; year-end wolf counts from Yellowstone National Park.

or to humans are killed. Coyotes and other park wildlife are wild and potentially dangerous and should never be fed or approached.

Comparisons of coyote population and behavioral data from before and after wolf restoration provide evidence of how the presence of wolves is changing ecological relationships on the northern range. A reduced coyote population could mean that smaller predators such as the native red fox, whose numbers were previously kept low by coyotes, will have less competition for small prey and their populations may increase.

WILDLIFE

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Coyotes (left) are smaller than wolves (right).

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Staff reviewer

Doug Smith, Senior Wildlife Biologist

Foxes

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. 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.

During winter, foxes may increase their activity around dawn and dusk, and even sometimes in broad daylight.

Behavior

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. In 1997, one fox 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 it returned twice. Finally the fox came to Mammoth where it was fed again and as a result was killed by managers. 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.

Most foxes in the lower 48 states, especially in the eastern and plains states, were introduced from Europe in the 1700s and 1800s 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.

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 when they

Foxes in Yellowstone

Number in Yellowstone
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.

Size and Behavior
- 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.


Foxes (left) are smaller than wolves (right) and coyotes (center).

were reintroduced. 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. Foxes do not 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.

Population

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.

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 using 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.

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Staff reviewer
Doug Smith, Senior Wildlife Biologist

Cougars

The cougar (*Puma concolor*), also known as mountain lion, is the one of the largest cats in North America and a top predator native to Greater Yellowstone. (The jaguar, which occurs in New Mexico and Arizona, is larger.) As part of predator removal campaigns in the early 1900s, cougars and wolves were killed throughout the lower 48 states, including national parks. Wolves (*Canis lupus*) were eradicated and, although cougars were probably eliminated from Yellowstone, the species survived in the West because of its cryptic nature and preference for rocky, rugged territory where the cats are difficult to track. Eventually the survivors re-established themselves in Yellowstone, possibly making their way from wilderness areas in central Idaho.

TONI K. RUTH, HORNOCKER WILDLIFE INSTITUTE AND WILDLIFE CONSERVATION SOCIETY

This male cougar was photographed recovering from capture by researchers under controlled research conditions.

Population

Yellowstone's northern range currently supports an estimated population of 14 to 23 adult cougars and numerous kittens. While disease and starvation are occasional causes of cougar deaths, competition with other cougars or predators, and human hunting (during legal seasons outside protected areas) are the main causes of cougar mortality. Habitat fragmentation and loss are the main long-term threats to cougar populations across the western United States.

Behavior

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.

Cougars in Yellowstone

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. Cougars living in areas where they are hunted have much shorter life spans.
- 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 and 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.

WILDLIFE

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 across a wide geographic area.

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.

Cougar Kills

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.

TONI K. RUTH, HORNOCKER WILDLIFE INSTITUTE AND WILDLIFE CONSERVATION SOCIETY

This female cougar was photographed during a research study.

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.

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-1900s.

From 1987 to 1996, the first cougar ecology study was conducted 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. Of the 88 cougars that were captured, 80 were radio-collared.

From 1998 to 2006, the second phase of that research was conducted. Researchers monitored 83 radio-collared cougars, including 50 kittens in 24 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 interfered with or scavenged more than 22 percent of the cougar-killed ungulates. The monitoring associated with this project has been completed and all of the radio-collars have been removed, but years of data are still being analyzed.

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.

Cougars and wolves

Although cougars and wolves once co-existed across much of their historical range, ecological research on each species has often had to be conducted in the absence of the other. By assessing pre- and post-wolf reintroduction data, biologists can learn about the ecological relationships between the two species. As social animals, wolves use different hunting techniques than the solitary cougar, but the two species prey on similar animals. While prey is abundant this competition is of little concern, but, a decrease in prey abundance could lead to an increase in competition between these carnivores.

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Staff reviewer

Kerry Gunther, Bear Management Biologist

Canada Lynx

Although historical records suggest that Canada lynx (*Lynx canadensis*) have been present in the Greater Yellowstone Ecosystem since at least 1893, recent surveys indicate the species is now rare and spotty in distribution. In 2000, the US Fish and Wildlife Service listed the lynx as "threatened" in the lower 48 states. Much of the park and surrounding area is considered much of the critical habitat for the species in the Greater Yellowstone Ecosystem.

Habitat

Lynx habitat in the Greater Yellowstone Ecosystem is often fragmented and generally limited to conifer forests above 7,700 feet where the distribution of its primary prey, snowshoe hare, is patchy and often insufficient to support lynx residency and reproduction. The lower quality habitat means home ranges in this ecosystem are larger than those farther north, with lynx traveling long distances between foraging sites.

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Lynx in Yellowstone

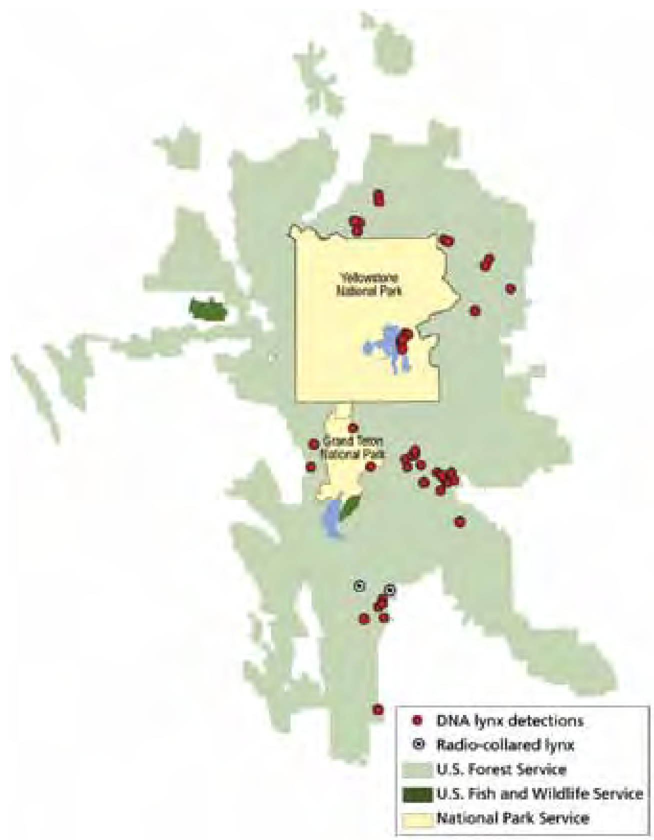
Number in Yellowstone
Few; 112 known observations

Where to see
- Very rarely seen.
- Typical habitat: cold conifer forests.

Size and Behavior
- 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.

COURTESY / FRED PAULSEN

In December 2007, Fred Paulsen, a Xanterra Parks and Resorts employee in Yellowstone, photographed this lynx along the Gibbon River. In 2010, visitors also saw a lynx, which was wearing a radio collar—indicating it may have come from Colorado where the population is collared.



DNA-based detections of lynx documented in the Greater Yellowstone Ecosystem, 1996 to 2008. Numerous locations of radio-collared lynx from Colorado that were obtained using satellite-based telemetry are unavailable. Data provided by Endeavor Wildlife Research, Wild Things Unlimited, the US Forest Service, and the National Park Service.

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Staff reviewer
Kerry Gunther, Bear Management Biologist

Bobcats in Yellowstone
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.

Size and Behavior
- 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.

WILDLIFE

Bats

The bat species that have been documented in Yellowstone National Park are all insectivores (insect-eaters). A single little brown bat (*Myotis lucifugus*, the most common of the species) can consume 1,200 mosquito-sized insects in an hour, and can forage for 3–5 hours per night. The distribution of these species tends to be highly localized near sources of food, water, and roosting structures. They roost in natural habitats, including thermally heated caves, as well as in bridges, buildings, and other human structures, which can lead to conflicts with human use and historical preservation plans.

Population

An inventory completed in 2004 identified bat habitat and documented the presence of these eight bat species in Yellowstone National Park:

- Little brown bat (*Myotis lucifugus*)
- Big brown bat (*Eptesicus fuscus*)
- Long-eared myotis (*Myotis evotis*)
- Long-legged myotis (*Myotis volans*)
- Townsend's big-eared bat (*Corynorhinus townsendii*)
- Fringe-tailed bat (*Myotis thysanodes*)
- Hoary bat (*Lasiurus cinereus*)
- Silver-haired bat (*Lasionycteris noctivagans*)
- Yuma myotis (*Myotis yumanensis*)

Researchers also found inconclusive evidence of three other species. Most of these bats are considered species of concern by Montana and/or Wyoming because of habitat loss and sensitivity to human disturbance. Two of the species probably migrate south for the winter, but most seek relatively warm places to hibernate a short distance from their summer roosts.

While the bulk of bat-related research investigated the taxonomy and distribution of bats in Yellowstone, recent efforts address population dynamics, summer roost site selection, and places for bats to hibernate in the winter (hibernacula). Researchers also sample for diseases that are affecting bat populations in other parts of North America.

Habitat

Roosts provide bats with protection from weather and predators, and the type of roosting structure available affects foraging and mating strategies, seasonal movements, morphology, physiology, and population distribution. Bats in Greater Yellowstone use both natural habitats and man-made structures including bridges and abandoned mines.

Physical adaptations to their environments have given bats their looks. The large ears of this brown bat held by a researcher help it locate its prey. A bat bug (*Cimex pilosellus*) appears on its wing.

Through investigations into the roost site characteristics of little brown bat maternal colonies (females with young during pregnancy and lactation) located in park structures, researchers learned the bats were selecting "warm places with tight spaces." The selection of these places makes sense from an evolutionary standpoint. Young bats can maximize their growth rate, wean, and begin to fly and forage earlier because they are not using much energy to stay warm.

Bats in Yellowstone National Park

Species in Yellowstone
8, and possibly 3 more

Where to see
Dawn and dusk in areas with insects

Behavior

- Develop and reproduce slowly, which is unusual given their small body size.
- Typically mate in the fall. In bats that hibernate, fertilization is delayed until the female emerges from hibernation. For most Greater Yellowstone bats, hibernation ends around mid-April and the females give birth in mid-June.
- Most give birth to one pup a year, although four species in the greater Yellowstone area have two or more pups at a time. These species typically begin flying in 2–6 weeks, are weaned around 5–10 weeks, and become mature in 1–2 years.
- Few predators specialize in bats. Predators are generally opportunistic and include owls, falcons, hawks, snakes, and raccoons.
- Of bats that survive their first year, 40–80 percent survive 7–8 years; many bats live 10–30 years.

Bats are long-lived creatures (10–30 years) and show a strong preference to return to maternal roost sites where they have successfully raised young. For this reason, park managers try to exclude bats from occupying park buildings where they may try to return in the future. In 1904, the "type specimen" describing the subspecies of little brown bat found in Yellowstone was collected from the Lake Hotel. Consequently, most management efforts directed towards bats involve excluding bats from occupying human facilities.

The presence of other bats in Yellowstone is probably restricted by the limited location of suitable roosts and/or the distribution of moths and beetles on which more specialized bats forage. It is likely that most western bat species migrate short distances from their summer roosts to their winter hibernating locations. However, some species migrate long distances to areas where temperature and insect populations remain high enough for continued activity. These species usually do not hibernate. In greater Yellowstone, the hoary bat and silver-haired bat likely migrate south for the winter.

Physical adaptations

Bats with long, narrow wings (e.g., the hoary bat) are fast but less maneuverable fliers that typically forage in open areas. Bats with short, broad wings (e.g., Townsend's big-eared bat) are slower but more agile and typically forage in forested areas or along the edge of vegetation. A few Yellowstone bats, such as long-eared myotis, pallid bat, and Townsend's big-eared bat can glean insects off the surface of vegetation, and have wing shapes that enable them to hover and carry larger prey.

Audio equipment can be used to listen to vocalizations by bats used for echolocation and to determine the level of bat activity at a site and identify some bat species. High frequency calls are less likely to alert predators and are best for locating prey, although some moths have developed "ears" on their abdomens capable of detecting such calls. Most bats also use lower frequency calls (often audible to humans) to communicate with each other. Also, contrary to the expression "blind as a bat," bats typically have excellent vision that can be used for hunting.

Bats make efficient use of the energy obtained through foraging by regulating their body temperature (thermoregulation). To conserve energy, bats can lower their metabolic rate and body temperature (torpor), but they are then unable to carry out normal activities. Most bat species in Greater Yellowstone undergo torpor that may continue for months and is typically a seasonal response to a prolonged fall in temperature or reduction in food supply.

At rest, bats roost head down, which makes them less vulnerable to predators and facilitates flight. A bat can remain upside down for months because of cavities in its cranium that pool blood and other fluids away from the brain and an arrangement of ligaments and leg muscles that enables them to hang passively from their perch while sleeping.

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Staff reviewer

Roy Renkin, Vegetation Specialist

Beavers

The beaver (*Castor canadensis*) is a keystone species that affects habitat structure and dynamics through the damming and diverting of streams, and the felling of trees and other woody vegetation. The resulting ponds and flooding help create an environment favorable to willow and aspen, the beavers' preferred winter foods and used in building their lodges. The territoriality of beavers probably deters two colonies from locating within 50 meters of each other, and most streams in the park lack either suitable vegetation or a sufficiently low gradient to provide beavers with habitat, but information about the distribution and number of beaver colonies in the park over time adds to our understanding about the long-term effects of changes in vegetation and climate.

The beaver is a keystone species that affects habitat structure and dynamics through the damming and diverting of streams, and the felling of trees and other woody vegetation

Habitat

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. These areas are likely important habitat because of their waterways, meadows, and the presence of preferred foods such as willow, aspen, and cottonwood.

However, beavers are not restricted to areas that have their preferred foods. Essentially no aspen exist in most areas where beavers' sign is most abundant, such as the Bechler River and 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 cut conifer trees and feed on submerged vegetation such as pond lilies.

Beavers are famous dam builders, and examples of their work can be seen from the roads in the park. 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. An old dam is visible at Beaver Lake between Norris and Mammoth.

When hunched over their food, beaver can resemble round rocks. Beavers are most active in the early morning and late evening, which seem to allow them to use areas near human use. Beavers do not appear

Beavers in Yellowstone

Number in Yellowstone
112 colonies counted in 2011

Where to see

- Willow Park (between Mammoth and Norris), Beaver Ponds (Mammoth area), Harlequin Lake (Madison area), and the Gallatin River along US 191.
- In the backcountry: upper Yellowstone River (Thorofare region), Bechler River, and Slough Creek. Occasionally seen in the Lamar, Gardner, and Madison rivers.
- Wait in areas near known beaver activity. You may see them swimming or clambering onto the bank to gnaw at trees and willows. Listen for the sound of the beaver slapping its tail on the water before it submerges to seek safety.

Behavior and Size

- Crepuscular: active in evening and morning
- If living on rivers, may build bank dens instead of lodges.
- One colony may support 2–14 beavers that are usually related. Six is considered average.
- 35–40 inches long, including tail.
- Weighs 30–60 pounds.
- Average life span: 5 years.
- Male and female beavers look alike—thick brown fur, paddle-shaped tail.
- Like wolves, beavers live in family groups, which are called colonies. Fewer than 5% of mammals live organized like this.

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.

to avoid areas of moderate to high levels of human use. Several occupied lodges in Yellowstone are close to popular backcountry trails and campsites.

Population

The first survey of beavers in the park, conducted in 1921, reported 25 colonies, most of them cutting aspen trees. Although it was limited to parts of the northern range, comparing the locations of those beaver colonies with subsequent survey results demonstrates how beavers respond and contribute to changes in their habitat. A 1953 survey found eight colonies on the northern range, but none at the sites reported in 1921 and a lack of regrowth in cut aspen. Willow were also in decline during this period.

To help restore the population of beavers on Gallatin National Forest, 129 beavers were released into drainages north of the park from 1986 to 1999. Park-wide aerial surveys began in 1996 with a count of 49 colonies and increased to 127 by 2007; dropping to 118 in 2009 and 112 in 2011. While the long-term increase is partly attributable to the improving ability of aerial observers to locate colonies, the park's population of beavers probably has grown in the last 15 years. Some of the increase likely came from beavers dispersing from the national forest, but they would not have survived without suitable habitat. The increase has occurred throughout the park and is likely related to the resurgence in willow since the late 1990s, at least on the northern range, and possibly in the park interior. Nearly all of the colonies documented in recent years were located in or near willow stands, none near aspen.

Willow, which is more common in the park than aspen, is a hardier shrub that quickly regenerates after being clipped by beavers. The reason for the prolonged decline and relatively sudden release of willow on the northern range, and whether aspen have begun a sustained surge in recruitment, are topics of intense debate. Possible factors include the relationship of these plant species to changes in the abundance of beavers and elk, fire suppression, the reintroduction of wolves, and climate change.

The preferred foods of beaver are willow, aspen, and cottonwood. Where their preferred plants are few or absent, beavers may cut conifer trees and feed on submerged vegetation such as pond lilies.

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Staff reviewer
Doug Smith, Senior Wildlife Biologist

Pikas

Pikas (*Ochotona princeps*) are small territorial mammals about the size of guinea pigs. They inhabit rocky alpine and sub-alpine zones feeding on the vegetation that fringes their preferred talus slopes. Colored gray to brown with round ears and no tail, they blend in with their rocky home and agilely maneuver between and underneath obstacles. Because pikas do not hibernate, this relative of the rabbit must gather enough plant materials during the short growing season to survive the winter. Piles of drying vegetation, called haystacks, and a distinctive high-pitched call are the most recognizable indicators of active pika habitat. Prolific breeders, pikas usually have two litters of young each summer. The mortality rate is high for the youngsters and the first litter has a greater rate of survival. These small mammals are sensitive to temperatures above 77.9°F; therefore, they are most active during cooler parts of the day.

While abundant in the Greater Yellowstone Ecosystem, pika numbers are declining in other western regions. Studies suggest changing climate is the probable cause of their overall decline. While the recent US Fish and Wildlife Service review of the pika found no current need to list the species as threatened or endangered, pikas will likely disappear from some lower elevation or warmer sites. The pika's sensitivity to temperature change draws increased interest in the species.

Research

The National Park Service Climate Change Response Program funded a project to address questions regarding the vulnerability of the American pika to future climate change scenarios projected for the western United States. A large team of academic researchers and National Park Service staff are involved in this project, and will be working in these eight National Park Service Units: Crater Lake, Great Sand Dunes, Grand Teton, Lassen Volcanic, Rocky Mountain and Yellowstone national parks, and in Craters of the Moon and Lava Beds National Monuments. More information can be found at the "Pikas in Peril" project website: science.nature.nps.gov/im/units/ucbn/monitor/pika/pika_peril/index.cfm.

A pika, blending in with its surroundings, carries grass to its haystack.

Staff reviewer
Kerry Gunther, Bear Management Biologist

Pikas in Yellowstone

Number in Yellowstone
Abundant

Where to See
Tower and Mammoth areas, most often

Identification and behavior

- 7–8.4 in. long, 5.3–6.2 ounces (about the size of a guinea pig).
- 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, which allows additional digestion of food.

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.

White-tailed Jackrabbits

Considered an agricultural or garden pest in many parts of the country, the white-tailed jackrabbit (*Lepus townsendii*) has found a niche in Yellowstone. Most of the park is too forested or accumulates too much snow to provide suitable habitat, but in lower elevation areas of the northern range it can feed on sagebrush, rabbitbrush, and other shrubs during the winter. The jackrabbit is preyed upon by bobcats, coyotes, wolves, eagles, hawks, and owls in the park, but perhaps because of its limited distribution, it does not appear to provide a significant source of food for these species.

The coat of white-tailed jackrabbits turns white during winter in Yellowstone and other areas with snow.

Description

Despite its common name, the jackrabbit is more closely related to other hares than to rabbits (*Sylvilagus* spp.) Like the much smaller snowshoe hare (*Lepus americanus*), which resides in Yellowstone's coniferous forests, the jackrabbit has a grayish-brown summer coat that turns nearly white to provide winter camouflage in areas with persistent snow cover. The slightly smaller black-tailed jackrabbit (*Lepus californicus*), which is found in lower elevation areas, has not been documented in the park and is generally less common in Greater Yellowstone.

Population

Nearly all of the 501 jackrabbit observations recorded in 2008 and spottier records prior to that were made in sagebrush-grassland habitat at elevations below 6,500 feet (2,000 m) where the average annual precipitation is less than 16 inches (40 cm). Less than 1 percent of the park (about 18,700 acres) is located in these areas, which are found in the Gardiner Basin, along the Gardner River, and in Mammoth Hot Springs. Although some jackrabbit populations are known to fluctuate markedly over the short- or long-term, no evidence has been found that the abundance or distribution of jackrabbits in Yellowstone has changed substantially since the park was established in 1872. Jackrabbits are found as high as 14,600 feet (4,200 m) in Colorado, but a limiting factor in Yellowstone appears to be snow, which begins to accumulate earlier in the winter, attains greater depths, and lasts later into spring with increasing elevation.

More information

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White-tailed Jackrabbits in Yellowstone

Number in Yellowstone
Common in habitat

Where to See
Mammoth area

Identification
- Easily distinguished from true rabbits by their large ears, large feet, and generally large body size.
- Use their ears to listen for danger and to radiate body heat. Large ears allow them to release excess body heat and tolerate high body temperatures.
- Summer coat is grayish brown, with a lighter underside. In Yellowstone and other places where there is persistent and widespread snow cover, the coat changes to nearly white in winter. Ears are rimmed with black.

Habitat
- Found in prairie-grassland and grass-shrub steppe habitat types in western high plains and mountains. They generally prefer grass-dominated habitats and have also been found to flourish above treeline in the alpine zone and avoid forested areas.

Behavior
- Have 1–4 litters per year with 1 to 15 offspring. Gestation is 36–43 days.
- In most areas, the breeding season of white-tailed jackrabbits averages 148 days and may run late February to mid July. Breeding in the northern Yellowstone ecosystem is not well documented.
- Feed on grasses, forbs, and shrubs at night and are less active during the day.
- Can run from 35 to 50 mph (56 to 80 kph) and cover 6–10 ft (2–3 m) with each bound. Will also swim when being pursued by predators.

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Staff reviewer
Kerry Gunther, Bear Management Biologist

WILDLIFE

Snowshoe Hares in Yellowstone
Lepus americanus

Number in Yellowstone
Common in some places

Where to see
Mammoth area

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.
- 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.
- Mostly nocturnal; their presence in winter is only advertised by their abundant tracks in snow.

Wolverines

A mid-size carnivore in the weasel family, the wolverine (*Gulo gulo*) is active throughout the year in cold, snowy environments to which it is well adapted. Its circumpolar distribution extends south to mountainous areas of the western United States, including the greater Yellowstone area where they use high-elevation islands of boreal (forest) and alpine (tundra) habitat. Wolverines have low reproductive rates, and their ability to disperse among these islands is critical to the population's viability. Climate change models predict that by 2050, the spring snowpack needed for wolverine denning and hunting will be limited to portions of the southern Rocky Mountains, the Sierra Nevada range, and greater Yellowstone, of which only the latter currently has a population. Wolverines are so rarely seen and inhabit such remote terrain at low densities that assessing population trends is difficult sudden declines could go unnoticed for years.

US FOREST SERVICE/GARDINER RANGER DISTRICT

Remote cameras, like the one that took this photo, were used to record wolverine activity at live traps during a collaborative study in the greater Yellowstone area from 2006 to 2009. Here, wolverine F3 revisits a live trap, which did not capture her, in 2008. Each trap was baited with a skinned beaver carcass obtained from Montana fur trappers and had a transmitter that signaled up to 18 miles when the trap was triggered.

Population

Commercial trapping and predator control efforts substantially reduced wolverine distribution in the lower 48 states by the 1930s. Some population recovery has occurred, but the species has not been documented recently in major portions of its historic range. In the Greater Yellowstone Area, wolverines have been studied using live traps, telemetry, and aerial surveys. A group sponsored by the Wildlife Conservation Society has documented ranges that extend into Yellowstone National Park along the northwest and southwest boundary. A second group, which included researchers from the National Park Service, the US Forest Service, and the Northern Rockies Conservation Cooperative, which surveyed the eastern part of the park and adjoining national forest from 2006 to 2009, documented seven wolverines. The average annual range for the two monitored females was 172 mi^2 (447 km^2); for three males, 350 mi^2 (908 km^2). The other two males, both originally captured by the Wildlife Conservation Society, dispersed from west and south of the park: M557 established a home range north of the park in 2009; M556 became the first confirmed wolverine in Colorado in 90 years. But to create a breeding population there, he will need to find a female.

In February 2013, the US Fish and Wildlife Service proposed listing wolverines in the lower 48 states as a threatened species under the Endangered Species Act.

Wolverines in Yellowstone

Number
2006–2009: seven documented in eastern Yellowstone and adjoining national forests (two females and five males)

Size and Behavior
- 38–47 inches long, 13–31 pounds.
- 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, elk, and moose.
- Active year-round, intermittently throughout the day.
- Breed April to October; one 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.

Management Concerns
In February 2013, the US Fish and Wildlife Service proposed listing wolverines living in the lower 48 states as a threatened species under the Endangered Species Act.

Conservation status

Wolverine populations in the US Rockies are likely to be genetically interdependent. Even at full capacity, wolverine habitat in the Yellowstone area would support too few females to maintain viability without genetic exchange with peripheral populations. The rugged terrain that comprises a single wolverine

COURTESY / JASON WILMOT

Wolverines have a distinctive gate.

WILDLIFE

home range often overlaps several land management jurisdictions. Collaborative conservation strategies developed across multiple states and jurisdictions are therefore necessary for the persistence of wolverines in the continental United States. The wolverine has been petitioned for federal listing as an endangered species. In Montana, which has the largest wolverine population of the lower 48 states, about 10 wolverines are harvested annually by licensed trappers.

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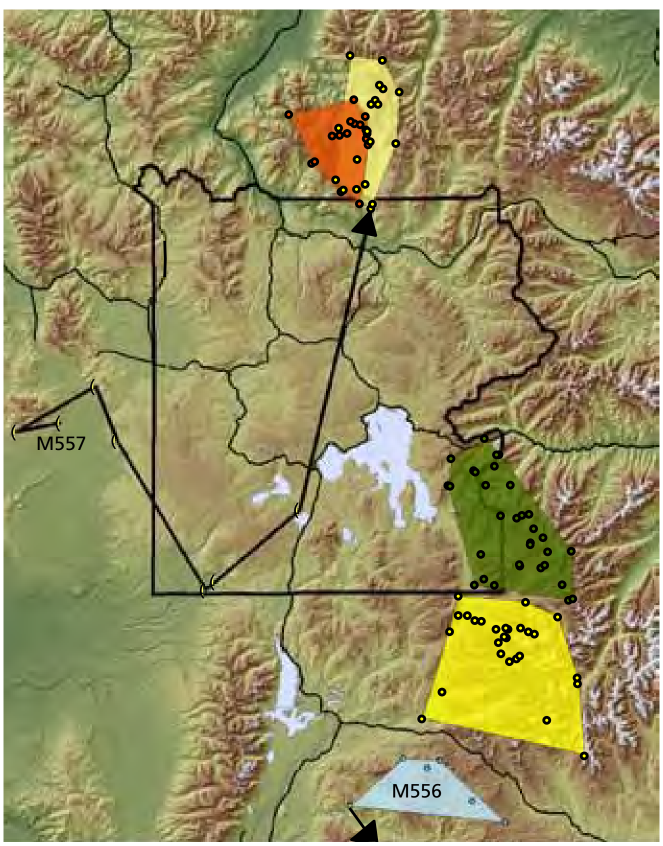

Home ranges of five wolverines documented in 2009.

Staff reviewer

Kerry Gunther, Bear Management Biologist

Other Small Mammals

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 percent 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 five young per year.

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.

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.

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; 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.

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 percent 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.

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.

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 percent larger than females.
- Compare to marten and short-tailed weasel.

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 and short-tailed weasel.

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 and 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 four litters of 2–10 young per year.

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 five young per year.
- Burrow systems are elaborate and often bi-level; can be 400–500 feet long.
- Very territorial; only one per burrow.

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. Mostly crepuscular but have been seen at all times of the day.
- 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.
- May move long distances between water bodies.

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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.
- Sometimes referred to as "rockchucks."

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.

More than 300 bird species have been sighted in Yellowstone National Park, including raptors, songbirds, shorebirds, and waterfowl. About 150 species build their nests and fledge their young in the park.

Birds

Records of bird sightings have been kept in Yellowstone since its establishment in 1872. These records document 330 species of birds to date, including raptors, songbirds, shorebirds, and waterfowl. Approximately 150 species nest in the park. The variation in elevation and broad array of habitat types found within Yellowstone contribute to the relatively high diversity. Many of the birds are migratory species. There are currently no federally listed bird species in Yellowstone National Park.

The Yellowstone National Park bird program monitors a small portion of its breeding bird species to gather information like reproduction, abundance, and habitat use, on multiple species from a wide variety of taxonomic groups; and maintain data from 20 or more years for several species. Long-term monitoring efforts help inform park staff of potential shifts in ecosystem function (e.g., climate change effects) for Yellowstone's bird community and may guide future conservation of the park's birds and their habitats.

Climate change

The timing of the availability of food sources for birds may change with rising temperatures and changing weather patterns. Birds are sensitive to shifts in seasonal weather patterns and show a relatively rapid response to these fluctuations. For example, climate change has been shown to influence migration patterns, population size and distribution, and the timing of reproduction and nesting success for birds. Through monitoring, birds can be used as a "canary in the coal mine" to help managers detect changes in ecosystem function so that appropriate management action can be taken.

The Yellowstone bird program will monitor the arrival of species to the park, timing of nest initiation, incubation, and fledging for several raptor species, which may be useful in observing the effects of climate change in Yellowstone.

Breeding bird surveys

Breeding bird surveys are a nationwide monitoring effort coordinated by the US Geological Survey and the Canadian Wildlife Service's Research Center. Since the 1980s, Yellowstone National Park has participated in these long-term surveys conducted throughout North America. The surveys are

Birds in Yellowstone

Number in Yellowstone
330 documented species; approximately 150 species nest in the park.

Species of Concern
- Trumpeter swans
- Common loons

Current Management
The Yellowstone National Park bird program monitors the park's bird species, including species of concern. The program's core activities are monitoring raptors (bald eagles, ospreys, and peregrine falcons), wetland birds, and passerine/near passerine birds (songbirds and woodpeckers).

Birding in Yellowstone

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 August. At the same time, other birds pass through Yellowstone. Hawk-watching can be especially rewarding in Hayden Valley late August through early October. In early November, look for tundra swans on the water.

Birds that stay in Yellowstone year-round include the common raven, Canada goose, trumpeter swan, dusky grouse (formerly blue grouse), gray jay, red-breasted nuthatch, American dipper, and mountain chickadee. A few species, such as common goldeyes and bohemian waxwings, migrate here for the winter.

Visitors may report sightings with a bird observation form, available at http://www.nps.gov/yell/naturescience/upload/Rare_Bird_Observation_Form.pdf and at visitor centers.

Please note: The use of audio bird calls is illegal in the park.

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road-based with the registered observer recording all birds seen and heard within a quarter mile radius with points occurring every half mile. The surveys are conducted in June, during the height of the songbird breeding season. Yellowstone has three routes: Mammoth area, Northeast Entrance area (Tower Junction to Round Prairie), and the interior (Dunraven Pass through Hayden Valley and Yellowstone Lake).

In 2011, surveyors detected 2,405 individuals of 71 species. The Mammoth route had the highest diversity of species, while the interior route had the highest number of individuals counted. Large flocks of Canada geese along the Yellowstone River accounted for 70 percent of all observations along the interior route. Canada goose numbers vary widely from year to year, however during 2011 were the highest they have been since Breeding Bird Surveys began in Yellowstone.

FREQUENTLY ASKED QUESTION:

Where are good birding locations?

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

Hayden Valley is one of the best places to view water birds and birds of prey. Shorebirds 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 Pond and Floating Lake Island, between Mammoth and Tower Junction, and the Madison River west of Madison Junction are also good places to look for birds.

More information

Annual Bird Program Reports. National Park Service, Yellowstone National Park. http://www.nps.gov/yell/naturescience/birdreports.htm

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Staff reviewers

Doug Smith, Senior Wildlife Biologist
Lisa Baril, Yellowstone Raptor Initiative
Katy Duffy, Interpretive Planner

Bald eagles are one of more than a dozen raptor (birds of prey) species in Yellowstone. The peregrine falcon and bald eagle are recovered endangered and threatened species.

Raptors

More than a dozen raptor (birds of prey) species can be seen in Yellowstone. The park supports 12 diurnal raptor and 7 breeding owl species. Additional species use the Yellowstone landscape during migrations and seasonal movements. The park's bird program monitors bald eagles, ospreys, and peregrine falcons. The bald eagle and peregrine falcon were previously listed as endangered and threatened species and their monitoring is required by law. The osprey is monitored because a food source, the cutthroat trout, declines in Yellowstone Lake. Other species that occur in the park such as golden eagles and Swainson's hawks are of growing conservation concern throughout their ranges in the United States.

Yellowstone Raptor Initiative

The Yellowstone Raptor Initiative is a five-year, science-based program started in 2011 designed to learn more about the park's raptors that are not monitored under the bird program. The initiative inventories and monitors select raptor species to provide baseline information on population size, productivity, and seasonal movements for these other species.

The Yellowstone Raptor Initiative selected golden eagles (*Aquila chrysaetos*), red-tailed hawks (*Buteo jamaicensis*), Swainson's hawks (*Buteo swainsoni*), American kestrels (*Falco sparverius*), prairie falcons (*Falco mexicanus*), and owls as focal species with specific research goals. Accipiters (sharp-shinned hawks, Cooper's hawks, and northern goshawks) were not selected because of the intensity of surveys needed to gather enough information to analyze.

The Yellowstone Raptor Initiative relies on citizen science to acquire valuable data on raptors in the park, and raptor observation forms are available at all visitor centers and ranger stations for employee and visitor sightings and www.nps.gov/yell/naturescience/upload/Raptor_Observation_Form.pdf.

Bald eagles

The bald eagle (*Haliaeetus leucocephalus*) was named the national symbol of the United States by Congress in 1782. Found near open water from Mexico to Alaska, bald eagles may range over great distances but typically return to nest in the vicinity where they fledged. In Greater Yellowstone they feed primarily on fish, but also on waterfowl and carrion. Numbers declined dramatically during most of the 1900s due to habitat loss, shooting, and pesticide contamination. In 1978, the US Fish and Wildlife Service listed the bald eagle as an endangered species in 43 states, including Idaho, Montana, and Wyoming. Habitat protection and restrictions on killing the birds and pesticide use led to population growth and delisting of the species in 2007. Bald eagles nesting in northwestern Wyoming are part of a significant Rocky Mountain breeding population that extends into Idaho and Montana.

Population

Bald eagles, which may reuse the same nest year after year, occupy territories near the park's major rivers and lakes. Juveniles may migrate to warmer habitat in the fall but adults often stay in the park year-round. Winter numbers in the park are increased by the arrival of bald eagles that breed farther north. The

Bald eagles are frequently seen near Yellowstone's major rivers.

number of eaglets that fledge each year depends partly on weather and can fluctuate widely.

More than half of the park's known bald eagle nests have been in the Yellowstone Lake area, where the productivity and success rates are generally much lower than the productivity and success rate for bald eagles nesting in the rest of the park. However, in 2012 nest success and productivity were the same for both areas.

Outlook

Because research has shown that human presence can disturb eagle nesting and foraging, nest areas in national parks may be closed to visitors. Yellowstone manages nest sites on a case by case basis.

In a raptor program that documented 964 sightings of 22 raptor species in Yellowstone during 2010 and 2011, bald eagles were the second most commonly reported species (13 percent) after red-tailed hawks (28 percent). A recent study found little evidence to support the claim that cutthroat trout declines have resulted in lower nesting success for bald eagles on Yellowstone Lake.

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Staff reviewers

Doug Smith, Senior Wildlife Biologist
Lisa Baril, Yellowstone Raptor Initiative
Katy Duffy, Interpretive Planner

Bald Eagles in Yellowstone

Number in Yellowstone

In 2012, park staff monitored 22 pairs of eagles.

- Of the 22 active nests, 14 (64%) were successful, which is greater than the 29-year average of 49% nest success.
- 21 young were produced. Productivity (young per nesting female) for active nests in 2012 averaged 0.95, which is greater than the 29-year average of 0.69.
- The reproductive rate of bald eagles in Yellowstone is stable, but the productivity and success rate of bald eagles nesting in the Yellowstone Lake area are generally much lower than the productivity and success rate for bald eagles in the rest of the park. However, in 2012 nest success and productivity were the same for both areas.

Where to See

Near water and animal carcasses

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. They also nest in large trees close to water.
- Golden eagles hunt in open country for rabbits and other small mammals.
- Exception: Both feed on carcasses in the winter, sometimes together.

Behavior

- 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 and waterfowl, except in winter when fish stay deeper in water and they eat more waterfowl. Eagles will also eat carrion in winter if it is readily available.
- Form long-term pair bonds.
- Many adults stay in the park year-round. 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, young (eaglets) are immobile, downy, have their eyes open, and are completely dependent upon their parents for food.
- Can fly from the nest at 10–14 weeks old.
- Some young migrate in fall to western Oregon and Washington.

Management Concerns

Bald eagles, like osprey, are among the fish-eating wildlife being monitored to determine any effect from the declining cutthroat trout population.

Ospreys

Like many other birds of prey, osprey (*Pandion haliaeetus*) populations declined due to pesticides in the mid-1900s. Its populations rebounded during the latter part of the 1900s. The first study of ospreys in Yellowstone National Park occurred in 1917 by M. P. Skinner, the park's first naturalist. It was not until 1987 that the Yellowstone National Park bird program began monitoring breeding ospreys annually, although an extensive survey on reproduction, diet, and habitat was conducted during the 1970s.

Since monitoring began, Yellowstone's population of osprey has been considered relatively stable. On average, 50 percent of nests succeed (produce eggs) each year, with each successful nest producing an average of one to two young. These statistics are slightly lower than expected for a stable and healthy population, and may be explained by the park's harsh environment. In a recent study, scientists found that declining nest success for osprey around Yellowstone Lake is due, in part, to the decline of cutthroat trout.

Ospreys are surveyed via fixed-wing aircraft and by ground-based surveys from May through August. During the survey flights, the majority of nests are monitored for occupancy and breeding activity. In addition, all suitable lakes and rivers are surveyed for potential new territories and nest sites.

Ospreys are monitored by park staff. In 2012, 25 nests were monitored in Yellowstone.

More information

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Staff reviewers

Doug Smith, Senior Wildlife Biologist
Lisa Baril, Yellowstone Raptor Initiative
Katy Duffy, Interpretive Planner

Ospreys in Yellowstone

Number in Yellowstone

- In 2012, 25 nests were monitored, with 60% successful, while the 26-year average was 49% successful nests.
- Young produced per breeding pair averaged 1.12 in 2012, while the 26-year average was 0.82.
- For the first year since 2007, one of four monitored osprey nests at Yellowstone Lake was successful.
- Parkwide, osprey reproduction has increased each year since 2003.

Where to See

Near water

Identification

- Slightly smaller than the bald eagle.
- Mostly white belly, white head with dark streak through eye.
- Narrow wings, dark patch at bend.
- Fledglings have light edges to each dark feather on their backs and upper wing surfaces, which gives them a speckled appearance.

Habitat

- Usually near lakes (such as Yellowstone Lake), river valleys (such as Hayden, Madison, Firehole, 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 and leaves in 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.

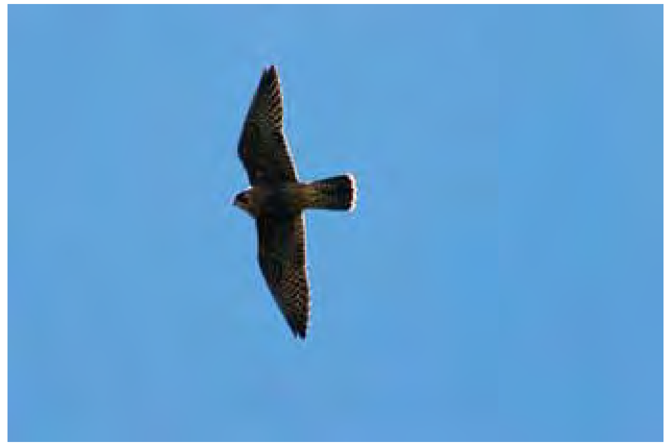
Research

A recently completed study conducted by park biologists found a significant relationship between the declines in cutthroat trout and osprey reproduction at Yellowstone Lake. Recent increases in the number of young cutthroat trout caught by the Yellowstone fisheries program during the fall netting assessment are encouraging. An increase in cutthroat trout production may lead to an increase in nesting pairs of ospreys and improved nest success at Yellowstone Lake.

WILDLIFE

Peregrine falcons

The peregrine falcon is among the fastest birds, flying at up to 55 mph and diving at more than 200 mph when striking avian prey in mid-air. Peregrine populations began to decline in the 1940s because of pesticide contamination. One of three North American subspecies, the peregrine in Greater Yellowstone (*Falco peregrinus anatum*) was considered extirpated by the 1960s. As part of a national reintroduction program, captive-bred peregrines were released in Yellowstone and Grand Teton national parks during the 1980s. They typically reside in Greater Yellowstone from March through October, when their favored prey—songbirds and waterfowl—are most abundant. During winter they may migrate as far south as Mexico or farther.



Peregrine falcons (juvenile shown here) are a recovered endangered species in Yellowstone.

History

In 1962, Rachel 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. Yellowstone National Park was a site for peregrine reintroductions in the 1980s, which were discontinued when the peregrine population began increasing on its own following restrictions on organochlorine pesticides in Canada and the United States, habitat protection, and the reintroduction program. The falcon made a comeback in much of its former range, and was delisted in 1999. For 15 years after the delisting, the peregrine will be monitored closely, and scientists will watch for threats to their population.

In Yellowstone, the most nesting pairs recorded was 32 in 2007, and they produced 47 fledglings. Although nesting pairs may reuse the same eyrie for many years, their remote locations on cliff ledges makes it impractical to locate and monitor activity at all eyries in a single year.

Yellowstone National Park's relatively pristine conditions and long-term monitoring of peregrines provide baseline information to compare against other populations in the United States. Continued monitoring is essential, not only for comparisons with other populations, but also because peregrine falcons and other raptors are reliable indicators of

Peregrine Falcons in Yellowstone

Number in Yellowstone
2012:
- From April to July, biologists monitored 23 of the 33 of the known eyries in Yellowstone; 19 were occupied by at least one adult.
- Nesting occurred in 14 eyries; 12 pairs raised 26 young.
- The 25-year average nest success is 79%, while the average nest success for 2012 is 86%.
- The 25-year average productivity is 1.73 young per breeding pair, while the 2012 average is 1.86 young per breeding pair.

Where to See
Areas with cliffs

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.
- Lays 3–4 eggs in late April to mid-May.
- Young fledge in July or early August.
- Dives at high speeds (can exceed 200 mph) and strikes prey in mid-air.

contaminants (such as PBDE—polybrominated diphenyl ether) and climate change. For example, to assess the levels of PBDE, scientists collect eggshell remains after peregrines have left their nests for the season.

Recovery in Yellowstone

While the organochlorines found in peregrine eggshell fragments and feather samples have declined significantly, several studies indicate that certain flame retardant chemicals developed in the 1970s for use in electronic equipment, textiles, paints, and many other products leach into the environment and have been found in birds of prey at levels that impair their reproductive biology. In 2010 and 2011, eggshell fragments, feathers, and prey remains have been collected from nest sites in Yellowstone after fledging occurred. Comparative data on eggshell thickness, which is an indicator of environmental contaminants, is not available for the northern Rockies, but the eggshells from Yellowstone have been within the range considered normal for the Pacific Northwest. The prey remains have included fish fins, snake remains, and the foot of a pine marten.

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Staff reviewers

Doug Smith, Senior Wildlife Biologist
Lisa Baril, Yellowstone Raptor Initiative
Katy Duffy, Interpretive Planner

American white pelicans, sometimes mistaken for trumpeter swans at a distance, appear to be stable. Pelicans and other colonial nesting birds nest primarily in the southeast arm of Yellowstone Lake.

Wetland Birds

Approximately 30 percent of bird species that breed in the park depend on wetlands. Scientists are concerned about these species because wetlands are expected to diminish as temperatures increase. They are monitoring the trumpeter swan, common loon, and colonial nesting species, like the double-crested cormorant and American white pelican. Yellowstone has years of data about the rate and success of nesting for some of these species, but not enough information about changes in the timing of their nesting activity, which is an indicator of climate change.

Colonial nesting birds

Colonial nesting birds nest primarily on the Molly Islands in the southeast arm of Yellowstone Lake. These two small islands are cumulatively just 0.7–1.2 acres in size, depending on lake water levels, yet hundreds of birds have nested there in a single year. The birds have been surveyed for more than 30 years, with some data going back to 1890 when nesting American white pelicans (*Pelecanus erythrorhynchos*) and California gulls (*Larus californicus*) were first noted in this area.

Currently, pelicans, California gulls, and double-crested cormorants (*Phalacrocorax auritus*) are nesting, with success rates that vary from year-to-year. Very wet and cold late spring weather and the declining cutthroat trout population could be factors. In 2012, 270 pelican chicks, 19 California gull chicks, and 21 cormorant chicks fledged.

Habitat

Birds nesting on the Molly Islands are subject to extreme environmental conditions ranging from flooding, frosts that can occur at any time of year, and high winds. As a result, birds nesting there experience large year-to-year fluctuations in the number of nests initiated and fledglings produced. Overall, populations appear stable for American white pelicans, California gulls, and double-crested cormorants. Caspian terns (*Hydroprogne caspia*), however, have been declining for a number of years and currently no terns nest on the islands. The reason(s) for these declines are unknown.

Caspian terns were suspected of nesting on the Molly Islands by 1917, although information on breeding status was not collected until 1933. Double-crested cormorants were confirmed nesters by 1928. Prior to the late 1970s, the Molly Islands were surveyed only intermittently, but have been surveyed annually since that time.

American white pelicans 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.

More information

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Staff reviewers

Doug Smith, Senior Wildlife Biologist
Lisa Baril, Yellowstone Raptor Initiative
Katy Duffy, Interpretive Planner

The population of California gulls appears to be stable.

Common loons

The park's common loon (*Gavia immer*) population is one of the most southerly breeding populations in North America. Approximately 75 percent of Wyoming's population of breeding common loons occurs in Yellowstone. The common loon is listed as a Species of Special Concern in Wyoming because of its limited range, small population, sensitivity to human disturbance, and loss of breeding habitat outside of Yellowstone. Wyoming's breeding loon population is isolated from populations to the north by more than 200 miles, making immigration from other populations limiting. Since the mid-2000s, Wyoming's population has declined by 42 percent. Yellowstone's loon population has declined since surveys began in 1989, but the factors responsible for the decline are unknown. A three-year study (2012–2014) is being conducted to identify these factors.

The common loon is a species of concern in Yellowstone.

Population

In 2012, park biologists checked 24 lakes for loon activity. Some lakes, like Yellowstone Lake, had more than one loon territory. Fourteen of the lakes were occupied by at least one loon, with an estimate of 28 total adult loons. Eight loonlets fledged during 2012. The number of territorial pairs has declined since surveys began in 1989. The average number of chicks fledged also declined since the 1990s.

Distribution

In the western United States, common loons breed

Common Loons in Yellowstone

Number in Yellowstone
In 2012, 28 loons in 14 of 24 surveyed lakes, including 12 territorial pairs

Where to See
- Large lakes, such as Yellowstone, Lewis, and Heart Lakes; and smaller ones such as Grebe and Riddle Lakes

Identification
- Breeding adults (March–October) have black and white checkering on back, a black bill, red eyes, and iridescent green head and neck. The neck has a black and white chinstrap and distinctive collar.
- Loon chicks hatch with a blackish-brown down and white belly and retain this plumage for two weeks. Body feathers emerge at 4½ weeks on the chick's upper back. By six weeks, brown down only remains on the neck and flanks.
- Gray juvenile plumage is present at seven weeks.
- Juveniles and winter adults have dark upperparts and white underparts.

Habitat
- Summer on ponds or lakes and winter on open water.
- May be found foraging or resting on larger, slow moving rivers.
- Nest sites are usually on islands, hummocks in wetlands, or floating bog mats.
- Pairs nesting on lakes smaller than 60 acres usually require more than one lake in their territory. Lakes smaller than 15 acres are rarely used.

Behavior
- Primarily eat fish (4–8 inches).
- Migrate in loose groups or on own, not in organized flocks. Arrive at summer lakes and ponds at or soon after ice-off.
- Four common calls: wail (for long distance communication), yodel (by males only, used as a territorial signal), tremolo (a staccato call usually by an agitated adult), and hoot (a contact call often between adults or adults and their young).
- Females generally lay two eggs, typically in June, males and females equally share incubation duties, with chicks hatching 27–30 days later. Both adults also care for their young.
- Chicks are able to fend for themselves and attain flight at 11–12 weeks.
- In late summer, adults form social groups, especially on larger lakes, before leaving in October.
- Unable to walk on land.

Management Concerns
- The breeding population in Wyoming is isolated; populations to the north are more than 200 miles away.
- Loons can be used as bioindicators for the aquatic integrity of lakes.
- Factors responsible for the loon's decline in Yellowstone are unknown, but studies are planned to learn more about the decline.

in Idaho, Montana, Washington, and Wyoming; the total US breeding population is estimated at 90 territorial pairs. Wyoming's breeding population is isolated and totals approximately 16 territorial pairs including Yellowstone. Western populations of breeding common loons are known to overwinter from Washington south to California. Spring and fall migrants in Wyoming represent breeding populations from Saskatchewan that overwinter around Mexico's Baja California peninsula.

Outlook

Threats to Wyoming's loon populations include: loss of breeding habitat; direct human disturbance to shoreline nests and chicks; water level fluctuations (e.g., erratic spring flooding); contaminants (e.g., lead and mercury); and hazards on the wintering grounds (e.g., marine oil spills and fishing nets).

Loons are long-lived; they have relatively low chick production and a poor ability to colonize new breeding areas. Given the very small size and isolation of Wyoming's breeding loon population, it is at a particularly high risk of local extinction. The National Park Service and collaborating scientists are conducting studies to determine the reason for lower reproductive success.

More information

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Staff reviewers

Doug Smith, Senior Wildlife Biologist
Lisa Baril, Yellowstone Raptor Initiative
Katy Duffy, Interpretive Planner

Trumpeter swans

The trumpeter swan (*Cygnus buccinator*), named for its resonant call, is North America's largest wild waterfowl, with a wingspan of up to eight feet. These swans require open water, feed mainly on aquatic plants, and nest in wetlands. Although they once nested from Alaska to northern Missouri, trumpeter swans were nearly extirpated in the lower 48 states by 1930 due to habitat loss and hunting. Small populations survived in isolated areas such as the Greater Yellowstone Ecosystem, where the population was thought to number only 69.

As a result of conservation measures, populations across the continental United States began increasing. Today there are approximately 46,000 trumpeter swans in North America. Swans in the Greater Yellowstone Ecosystem played a significant role in the population resurgence, but by the early 1960s, cygnet production in Yellowstone and subsequent recruitment of adults into the breeding population began declining.

A pair of trumpeter swans successfully fledged four young cygnets on Grebe Lake in 2012.

Population

The park's resident trumpeter swan population increased after counts began in 1931 and peaked at 69 in 1961. The number dropped after the Red Rock Lakes National Wildlife Refuge feeding program ended and winter ponds were drained in the early 1990s. The population dropped to 10 in 2010, and increased to 16 in 2012. Nest attempts in Yellowstone, which reached a recorded high of 17 in 1978, dropped to zero by 2011.

During the 2012 breeding season, two pairs of trumpeter swans nested in Yellowstone and one pair successfully produced fledglings. A pair of swans at Grebe Lake nested on a floating nest platform installed in 2011 as part of a new management plan to increase swan productivity in the park. Eggs were incubated in captivity and released to the pair after hatching. Four cygnets successfully fledged in September, making 2012 the most successful breeding season since 2003. A pair of swans at Riddle Lake nested successfully and produced three cygnets, but all of these cygnets were killed by a predator, likely a resident bald eagle.

Nearly all Rocky Mountain trumpeter swans, including several thousand that migrate from Canada, winter in ice-free waters in the Greater Yellowstone Ecosystem, but only a small portion of them remain here to build their nests. The resident swans may be unable to compete with the migratory flocks for habitat.

The best available scientific evidence suggests that Yellowstone provides marginal conditions for

Trumpeter Swans in Yellowstone

Number in Yellowstone
16 resident swans in 2012

Trumpeter swans are increasing in the Rocky Mountain region, stable in the Greater Yellowstone Ecosystem, but declining in Yellowstone National Park.

Where to See
Rivers and lakes

Identification
- 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, has rounder head, lacks pink mandible stripe, sometimes has yellow spot in front of eye.

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.
- Can fail to hatch eggs if disturbed by humans.
- Lay 4–6 eggs in June; young (cygnets) fledge in late September or early October.
- Usually in pairs with young in summer; larger groups in winter.

Management Concerns
- Limiting factors in Yellowstone appear to be flooding of nests, predation, competition with wintering swans, possibly effects of drought, and less immigration into the park from outside locations.
- Because swans are sensitive to human disturbance during nesting, nest areas are closed to public entry.

Trumpeter swans area species of concern in Yellowstone.

Current nesting range of trumpeter swans.

nesting and acts as a sink for swans dispersing from more productive areas. This effect has been compounded in recent decades by habitat changes (e.g., reduced wetland areas due to long-term drought or warmer temperatures) and community dynamics (e.g., recovery of wolf, bear, and raptor populations). Trumpeter swan presence in the park may therefore be primarily limited to occasional residents and wintering migrants from outside the park. Concern about the Greater Yellowstone Ecosystem population has resulted in cooperative efforts between state and federal agencies to monitor swan distribution and productivity.

Federal agencies conduct two annual surveys: The February survey counts how many migrant swans winter in the region; the September survey estimates the resident swan population and annual number of young that fledge (leave the nest).

Outlook

Trumpeter swans are particularly sensitive to human disturbance. Because of this, park managers restrict human activity in known swan territories and nesting areas. Scientists are also conducting studies to determine the habitat requirements for the swan's nesting.

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Staff reviewers

Doug Smith, Senior Wildlife Biologist
Lisa Baril, Yellowstone Raptor Initiative
Katy Duffy, Interpretive Planner

Songbirds and woodpeckers, or passerine and near passerine species, comprise the majority of bird species in Yellowstone National Park.

Songbirds and Woodpeckers

Songbirds and woodpeckers, or passerine and near passerine species, comprise the majority of bird species in Yellowstone National Park. They are monitored, in part, through the willow–bird study, the breeding bird survey, and the new forest burn survey.

Songbirds and willows

Scientists are studying how the growth of willows in Yellowstone's northern range might be affecting songbirds that use this habitat. Willows and other woody vegetation have been highly suppressed in Yellowstone's northern range since the early 1900s. The loss and low stature of willows has been attributed to factors including elk herbivory, loss of beaver, fire, and/or climate change. Since 1997–1998, however, park biologists have observed that some willow stands in the northern range are expanding in height. Willows are one of a few deciduous wetland habitat types in the Greater Yellowstone Ecosystem. Biodiversity is considerably higher in wetland habitat types than in adjacent grasslands, shrublands, and upland coniferous forests.

Several Yellowstone bird species only breed in willow communities including Wilson's warbler (*Cardellina pusilla*), willow flycatcher (*Empidonax traillii*), and gray catbird (*Dumetella carolinensis*). Willow growth has increased in some parts of the park's northern range, for reasons still being studied. An increase in willow growth may be important to the re-colonization by these and other bird species associated with this habitat type in the region.

Monitoring of willow–songbird communities in Yellowstone began in 2005. Using data collected through monitoring, scientists will compare the presence and abundance of breeding songbirds across the range of willow growth conditions found throughout Yellowstone's northern range. Over time, the study will be able to track changes in bird species composition as willows continue to change in structure.

Surveys of burned forests

Birds are among the first returning vertebrates to a fire-affected area. Birds that nest in cavities of trees depend on forest fires to provide their habitat—and different species depend on different effects of forest fires. For example, black-backed (*Picoides arcticus*), American three-toed (*P. dorsalis*), and hairy woodpeckers (*P. villosus*) use trees that burned in low to moderately severe fires in the two to four years after the fire; northern flickers move into severely burned areas three years after a severe burn. Standing dead trees left behind after a fire attract bark and wood-boring beetles—primary prey for woodpeckers. Nest cavities created by woodpeckers are used later by chickadees, nuthatches, and bluebirds.

Because fire size, frequency, and intensity is expected to increase with climate change, scientists are studying how the different bird species use different types of post-burn forests and they are developing monitoring methods for the future.

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Staff reviewers

Doug Smith, Senior Wildlife Biologist
Lisa Baril, Yellowstone Raptor Initiative
Katy Duffy, Interpretive Planner

Ravens are one of the more than 300 bird species that have been sighted in Yellowstone National Park. They are common and seen frequently in developed areas.

Other Notable Birds

American dippers

The dark gray American dipper (*Cinclus mexicanus*) bobs beside streams and rivers. Also called the water ouzel, the dipper dives into the water and swims in search of aquatic insects. Thick downy feathers and oil from a preen gland enable this bird to survive cold waters.

Ravens

Several raven relatives live in Yellowstone, including the common raven (*Corvus corax*). Common ravens are smart birds, able to put together cause and effect. Ravens are attracted to wolf kills and some have learned to follow wolves while they hunt elk. They wait until wolves finish at a carcass because ravens are not able to rip open thick skin. Ravens often show up where people are eating. They are willing to eat almost anything and are frequently seen near parking lots searching for food—some have even learned to unzip and unsnap packs. Do not feed them.

Recent surveys indicate 200–300 ravens are present in the northern range of Yellowstone. Based on a 2012 study, 64 percent of the total 243 ravens counted on the northern range were in natural settings away from human areas, while 36 percent were in human areas.

Sandhill cranes

Sandhill cranes (*Grus canadensis*) 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.

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Staff reviewers

Doug Smith, Senior Wildlife Biologist
Lisa Baril, Yellowstone Raptor Initiative
Katy Duffy, Interpretive Planner

Sandhill cranes are among the largest birds in Yellowstone.

Clark's nutcracker collect seeds from whitebark and limber pine trees and buries them for later. The seeds that aren't retrieved are important to growing new pine trees.

Yellowstone cutthroat trout are found in Yellowstone National Park and are a keystone species. They provide an important source of energy for many species of birds and mammals.

Fish and Aquatic Species

Fishing has been a major form of visitor recreation for more than a century and harvesting by humans stretches back several millennia. It is this long-standing tradition and integration with the parks' cultural significance that allows the practice of recreational fishing to continue in Yellowstone National Park today. In some cases, it also contributes to the National Park Service goal of preserving native species. The biological significance of fish to ecosystems makes them an ongoing subject of study and concern.

Native fish

Yellowstone's native fish have underpinned natural food webs, had great local economic significance, and provided exceptional visitor experiences. To address recent and historical losses and reverse declining trends in native fish populations and loss of ecosystem function, the National Park Service has sought to take actions that will ensure their recovery. Scientific peer review continues to provide guidance for future efforts on Yellowstone Lake.

An environmental compliance process culminating in a parkwide Native Fish Conservation Plan/

Fish in Yellowstone

Number in Yellowstone

11 native species

- 3 sport fish: cutthroat trout (Yellowstone and westslope), Arctic grayling, mountain whitefish
- 8 non-sport fish: 4 minnows: longnose dace, speckled dace, redside shiner, Utah chub; 3 suckers: longnose sucker, mountain sucker, Utah sucker; mottled sculpin

5 nonnative species: brook trout, brown trout, lake trout, lake chub, rainbow trout

History

- When the park was established, many of its waters were fishless.
- Park waters were stocked with native and nonnative fish until the mid-1950s.
- Stocking changed the ecology of many Yellowstone waters as nonnative fish displaced or interbred with native species.
- By the 1960s, Yellowstone's native 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.

Threats

- Lake trout that were apparently illegally introduced into Yellowstone Lake.
- Whirling disease now present in Yellowstone Lake, the Yellowstone and Firehole rivers, and Pelican Creek.
- New Zealand mud snails, which form dense colonies and compete with native species.
- Competition and hybridization with nonnative rainbow trout (Slough Creek) and brook trout (Soda Butte Creek).

Environmental Assessment was recently completed. The National Park Service aims to reduce long-term extinction risk and restore the ecological role of native species, including fluvial Arctic grayling, westslope cutthroat trout, and Yellowstone cutthroat trout, while ensuring sustainable native fish angling and viewing opportunities for visitors.

Native cutthroat trout are thought to be among the most ecologically important fish of the Greater Yellowstone Ecosystem and highly regarded by anglers. Several factors, nonnative species and disease among them, are threatening the persistence of native fish. The National Park Service strives to use the best methods available for addressing threats, with a focus on direct, aggressive intervention, and welcomed assistance by visiting anglers.

History

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 some 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.

Early park managers transplanted fish into new locations, produced fish in hatcheries, and introduced nonnative 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 Yellowstone's native trout and grayling were substantially altered during the 1900s due to exploitation and introduction of nonnative species. Nonnative species in the park include brook trout, brown trout, lake chub, lake trout, and rainbow trout.

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 in Yellowstone. Consequently, fish and other aquatic inhabitants continue to provide important food for grizzly and black bears, river otters, mink, ospreys, bald eagles, pelicans, and many other birds and other species.

The US Fish and Wildlife Service maintained an aquatic research and monitoring program in the park until 1996. Since then, National Park Service fisheries managers have focused on the same objectives: 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.

Influences of some nonnative species

Aquatic nuisance species disrupt ecological processes because they are not indigenous to the ecosystem. Invasive organisms can cause species extinction, with the highest extinction rates occurring in freshwater environments. Aquatic nonnative species that are having a significant detrimental effect on the park's aquatic ecology include lake trout in Yellowstone Lake; brook, brown, and rainbow trout in the park's streams and rivers; and the parasite that causes whirling disease. Though there are other aquatic nonnative species in the park, their effects are less dramatic. (See: "Nonnative Fish and Aquatic Invasive Species" in this chapter.)

Fishing in Yellowstone

About 75,000 of the park's three million visitors fish each year. Fishing has been a popular recreation activity for visitors here for more than 100 years, and many people come to Yellowstone just to fish. Though 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, fishing in Yellowstone supports preservation of native species.

Yellowstone cutthroat trout support a $36 million annual sport fishery. The money generated from

Many people, like this angler on the Gardner River, come to Yellowstone to fish.

FREQUENTLY ASKED QUESTION:

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.)

fishing licenses helps managers preserve native fish populations. 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. Anglers contribute to the fisheries database by filling out a Volunteer Angler Report card that is issued with each fishing license. This information helps managers monitor the status of fisheries throughout the park.

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 LeHardy's Rapids. In 1994, approximately 176,400 visitors watched fish at LeHardy's 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.

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Staff reviewers

Todd Koel, Supervisory Fishery Biologist
Jeff Arnold, Ecologist

Of the 11 native species in Yellowstone, three are considered sport fish: Arctic grayling (above), cutthroat trout (two subspecies: Yellowstone cutthroat trout and westslope cutthroat trout), and mountain whitefish.

Native Sport Fish

Arctic grayling

Fluvial (entirely stream-dwelling) Arctic grayling (*Thymallus arcticus*) were historically common within the Madison, Gibbon, Firehole and Gallatin rivers. However, by the 1950s the introduction of competing nonnative fishes such as brown trout (*Salmo trutta*) and brook trout (*Salvelinus fontinalis*), and the fragmentation of migratory pathways by the construction of the Hebgen Dam outside the park led to the elimination of fluvial grayling from their entire native range within the park. The only known populations left in the park are adfluvial (fish that spend a majority of their life in a lake and spawn in tributary streams) descendants of fish that were stocked in Cascade and Grebe lakes. They are also present in Wolf Lake and occasionally in the Gibbon River.

The arctic grayling is sometimes confused with mountain whitefish, but can be easily differentiated by its large dorsal fin.

Restoration

One of the goals of the park's 2010 Native Fish Conservation Plan is to restore fluvial grayling so that they reside in approximately 20 percent of their historical distribution. The upper reaches of Grayling Creek are considered the best potential site for immediate fluvial grayling restoration, but are currently occupied by brown trout and hybridized cutthroat trout. A small waterfall exists near the park boundary in Grayling Creek, which flowed directly into the Madison River prior to the construction of Hebgen Dam in 1914. It is not known if grayling were ever present upstream of the waterfall, but they were historically abundant downstream from it. Yellowstone National Park and Montana Fish, Wildlife and Parks are working together to restore the Arctic grayling to this site. This project, begun with barrier construction in 2012, aims to restore Arctic grayling and westslope cutthroat trout to one of the largest and most remote drainages in the species historic range within Yellowstone. The project is expected to take nearly a decade to remove nonnative fish and reintroduce both native species.

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Staff reviewers

Mike Ruhl, Fish Biologist
Todd Koel, Supervisory Fishery Biologist

Mountain whitefish

The mountain whitefish (*Prosopium williamsoni*) is a slender silver fish, sometimes confused with Arctic grayling. It lives in Yellowstone's rivers and streams and requires deep pools, clear and clean water. This species is very sensitive to pollution. The mountain whitefish has persisted in its native waters, unlike the Arctic grayling. Mountain whitefish are commonly caught by anglers in most of the park's large rivers. They are less common in smaller streams.

Unlike other native fish, the mountain whitefish spawns in the fall. It generally feeds along the bottom, eating aquatic insect larvae, and competes with trout for the same food.

To prevent rainbow trout and other nonnative fish living downstream from invading the westslope cutthroat trout restoration area, park staff constructed a barrier on East Fork Specimen Creek.

Westslope cutthroat trout

Historically the most abundant and widely distributed subspecies of cutthroat trout throughout the West, the westslope cutthroat trout (*Onchorhynchus clarkii lewisi*, WCT) occupies less than 5 percent of its former range in the upper Missouri River drainage. It evolved from a common ancestor of the Yellowstone form of the species, and shares their food and habitat requirements. By the 1930s, WCT were nearly eliminated from park streams because of the stocking of competing (nonnative brook and brown trout) and interbreeding (rainbow trout and Yellowstone cutthroat trout) species. In most of its remaining habitat (an estimated 64 percent of the approximately 641 stream miles it once occupied in the park), it exists only in a hybridized form.

Restoration

WCT have only persisted in one tributary of the Madison River drainage (Last Chance Creek), and can also be found in the Oxbow/Geode Creek complex where they were introduced outside of their native range in the 1920s. In 2006, Yellowstone began efforts to restore WCT in East Fork Specimen Creek and High Lake by constructing a fish barrier, removing nonnative fish, and stocking genetically pure WCT. Stocking was completed in High Lake in 2009, and in East Fork Specimen Creek in 2012. Evidence suggests those populations are becoming rapidly established. Another restoration project is designed to create an Upper Missouri River WCT brood stock in Goose Lake, where nonnative fish removal was conducted in 2011 and stocking will begin in 2013. The largest WCT restoration effort in Yellowstone is the Grayling Creek project (See: "Arctic grayling"), which will restore WCT to over 20 miles of native habitat.

Yellowstone cutthroat trrout

Yellowstone cutthroat trout (*Oncorhynchus clarkii bouvieri*; YCT) are an important species in Yellowstone National Park, upon which many other species depend. They provide an important source of food for an estimated 42 species of birds and mammals including grizzly bears, osprey, and bald eagles and, in the recent past, have supported a $36 million annual sport fishery.

YCT are at great risk from hybridization and competition with nonnative trout, and predation by nonnative lake trout. Genetically pure YCT populations have declined throughout their natural range in the Intermountain West, succumbing to competition with and predation by nonnative fish species, a loss of genetic integrity through hybridization, habitat degradation, and angling harvest. Many of the remaining genetically pure YCT are found within the park. State and federal wildlife agencies classify YCT as a sensitive species. In February 2006, however, the US Fish and Wildlife Service announced that listing the YCT as a threatened species under the Endangered Species Act was not warranted.

A volunteer angler holds a Yellowstone cutthroat trout from Riddle Lake

Population

The Yellowstone cutthroat trout (YCT) population in the Yellowstone Lake ecosystem has declined substantially since the mid-1980s. The number of YCT caught per net at lake-wide sampling sites during an annual monitoring program that began in 1969 reached 19.1 in 1984 and dropped to an all-time low of 5.3 in 2010. The number of YCT spawning at Clear Creek, a Yellowstone Lake tributary where monitoring began in 1945, peaked at more than 70,000 in 1978 and fell to 538 by 2007. The decline is attributed to predation by nonnative lake trout, low water during drought years, and the nonnative parasite that causes whirling disease.

Two-thirds of the park streams that were part of the species' native habitat outside the Yellowstone Lake watershed still contain genetically pure YCT; the other streams have YCT hybridized with introduced rainbow trout. The objectives of Yellowstone's Native Fish Conservation Plan (2010) include maintaining access for spawning YCT in at least 45 of 59 Yellowstone Lake's historical spawning tributaries, recovery of YCT abundance in the lake to that documented in the late 1990s, and maintaining or restoring genetically pure YCT in the current extent of streams occupied by pure or hybrid YCT.

History

Yellowstone Lake and the Yellowstone River together contain the largest inland population of cutthroat

Yellowstone Cutthroat Trout in Yellowstone

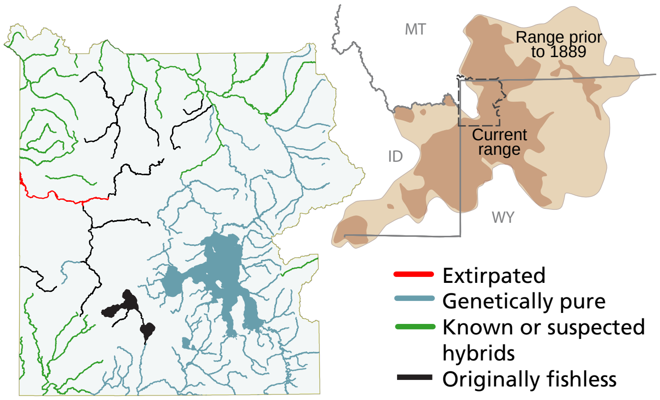
Number in Yellowstone
The number of Yellowstone cutthroat trout spawning at Clear Creek, a Yellowstone Lake tributary where monitoring began in 1945, peaked at more than 70,000 in 1978 and fell to 538 by 2007.

Where to See
Yellowstone Lake, Fishing Bridge, LeHardy's Rapids, Trout Lake

Identification
Red jaw slash

Behavior
- Yellowstone cutthroat is native to the Yellowstone River, its tributaries, the Snake River, and the Falls River.
- 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.—and other small aquatic animals, plus terrestrial insects that fall into the water.
- Also eat smaller fish, fish eggs, small rodents, frogs, algae and other plants, and plankton.

Management Concerns
- 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 apparently illegally introduced lake trout in Yellowstone Lake now pose a serious threat to the cutthroat trout population.



Past and present range of the Yellowstone cutthroat trout.

trout in the world. 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 that fish swam across the Continental Divide at the headwaters of Pacific Creek and Atlantic Creek and, thus, swam from the Pacific to the Atlantic watersheds.

Restoration

Restoring YCT to park waters is an important component of the Native Fish Conservation Plan. In 2012 park staff began an effort to remove nonnative brook trout from the Elk Creek drainage above a natural fish barrier near the Yellowstone River. This project will require multiple years of nonnative fish removal before YCT can be reintroduced, but the project is an opportunity to replicate rare small-stream resident YCT in the park. Further efforts to restore and conserve YCT are occurring in the Lamar River Drainage where a barrier to protect upper Soda Butte Creek is planned for 2013 and similar barriers are being considered for Slough Creek and the upper Lamar River.

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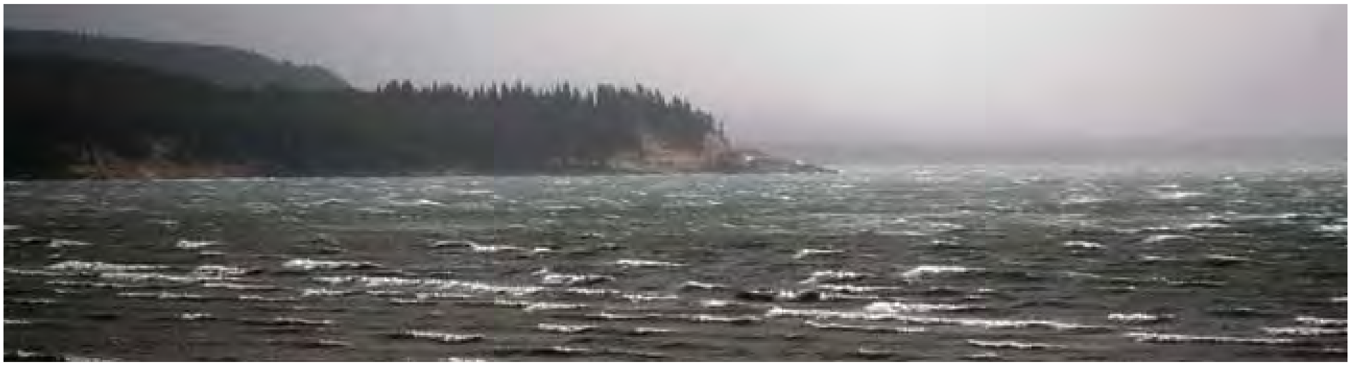
Staff reviewers

Jeff Arnold, Ecologist
Mike Ruhl, Fish Biologist
Todd Koel, Supervisory Fishery Biologist



Yellowstone Lake is home to one species of native non-sport fish, the longnose dace. Like other minnows in Yellowstone, this small fish lives in a variety of habitats and is food for trout.

Other Native Fish

Mottled sculpin

The mottled sculpin (*Cottus bairdi*) lives in shallow, cold water throughout Yellowstone except in the Yellowstone River above Lower Falls and in Yellowstone Lake. This species eats small insects and some fish, and is consumed by trout.

Suckers

Suckers are bottom-dwelling fish that use ridges on their jaws to scrape flora and fauna from rocks. They are eaten by birds, bears, otters, and large cutthroat trout. Sucker species can be distinguished by their habitat:

- 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 drainage.

Minnows

Yellowstone's minnows are small fish living in a variety of habitats and eating a variety of foods. All four species occurring in Yellowstone are 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, and can be found in Yellowstone Lake.
- 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.

This sucker was caught in Pelican Creek.

WILDLIFE

The lake trout, introduced to Yellowstone Lake, is one of several aquatic nonnative species having a significant detrimental effect on the park's aquatic ecology.

Nonnative Fish and Aquatic Invasive Species

An aquatic invasive species disrupts ecological processes because it is not indigenous to the ecosystem. Invasive organisms can cause species extinction, with the highest extinction rates occurring in freshwater environments. In addition to nonnative fish in Yellowstone, three aquatic invasive species are having a significant detrimental effect:

- *Myxobolus cerebralis*, a parasite that causes **whirling disease** in cutthroat trout and other species.
- **New Zealand mud snails** (*Potamopyrgus antipodarum*), which form dense colonies and compete with native species; and
- **Red-rimmed melania** (*Melanoides tuberculatus*), a small snail imported by the aquarium trade starting in the 1930s, was discovered in the warm swimming area at the confluence of the Boiling River with the Gardner River in 2009.

Preventing the arrival of additional aquatic invasive species is critical because eliminating them after they become established in a watershed is usually impossible and efforts to reduce their impact can be extremely expensive. Each summer a small team of park technicians and volunteers is employed throughout the park to contact park visitors before they put their boats or angling gear in the water. They

Each year a team of park staff and volunteers contact park visitors before they put their boats or angling gear in the water to prevent the arrival of more aquatic nuisance species.

Aquatic Invasive Species in Yellowstone

The Issue
Aquatic invaders can irreversibly damage the park's ecosystems.

Current Status

- In the US currently, more than 250 nonnative (from another continent) aquatic species and more than 450 nonnative (moved outside their natural range) aquatic species exist.
- At least 7 aquatic invasive species exist in Yellowstone's waters: two mollusks, five fish, one nonnative disease-causing microorganism (whirling disease). Three of these species are having a significant detrimental effect (lake trout, New Zealand mud snails, whirling disease).
- Park staff continues to educate visitors about preventing the spread of aquatic invasive species.

What You Can Do

- 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 all 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.

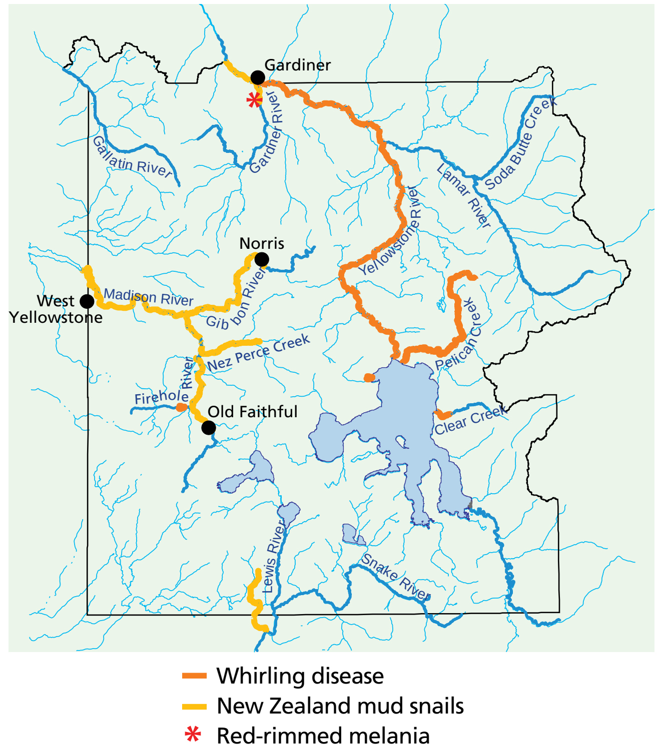
WILDLIFE

inspect and clean visitor's equipment if necessary. Such decontamination is usually adequate to prevent the entry of most aquatic invasive species.

Arrival in Yellowstone

During the late 1880s when the Army administered Yellowstone, the US Fish Commission (a predecessor of today's US Fish and Wildlife Service) stocked nonnative fish in some park waters. These stockings comprise the first known, deliberate introductions of nonnative 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 aquatic invasive species, such as the New Zealand mud snail and the parasite causing whirling disease, probably arrived via unaware boaters and anglers carrying the organisms from other locations around the country. We may never know exactly how those species were introduced to the park, but anglers can help prevent other species from arriving.



Locations in Yellowstone National Park where whirling disease, New Zealand mud snails, or red-rimmed melania have been documented.

Are more aquatic invasive species on their way?

Several nonnative 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.

Eurasian water-milfoil 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 nonnative 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, emphasizing why boats should be thoroughly cleaned, rinsed, and inspected before entering Yellowstone National Park.

Three **nonnative photoplankton** species that can displace native zooplankton that are important food for cutthroat trout may be on their way. These nonnative zooplankton have long spines, which make them difficult for young fish to eat.

Zebra mussels are a particularly damaging aquatic invasive species. They are native to Eastern Europe and western Asia. They were first discovered in North America in 1988 in Lake St. Clair, one of the water bodies connecting the Great Lakes. It is believed that this invasive species was introduced through ballast water discharges from international shipping.

Following their initial invasion, zebra mussels spread quickly across most of the eastern United States and Canada. Zebra mussels are inadvertently transported to new water bodies by boaters.

Zebra mussels cause severe economic and ecological damage. Zebra mussels attach to most hard surfaces forming thick mats that may be up to 18 inches thick. Zebra mussels drastically alter the ecology of infested water bodies and may severely impact sport fisheries.

Lake trout

Lake trout (*Salvelinus namaycush*) are native to northern Canada, Alaska, the Great Lakes, New England. In 1994, their presence was confirmed in Yellowstone Lake, where they were apparently introduced in the 1980s and 1990s. Despite major efforts to remove them by gillnetting, the lake trout are having a significant ecological impact on the native Yellowstone cutthroat trout, an important food for other native animals. Lake trout differ from cutthroat trout as potential prey because they can grow larger, occupy deeper areas of the lake, and spawn in the lake instead of shallow tributaries.

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.

Population in Yellowstone Lake

In 2008, a scientific review panel set up to evaluate the lake trout suppression program 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 believed very little time remained to turn the situation around, and recommended park managers increase lake trout removal.

The 2008 review panel reconvened in 2011 to assess progress and provide further guidance. Population modeling suggests that the removal effort in 2010 must be doubled to curtail further population growth. Even if a measurable decline in lake trout abundance can be obtained, a maintenance program of monitoring and removals will be required.

Nonnative lake trout predate on native Yellowstone cutthroat trout. Biologists estimate 41 cutthroat trout are saved each year for every mature lake trout caught.

Starting in 2009, the park contracted with Hickey Brothers Fisheries, LLC, a commercial fishing company, to increase the take of lake trout. In 2012, they also used 10 large, live entrapment nets that allow removal of large lake trout from shallow water and return of cutthroat trout to the lake with little mortality.

To increase the efficiency of lake trout suppression through identification of more spawning areas and movement patterns, the National Park Service and US Geological Survey launched a pilot study in 2011 with support from Trout Unlimited, the National Parks Conservation Association, and the Greater Yellowstone Coalition to implant transmitters in 159 lake trout and deploy 40 receivers in the lake.

Hydroacoustic surveys (using sonar-based fish finders) are used to assess the lake trout's seasonal movements within the lake. The surveys confirmed lake trout concentrations in the western portion of Yellowstone Lake. These surveys also revealed medium-sized (12–16 inches) lake trout tended to

Lake Trout in Yellowstone

The Issue

Nonnative lake trout in Yellowstone Lake threaten the survival of native Yellowstone cutthroat trout and species that depend on it.

Background

- During the time the park stocked fish, lake trout were introduced to Lewis and Shoshone lakes.
- Lake trout probably were apparently introduced into Yellowstone Lake in the 1980s and 1990s.
- In 1994, an angler caught the first verified lake trout in Yellowstone Lake.
- One mature lake trout can eat approximately 41 cutthroat trout per year.
- The cutthroat trout population in Yellowstone Lake could fall to 10% or less 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.
- Staring in 2009, Yellowstone National Park annually contracted with a commercial fishing company to increase the catch of lake trout.

Current Status

- Gillnetting has removed more than 1.1 million lake trout since 1994.
- Recreational anglers catch approximately 9,000 lake trout each year.

Outlook

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

reside in deeper water (greater than 130 feet) than Yellowstone cutthroat trout. 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.

Gill nets and anglers control the population

Lake trout gillnetting begins as ice is leaving the lake and continues into October. Gill net operations provide valuable data—numbers, age structure, maturity, and potential new spawning areas—leading to more effective control.

To minimize the bycatch of cutthroat trout while maximizing the removal of lake trout requires knowledge of the optimum location, timing, and type of gear to use. Most gillnetting by National Park Service crews focuses on juvenile lake trout, using small-mesh nets from ice-out through mid-August. As spawning approaches, adult lake trout become more active and more concentrated, making them more susceptible to netting in large-mesh nets.

Anglers also 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 tend to be most successful at catching lake trout 15–24 inches long, which are found in shallow, near-shore waters in June and early July. Of the total lake trout removed from Yellowstone Lake, anglers have removed approximately 30 percent.

Results

More than 1.1 million lake trout have been removed from Yellowstone Lake since the lake trout's presence was confirmed in 1994. In 2012, National Park Service and contracted crews captured more than 300,000 lake trout, including the largest one documented from Yellowstone Lake (a greater than 30 lb. male). Because the amount of effort put into gillnetting as well as the lake trout's abundance affects the number removed, the number caught per 100 meters of net in one night (catch per unit of effort, CPUE) is also monitored. This number has been rising since 2002, suggesting that the population has been increasing faster than the fish are being removed, until 2012. In 2012, increases in net effort led to a significant decrease in CPUE, the first drop seen since 2002.

Student Conservation Association interns hold a large lake trout from Yellowstone Lake.

One goal of Yellowstone's Native Fish Conservation Plan (2010) is to reduce the population by 25 percent each year until it collapses to an insignificant level. Population modeling suggests this may be possible with a continued increased effort.

Future of lake trout control

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

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Staff reviewer

Todd Koel, Supervisory Fishery Biologist

New Zealand mud snails

The New Zealand mud snail (*Potamopyrgus antipodarum*) is an invasive species that became established in the western United States since the 1980s. In suitable habitat, especially in geothermal streams with high primary production, it can form dense colonies on aquatic vegetation and rocks along streambeds, crowding out insect communities—a primary food for immature trout and other native species.

New Zealand mud snails consume a large amount of algae, which is a primary food for native aquatic invertebrates. Its overall impact on algae is likely to affect entire stream food webs. With its protective shell, the mud snail provides little if any nutrition as prey and may pass through a fish alive. Scarcely a quarter-inch long, mud snails may cling to boats, waders, and other fishing gear by which they are inadvertently transferred to another watershed. Because the species can reproduce asexually, a single mud snail is all that is required to establish a new colony.

Population

First detected in the park in 1994, New Zealand mud snails are now in all of the major watersheds. Although the mud snail is abundant in several streams, it remains absent or uncommon in other Greater Yellowstone streams, suggesting that its upstream population density and distribution is limited by colder temperatures, low productivity, and unstable substrates associated with spring runoff.

Impacts of mud snails

Once mud snail colonies become established in a stream, removing them without disrupting native invertebrate populations is not feasible with any known method. Mud snail research in Greater Yellowstone aims to determine the species' impacts on other aquatic organisms and stream ecology. A study of the Gibbon and Madison rivers found that 25–50 percent of the macroinvertebrates were mud snails, and the areas they occupied had fewer native mayflies, stoneflies, and caddisflies—insects important in the diet of salmonids and several bird species.

New Zealand mud snails shells resting on a dime.

Red-rimmed melania

The red-rimmed melania (*Melanoides tuberculatus*), a small snail imported by the aquarium trade starting in the 1930s, was discovered in the warm swimming area at the confluence of the Boiling River with the Gardner River in 2009. The following year, a survey of 18 of the park's most popular hot springs found melania only in the Boiling River soaking area and downstream approximately 1 km. The species has a narrow temperature tolerance (18–32°C) and is unlikely to survive downstream of the Boiling River during the winter, but it could become established in other thermal water in the park.

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Whirling disease

Whirling disease is caused by a microscopic parasite from Europe (*Myxobolus cerebralis*) that can infect some trout and salmon; it does not infect humans. It has been detected in 25 states. During the parasite's life cycle, it takes on two different forms as spores and requires two hosts: a common aquatic worm (*Tubifex tubifex*) and a susceptible fish. Cutthroat trout are susceptible, especially during the first months of life. The parasite feeds on the fish's cartilage, and the infection can cause skeletal deformities, a blackened tail, and whirling swimming behavior. Because the fish cannot feed normally and are more vulnerable to predation, whirling disease can be fatal. No practical treatment exists for fish infected with this disease or for the waters containing infected fish.

Presence in Yellowstone

Whirling disease was first detected in Yellowstone in 1998 in cutthroat trout from Yellowstone Lake. It has since been found in the Firehole River and throughout the Yellowstone Lake watershed. In the lake, the infection has spread to about 20 percent of the cutthroat trout. The parasite is most prevalent in the two known infected tributaries, Pelican Creek and the Yellowstone River downstream of the lake. Infection has been most severe in Pelican Creek, which once supported nearly 30,000 upstream-migrating cutthroat trout. Significant declines in Pelican Creek's spawning population have been attributed to the combination of whirling disease and predation by nonnative lake trout in Yellowstone Lake. The finding of adult fish in the lake with the parasite's spores that survived their initial infection suggests some resilience of Yellowstone cutthroat trout to whirling disease.

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.

Park staff emphasize 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. Anglers should not transport fish between drainages and should clean fish in the body of water where they were caught.

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Staff reviewer

Todd Koel, Supervisory Fishery Biologist

Whirling Disease in Yellowstone

The Issue

Whirling disease is a parasitic infection of fish caused by a microscopic protozoan that destroys the cartilage of juvenile trout, resulting in skeletal deformities and sometimes whirling behavior. Seriously infected fish have a reduced ability to feed or escape from predators and mortality is high.

Background

- The disease was first described in Europe more than 100 years ago. It was detected in the United States in the mid-1950s, and in Yellowstone in 1998.
- It most likely came to the US in frozen fish products.
- 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 practical treatment.

Amphibians are valuable indicators of environmental stressors such as disease or climate change. Researchers monitor amphibian populations in the park.

WILDLIFE

Amphibians

Amphibians are an important part of Greater Yellowstone's aquatic and terrestrial ecosystems. They are valuable indicators of environmental change such as disease or climate change because of their sensitivity to disturbances such as disease, pollution, drought, the arrival of nonnative species, and other habitat alterations. Amphibians are prey for many fish, reptile, bird, and mammal species and, in turn, they eat a wide variety of vertebrate and invertebrate species. Amphibian populations that are affected by one or more of these stresses may exhibit increased deformities and changes in site occupancy, distribution, abundance, and species richness. These changes in amphibian populations have cascading effects on other aspects of the ecosystem.

Declines in amphibian population have been occurring globally in both protected areas and areas where habitat has been lost. About one-third of all amphibian species are believed to be threatened with extinction. In Yellowstone, amphibians depend on limited suitable habitat with the shallow, quiet waters needed for egg deposition and larval development.

Population

Annual surveys since 2002 have found the same

Amphibians in Yellowstone

Number in Yellowstone

4 species: blotched tiger salamander, boreal chorus frog, boreal toad, and Columbia spotted frog.

Identification

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

Status

- Columbia spotted and boreal 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 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.

Research

- 2000: Researchers begin inventorying amphibians.
- 2004: The Greater Yellowstone Network selects amphibian occurrence as a Vital Sign for monitoring ecosystem health.
- 2006: Long-term, vital sign amphibian monitoring begins in Yellowstone.

Survival in winter

- To survive the winter, some Yellowstone 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.

four native amphibian species in Yellowstone: the blotched tiger salamander, boreal chorus frog, boreal toad, and Columbia spotted frog. After five years of below-normal precipitation, the percentage of visited wetland sites that were suitable for amphibian breeding increased from 59 percent in 2007 to 96 percent in 2011.

Hydrological fluctuations change the extent and location of wetland sites, resulting in considerable year-to-year variation in amphibian reproduction, so longer-term data are needed to identify any significant trends. However, population data collected since 1992 appear to be within the range of natural variability and suggest that these species are resilient to at least short periods of drought. Reports from the 1950s suggest that the boreal toad was more widespread and common then, but it continues to be found at most of the major breeding sites that have been identified since the early 1990s, although at low numbers.

Studying amphibians in Yellowstone

Annual measures of amphibian occurrence and wetland suitability allow trends in amphibian populations to be considered in context of the available habitat. This work, when combined with historical data, will provide managers and the public with information on amphibians and wetlands in Yellowstone. This will be important to understand how these fauna may be affected by different disturbances such as disease or changes in climate.

To monitor amphibians in Yellowstone, the Greater Yellowstone Network is 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. 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 here may shed light on declines documented in other high-elevation protected areas of the western United States. Population declines may be caused by factors such as disease, drought or climate change, chemical contamination, nonnative species, and habitat loss and fragmentation. In addition, because many amphibians congregate to breed or overwinter, they can be adversely affected by disturbance or loss of key sites.

Amphibian or Reptile?

Both amphibians and reptiles 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.

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Staff reviewer

Jeff Arnold, Ecologist

Blotched tiger salamander (*Ambystoma tigrinum melanostictum*)

Identification

- The only salamander in Yellowstone.
- Adults range up to about 9 inches, including the tail.
- Head is broad, with a wide mouth.
- Color ranges from light olive or brown to nearly black, often with yellow blotches or streaks on back and sides; belly is dull lemon yellow with irregular black spots.
- Larvae, which are aquatic, have a uniform color and large feathery gills behind the head; they can reach sizes comparable to adults but are considerably heavier.

Habitat

- Breeds in ponds and fishless lakes.
- Widespread in Yellowstone in a great variety of habitats, with sizable populations in the Lamar Valley.

Behavior

- Adult salamanders come out from hibernation in late April to June, depending on elevation, and migrate to breeding ponds where they lay their eggs.
- Mass migrations of salamanders crossing roads are sometimes encountered, particularly during or after rain.
- After migration, return to their moist homes under rocks and logs and in burrows.
- Feed on adult insects, insect nymphs and larvae, small aquatic invertebrates, frogs, tadpoles, and even small vertebrates.
- Preyed upon by a wide variety of animals, including mammals, fish, snakes, and birds such as sandhill cranes and great blue herons.

Boreal 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.

Boreal toad (*Bufo boreas boreas*)

JEFF ARNOLD

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 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

- Common in suitable wetland habitat.
- 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).

Reptiles are not well studied in Yellowstone National Park. The bull snake, shown here, is one of six reptile species and the largest species found in the park.

Reptiles

Yellowstone provides a valuable study area; information about the status and trends of reptiles here may shed light on declines documented in other high-elevation protected areas of the western United States. Many reptiles congregate to breed or overwinter, and they can be adversely affected by disturbance or loss of key sites.

More information

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Staff reviewer
Jeff Arnold, Ecologist

Reptiles in Yellowstone

Number in Yellowstone
6 species: bull snake, prairie rattlesnake, rubber boa, sagebrush lizard, valley garter snake, and wandering garter snake. They are less studied than amphibians in Yellowstone.

Status

- None of the park's reptiles are federally listed as threatened or endangered.
- Researchers began inventorying reptiles and amphibians in 2000.

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.

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 and 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.

Rubber boa (*Charina bottae*)

Identification

- Infrequently encountered in Yellowstone, perhaps due to its nocturnal and burrowing habits.
- One of two species of snakes in the United States related to tropical boa constrictors and pythons.
- Maximum length of 24 inches.
- Back is gray or greenish-brown, belly is lemon yellow; scales are small and smooth, making it almost velvety to the touch.

Habitat and Behavior

- Eats rodents.
- May spend great deal of time partially buried under leaves and soil, and in rodent burrows.
- Usually found in rocky areas near streams or rivers, with shrubs or trees nearby.
- Recent sightings have occurred in the Bechler region and Gibbon Meadows.

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.

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 (*Thamnophis elegans vagrans*)

JEFF ARNOLD

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.

National Park Service Mission

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 National Park Service cooperates with partners to extend the benefits of natural and cultural resource conservation and outdoor recreation throughout this country and the world.

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Yellowstone National Park

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