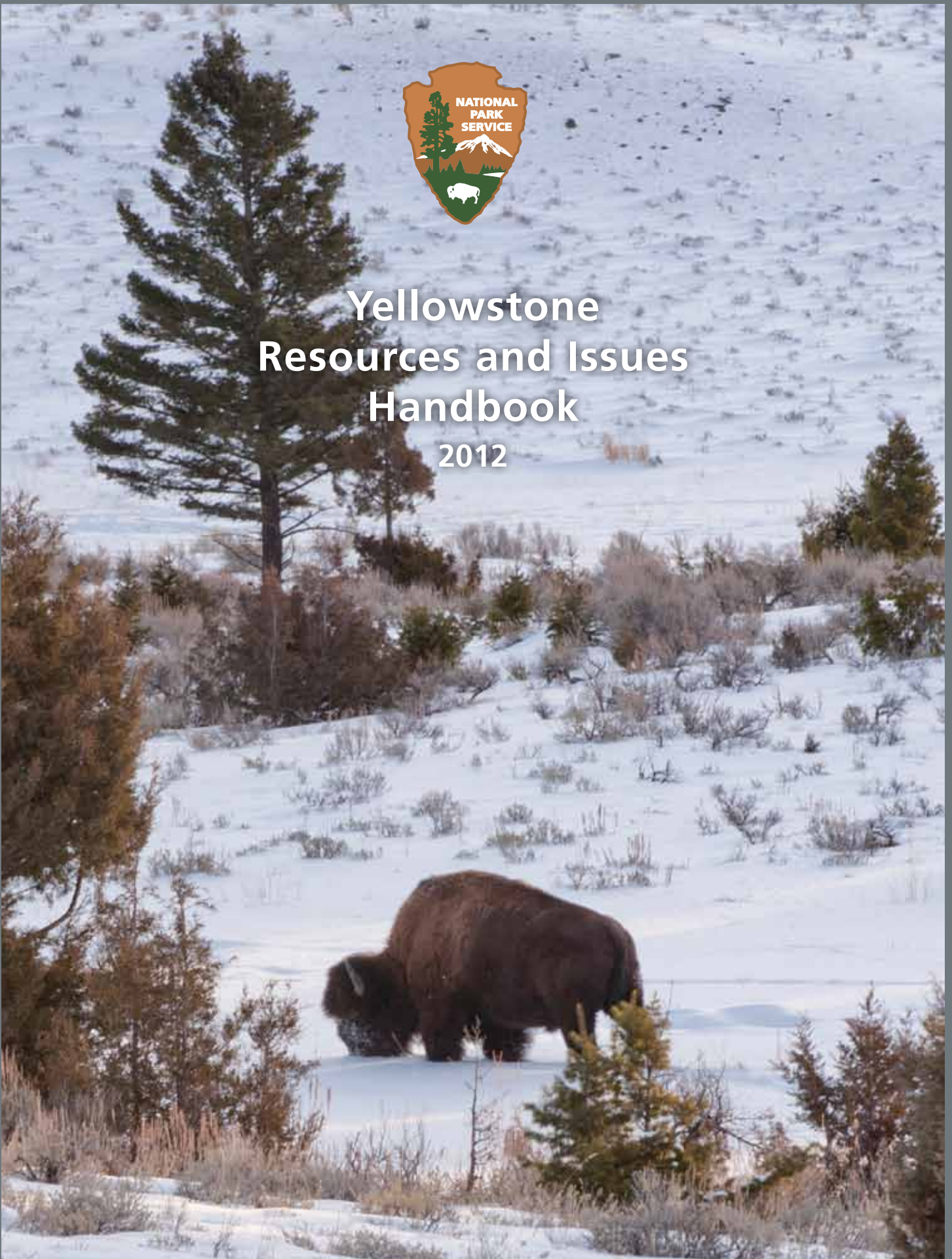




Yellowstone Resources and Issues Handbook 2012



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The Yellowstone National Park Protection Act states, “the headwaters of the Yellowstone River...is hereby reserved and withdrawn from settlement, occupancy, or sale...and dedicated and set apart as a public park or pleasuring-ground for the benefit and enjoyment of the people.”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

A bison grazes near Mammoth Terraces, early morning, New Year's Day 2012

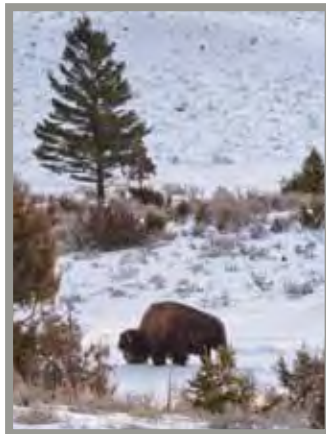
PHOTO COURTESY JAY ELHARD



Yellowstone Resources and Issues Handbook

2012

An annual compendium of information about
Yellowstone National Park



Yellowstone National Park thanks the Yellowstone Association for its support of this publication

Yellowstone Resources and Issues is produced and reviewed annually by Yellowstone National Park staff.

Emily Yost, designer

Jay Elhard, editor

Tami Blackford, managing editor

Linda Young, executive editor

Copyrights

All material is in the public domain unless copyright is owned by a listed person or organization.

All graphics are by the National Park Service unless credited otherwise.

Suggested citation

Yellowstone National Park. 2012. *Yellowstone Resources and Issues Handbook: 2012*. Yellowstone National Park, WY.

Available online at **www.nps.gov/yell** or for purchase through the Yellowstone Association **www.YellowstoneAssociation.org**

Contents

Frequently Asked Questions.....	3	Geology	43
General	3	What Lies Beneath	43
Geography	5	Volcano	44
Canyon Village Area	6	Hydrothermal Systems	46
Fishing Bridge and Lake	7	Lake Geology.....	48
Madison and West Yellowstone		Earthquakes.....	50
Area.....	8	Glaciers.....	50
Mammoth Area	9	Sedimentation and Erosion	51
Norris Area.....	10	Fossils	52
Old Faithful Area.....	11	Frequently Asked Questions:	
Tower-Roosevelt Area.....	12	Volcanic Geology.....	53
West Thumb and		Frequently Asked Questions:	
Grant Village Area	13	Hydrothermal Geology	54
Introduction.....	15	Frequently Asked Questions:	
The Beginning of an Idea	15	Glacial Geology	55
Today's National Park System.....	16	Life in Extreme Heat	57
National Park Service Mission	16	About Microbes.....	58
Guidance for Protecting		Thermophilic Bacteria.....	59
Yellowstone National Park	18	Thermophilic Archea.....	60
History of the Park.....	19	Thermophilic Viruses.....	61
The Earliest Humans		Thermophilic Eukarya	63
in Yellowstone.....	19	Thermophilic Communities	63
Increased Use.....	20	Communities.....	66
The Little Ice Age	21	Thermophiles in Time and Space	66
Historic Tribes	21	Vegetation	67
The "Sheep Eaters"	22	Major Types	68
European Americans Arrive.....	22	Effects of Disturbances	70
Looking for Gold	23	Trees	71
Expeditions "Discover"		Endemics	72
Yellowstone	23	Managing Invasive Plants	73
1872—Birth of a National Park	24	Restoring Native Plants.....	74
The Formative Years.....	24	Fire	75
1886—The Army Arrives	25	Fire Behavior.....	77
1916—The National Park Service		Managing Fire	77
Begins.....	26	The 1988 Fires.....	79
Boundary Adjustments	26	After the 1988 Fires	83
The 1940s.....	27	Frequently Asked Questions:	
Mission 66	27	The Fires of 1988	96
From Managed to "Natural"	27	Wildlife	89
Involving Native Americans.....	29	Mammals	92
Complex Times	29	Birds	121
Preserving the Park's History	30	Fish	128
Historic Structures & Districts	33	Reptiles and Amphibians.....	132
The Legacy of Yellowstone.....	34	Frequently Asked Questions:	
Greater Yellowstone Ecosystem	35	Wildlife	137
Biodiversity and Processes	36	Park Issues	139
Complexity.....	37	Aquatic Invaders.....	139
Winter in Yellowstone	39	Bear Management	144
Research in the Park	40	Bioprospecting and	
Challenges	41	Benefits-Sharing.....	148

Bison Management.....	151
Climate Change.....	157
Northern Range.....	165
Sustainable and Greening Practices	168
Wilderness	173
Winter Use.....	176
Wolf Restoration.....	181
For More Information.....	185
General	185
History of the Park	185
Greater Yellowstone Ecosystem	186
Geology.....	186
Life in Extreme Heat	187
Vegetation.....	188
Fire	189
Mammals	189
Park Issues.....	196

Preface

This compendium contains information about the park's history, natural and cultural resources, and issues. Each chapter is edited and carefully reviewed for accuracy and relevance. A resource list provided at the conclusion can lead you into subjects more deeply. More current and detailed information is available at websites listed below.

How the Book Is Organized

Organized to provide an introduction to Yellowstone information and major topics, the book begins with "Park Facts," followed by "Frequently Asked Questions" and a brief introduction. More detailed information and topic-related FAQ's follow in subsequent chapters.

Updating the Information

Information about Yellowstone constantly changes. Information provided here is considered current as of March 1, 2012.

For updates and more detailed information, visit:

- www.nps.gov/yell
- www.greateryellowstonescience.org

Exhibits, park publications, and rangers who staff visitor centers also have updated information.

Park Facts

Yellowstone National Park was established on March 1, 1872.

Yellowstone is the world's first national park.

GEOGRAPHY

3,472 sq. miles, 8,987 sq. km
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 ft. (Eagle Peak)
Lowest Point: 5,282 ft. (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: 9°F
July: 80°F
Records:
High: 99°F, 2002 (Mammoth)
Low: -66°F, 1933 (West Entrance, Riverside Station)

Yellowstone Lake

131.7 square miles of surface area
141 miles of shoreline
20 miles north to south
14 miles east to west
Average depth: 140 feet
Maximum depth: 410 feet

GEOLOGY

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

WILDLIFE

67 species of mammals, including:
7 species of native ungulates
2 species of bears
322 species of birds (148 nesting)
16 species of fish (5 non-native)
6 species of reptiles
4 species of amphibians
2 threatened species: Canada lynx, grizzly bear
1 endangered species: gray wolf

FLORA

7 species of conifers
±80% of forest is lodgepole pine
±1,150 species of native vascular plants
>210 species of exotic (non-native) plants
186 species of lichens
At least 406 species of thermophiles

CULTURAL RESOURCES

26 associated Native American tribes
About 1,900 archeological sites
More than 300 ethnographic resources (animals, plants, sites)
More than 24 sites, landmarks, and districts on the National Register of Historic Places
1 National Historic Trail
More than 900 historic buildings
More than 379,000 cultural objects and natural science specimens
Thousands of books (many rare), manuscripts, periodicals
90,000 historic photographs

EMPLOYEES

National Park Service

Permanent: 355
Full time, year-round: 210
Full time, seasonal: 139
Part time: 6
Term (variable duration): 36
Seasonal: 429

Concessioners

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 2010 (in millions)

Total: \$69.5
Federal Funding
Congressional Annual Appropriations:
Operations & staff (base): \$36.8
Wildland Fire: \$1.9
Other Appropriations: \$7.1
Other Funding
Donations & Grants: \$1.4
Fees: \$12.2
Reimbursable: \$10.1

Distribution of Budget

Administration: 12%
Includes human resources, contracting, budget & finance, property management, telecommunications & information technology
Facility Operations & Maintenance: 43%
Includes utilities, roads, trails, structures, historic preservation coordination, construction management
Resource Protection: 13%
Includes research & monitoring of natural and cultural resources, invasive species management
Visitor Services: 32%
Includes interpretation & education, law enforcement, emergency medical services, search & rescue,

entrance station operations, structural fire activities, and park concessions management

VISITATION

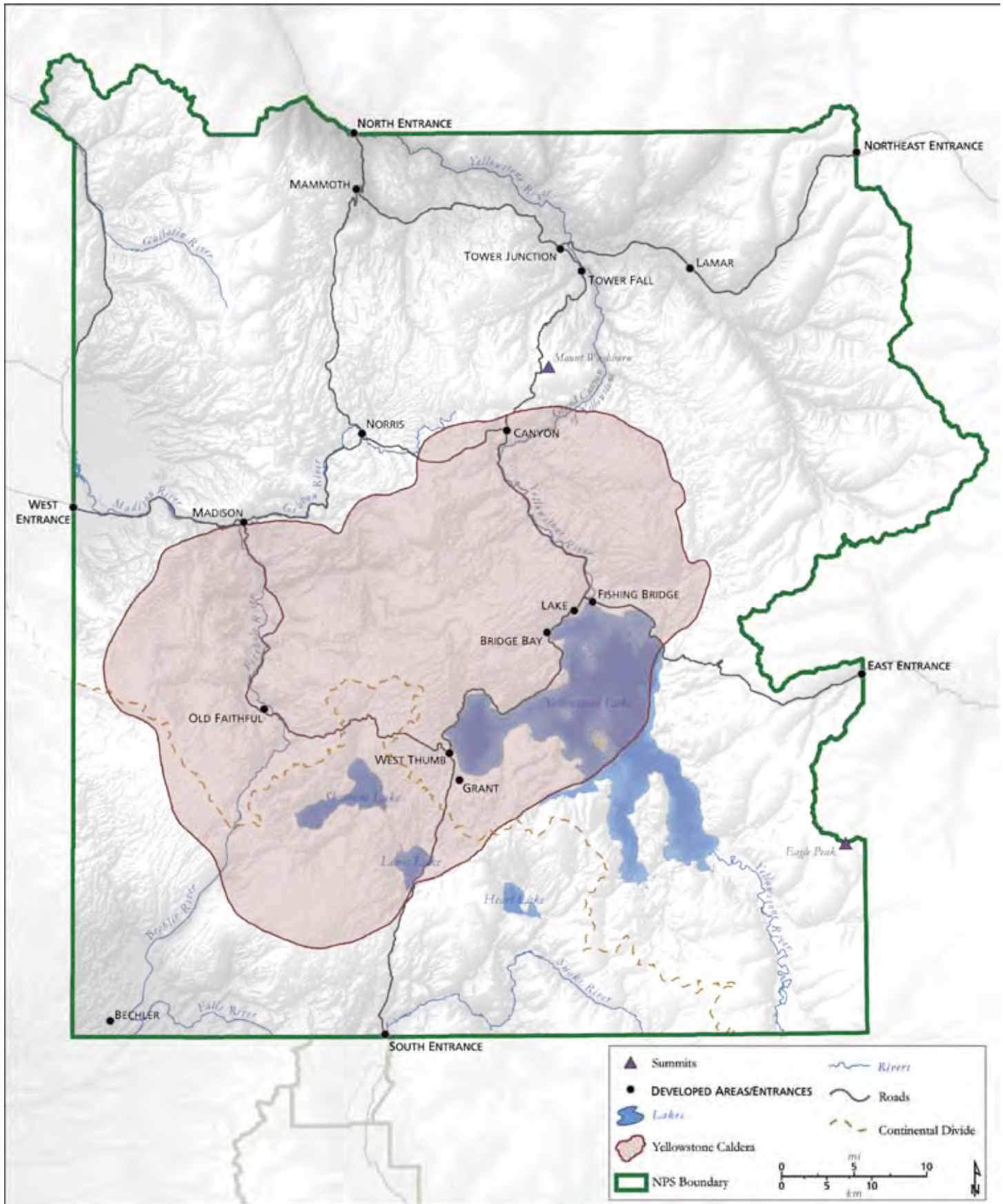
In 2011, park visitation topped the 3 million mark for the fifth straight year. While down 6.8 percent from the record number of people who visited the previous year, it was the second highest visitation year on record. More than one-fourth of the park's total annual visitation was recorded during the month of July. December visitation was down 5.0 percent compared to the previous year. 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 www.nature.nps.gov/stats/.

Top 10 Visitation Years

1.	2010	3,640,184
2.	2011	3,394,321
3.	2009	3,295,187
4.	2007	3,151,343
5.	1992	3,144,405
6.	1999	3,131,381
7.	1995	3,125,285
8.	1998	3,120,830
9.	2008	3,066,570
10.	1994	3,046,145

Yellowstone National Park





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

Frequently Asked Questions

For more information about the topics discussed in the frequently asked questions, see the chapters listed in the table of contents.

General

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.”

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.

Other sources argue Yosemite was the first national park. In 1864, Congress set aside the area surrounding the Yosemite Valley and the Mariposa Grove of Big Trees and gave them to the state of California to administer for public use and recreation. In 1890, new legislation returned the operation of Yosemite to the federal government, but did not specifically name it Yosemite National Park. That was accomplished later by the Secretary of the Interior.

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.

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.



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

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

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

The October 26, 1976, United Nations designation of Yellowstone as a Biosphere Reserve stated:

Yellowstone National Park is recognized as part of the international network of biosphere reserves. This network of protected samples of the world's major ecosystem types is devoted to conservation of nature and scientific research in the service of man. It provides a standard against which the effect of man's impact on the environment can be measured.

The September 8, 1978, United Nations designation of Yellowstone as a World Heritage Site, requested by U.S. President Richard Nixon and Congress, stated:

Through the collective recognition of the community of nations . . . Yellowstone National Park

has been designated as a World Heritage Site and joins a select list of protected areas around the world whose outstanding natural and cultural resources form the common inheritance of all mankind.

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.

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.



The southwest part of the park straddles the Continental Divide, which separates rivers flowing east and west.

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 2011. The Grand Canyon (4.3 million) and Yosemite (3.9 million) also received more recreational visits than Yellowstone (3.3 million) last year. Visit the website nature.nps.gov/stats to find out more details about how many visitors come to our national parks.

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 that begin along this road.

The interior of the park is open to various over-snow 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.

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.

Geography

What is the highest peak in the park?

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

What is the Continental Divide?

Think of the Continental Divide as the crest of the continent. Theoretically, when precipitation falls on the west side of the Divide, it eventually reaches the Pacific Ocean. When it falls on the east side of the Divide, it eventually reaches the Atlantic Ocean. In Yellowstone (as elsewhere), this ridgeline is not straight. You cross the Continental Divide three times between the South Entrance and the Old Faithful area. Craig Pass is the highest crossing, at 8,262 feet.

How cold is Yellowstone in winter?

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

Where does the Yellowstone River flow?

The river begins 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.

How did the Grand Canyon of the Yellowstone River 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.

How did Yellowstone Lake form?

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

Canyon Village Area

Grand Canyon of the Yellowstone River, Mount Washburn, and Hayden Valley

How big is the Grand Canyon of the Yellowstone River?

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

What causes the different colors in the canyon?

You could say the canyon is “rusting.” The colors are caused by oxidation of iron compounds in the rhyolite rock, which has been hydrothermally altered (“cooked”). The colors indicate the presence or absence of water in the individual iron compounds 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 the 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 on the Grand Loop Road south of Canyon Junction, between the entrances to North and South Rim drives.

Is there a place where I can see both falls at once?

No. The canyon bends between the Upper and Lower falls, so there is no location where they can be seen at the same time.

How tall are the falls?

Upper Falls: 109 ft.; Lower Falls: 308 ft.

How much water goes over the falls?

The volume varies from 63,500 gallons (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 green stripe in the Lower Falls?

A notch in the lip in the brink makes the water deeper and keeps it from becoming turbulent as it goes over the edge.

Can I get to the bottom of the canyon?

Only one trail in this area leads to the bottom of the canyon—Seven Mile Hole Trail, a strenuous, steep round trip of 11 miles.

This area has a point and a trail named after "Uncle Tom." Who was he?

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

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. Generally, six to ten osprey nests are occupied in the

canyon near Canyon Village. They nest here from late April until late August or early September. Also look for ravens, bald eagles, and swallows.

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

Hayden Valley, which begins approximately 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 when they may be eating winter-killed animals or preying upon elk calves. Large herds of bison may be viewed in the spring, early summer, and during the rut in August. Coyotes can almost always be seen in the valley; wolves are also sometimes seen.

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

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.

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 LeHardys 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.

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 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 in a tree about one mile 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 Area

Historic Areas and Structures:

- Mammoth Hot Springs Historic District
- Fort Yellowstone Historic Landmark District
- Obsidian Cliff National Historic Landmark
- U.S. 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. A large fault system runs between Norris Geyser Basin and Mammoth, which may allow thermal water to flow between the two. Also, multiple basalt eruptions have occurred in this area. Thus, basalt may be a heat source for the Mammoth area.

Why are the dry springs so white?

Limestone underlies this area. Water dissolves the mineral, which is deposited at the surface to form travertine. This rock is naturally white; colors in the hot springs come from heat-loving microorganisms called thermophiles.

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 it is still considered accurate.

What were these old buildings?

Most of these buildings belong to Fort Yellowstone, built by the U.S. Army from 1891 to 1913, when it managed the park. You can walk a self-guiding trail through this National Historic Landmark District.

Can we soak in the hot springs?

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

What is the 45th parallel?

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

What forms the canyon north of Mammoth?

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



Vegetation in the Greater Yellowstone Ecosystem has adapted to fire and in some cases may be dependent on it.

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

Why is Obsidian Cliff a National Historic Landmark?

For centuries Native Americans came to this cliff to 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 Hot Springs. South of Bunsen Peak is Swan Lake Flat, where visitors often see elk, bison, and sometimes grizzlies and wolves. It

is also an excellent place for watching cranes, ducks, and other birds.

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 *Zygonium* 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 housed 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.

Old Faithful Area

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 March 2012, the usual interval is 89 minutes \pm 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 203°F (95.6°C).

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 interpretive 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.

Tower-Roosevelt Area

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 the Petrified Tree become petrified?

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

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

Did Teddy Roosevelt really stay at Roosevelt Lodge?

No, but President Theodore Roosevelt camped nearby during his visit to Yellowstone in 1903. The lodge opened in 1920. The area is registered as the Roosevelt Lodge Historic District.

What animals can I see in this area?

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

The gorge and cliffs between the junction and Tower Fall provide habitat for bighorn sheep, osprey, peregrine falcons, and red-tailed hawks. Both grizzly and black bears are sighted throughout the area, particularly in the spring. Black bears are more commonly seen around Tower Fall and Tower Junction. Grizzlies are sometimes seen in the Lamar Valley and

on the north slopes of Mt. Washburn, particularly in the spring when elk are calving. Road pullouts provide excellent places from which to watch wildlife.

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 100°F to just over 200°F.

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.

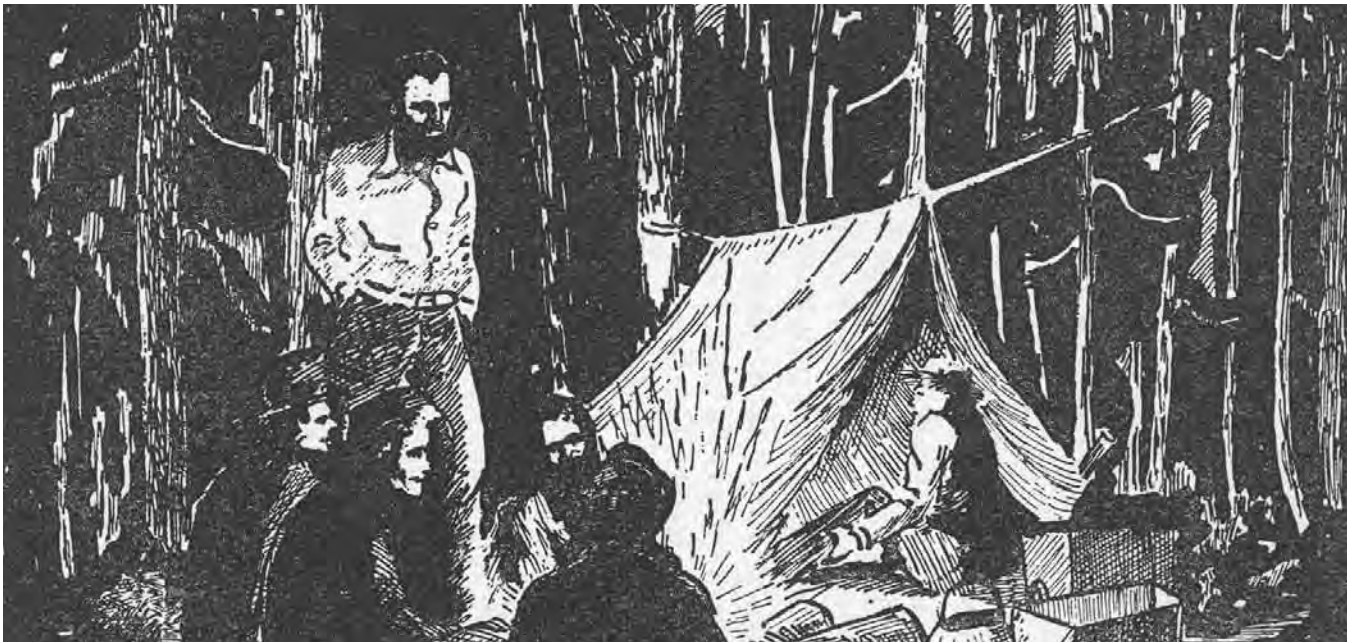
What's that big lake you see south of Craig Pass?

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.



The continued reports of 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.

Introduction

The Beginning of an Idea

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

It is a wonderful story—and a myth. But those men were real, and so is this land they explored. Thanks to their reports and the work of explorers and artists who followed, the United States Congress established Yellowstone National Park in 1872. The Yellowstone National Park Protection Act says “the headwaters of the Yellowstone River . . . is hereby reserved and withdrawn from settlement, occupancy, or sale

. . . and dedicated and set apart as a public park or pleasuring-ground for the benefit and enjoyment of the people.” In an era of expansion, the federal government had the foresight to set aside land deemed too valuable to develop.

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.

Yosemite became a park before Yellowstone, but as a state park. In 1864, the Lincoln administration put it under the care of the state of California. 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

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 U.S. Code Table of Popular Names: The Yellowstone National Park Protection Act and The National Park Service Organic Act.

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

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

Today's National Park System

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

- National parks are the oldest, most well-known part of the system and are usually areas of spectacular natural scenery relatively untouched by human development. National parks are established by acts of Congress.

- National monuments are areas of historic or scientific interest established by presidential proclamation.
- National historical parks and national historic sites are both set aside to commemorate some facet of the history of the people of those areas.
- Many national memorials fit the description for national historical parks or sites, but some of these are also set aside because of important historical issues not specifically linked to the site of the memorial, such as Mt. Rushmore and Vietnam Veterans.

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

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

Implementing the NPS Mission

Systemwide

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

- *Natural resources* (plants, animals, water, air, soils, topographic features, paleontologic resources, and esthetic values such as scenic vistas, natural quiet, and clear night skies) are managed to maintain, rehabilitate, and perpetuate their inherent integrity. Native species that have been exterminated should be reintroduced and exotic species eliminated,

if possible. Livestock grazing, hunting, and resource extraction are prohibited in National Park System areas, with a few exceptions.

- *Cultural resources* (prehistoric and historic structures and resources, landscapes, archeologic resources, ethnographic resources, and museum collections) are preserved.

International Leadership

The National Park Service example has inspired countries around the world to establish more than 100 national parks—modeled in whole or part on Yellowstone National Park and the National Park Service idea. Additionally, the NPS lends its experienced staff to other countries to evaluate park proposals, management plans, and resource issues. As the first national park, Yellowstone also continues to be a leader in developing and implementing policies in the National Park Service.

Guidance for Protecting Yellowstone National Park

Yellowstone National Park 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.

Yellowstone National Park Purpose Statement

Yellowstone, the world's first national park:

- preserves geologic wonders, including the world's most extraordinary collection of geysers and hot springs and the underlying volcanic activity that sustains them;
- preserves abundant and diverse wildlife in one of the largest remaining intact wild ecosystems on Earth, supporting unparalleled biodiversity;
- preserves an 11,000-year-old continuum of human history, including the sites, structures,

and events that reflect our shared heritage; and

- provides for the benefit, enjoyment, education, and inspiration of this and future generations.

Significance of Yellowstone National Park

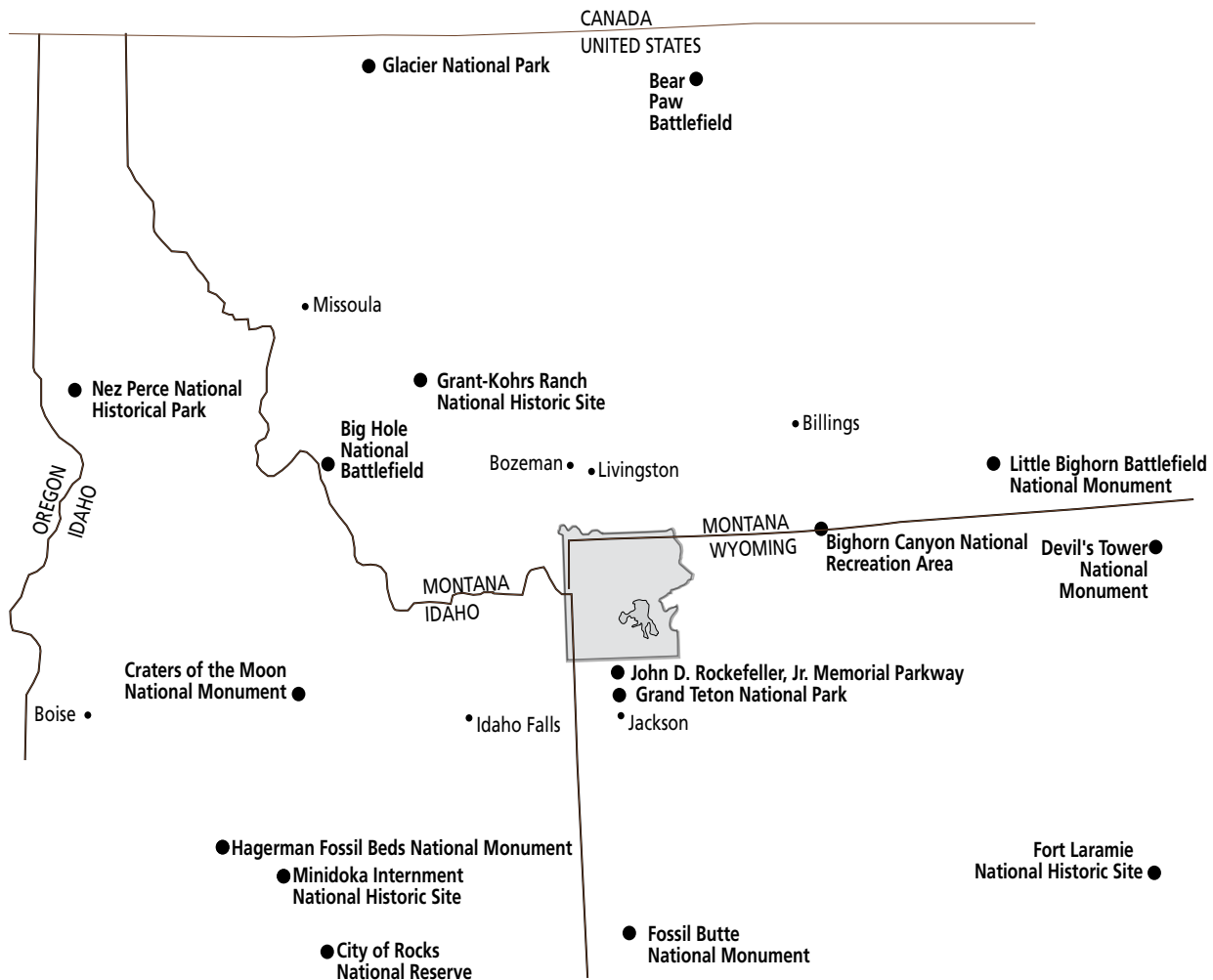
- An international symbol of natural preservation.
- A Biosphere Reserve and a World Heritage Site.
- Contains more than 10,000 thermal features—including more than 300 geysers, which represents more than half of the total number of geysers in the world.
- Home of the world's tallest active geyser, Steamboat, which erupts to more than 300 feet.
- One of the few places in the world with active travertine terraces.
- Hydrothermal features are habitats for microbes that are providing links to primal life, origins of life, and astrobiology; plus they are proving useful in solving some of our most perplexing medical and environmental problems.
- With the restoration of the gray wolf in 1995, the park now contains all the large mammal species known to be present when European Americans first arrived.

Total NPS areas = 397

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	58
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	397

- As of February 2012. For details, visit www.nps.gov/pub_aff/refdesk/index.html

- Home to one endangered species—the gray wolf, and two threatened species—the Canada lynx and the grizzly bear.
- Home to one of the largest concentrations of elk in the world.
- Only place in the United States where bison have existed in the wild since primitive times. The early legislation that protected these bison, the Lacey Act of 1894, was a precursor to the Endangered Species Act.
- Site of one of the largest volcanic eruptions in the world. Site of the spectacular Grand Canyon of the Yellowstone River.
- Location of largest lake above 7,000 feet in North America—Yellowstone Lake.
- Source of two great North American rivers: two of the three forks of the Missouri River, and the Snake, which is part of the Columbia River system. The Yellowstone River, which begins just south of the park, is the longest free-flowing river in the continental United States.





Humans have spent time in the Yellowstone region for more than 11,000 years. Rock structures like this, believed to be part of a vision quest site, are evidence of the early presence of people in the area. Although some structures are uniformly weathered and appear to be old, we do not know when or by whom they were constructed.

History of the Park

The human history of the Yellowstone region goes back more than 11,000 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. The last period of ice coverage ended 13,000–14,000 years ago, and sometime after that, humans arrived here.

The Earliest Humans in Yellowstone

Human occupation of the greater Yellowstone area seems to follow environmental changes of the last 15,000 years. Glaciers and a continental ice 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 first people arrived in this region sometime before 11,000 years ago. Archeologists have found little physical evidence of their presence except for their distinctive stone tools and projectile points. From these artifacts, scientists surmise that they hunted mammals and ate berries, seeds, and roots.

As the climate in the Yellowstone region warmed and dried, the animals, vegetation, and human lifestyles also changed. Large Ice Age animals that were adapted to cold and wet conditions became extinct. The glaciers left behind layers of sediment in valleys in which grasses and sagebrush thrived, and pockets of exposed rocks that provided protected areas for aspens and fir to grow. The uncovered volcanic plateau sprouted lodgepole forests. People adapted to these changing conditions and were eating a diverse diet of medium and small sized animals as early as 9,500 before present (B.P.) 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

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



Paleoindian Period (B.P.)

~12,000 B.P.

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

B.P. = Before Present

10,000 B.P.

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



**Hell Gap point,
9,600–10,000
B.P.**

9,350 B.P.

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

plants such as prickly pear cactus. They may have also established a distinct home territory in the valleys and surrounding mountains.

This favorable climate would continue more than 9,000 years. Evidence of these people in Yellowstone remained uninvestigated, even long after archeologists began excavating sites elsewhere in North America. Archeologists used to think high regions such as Yellowstone were inhospitable to humans and thus, did little exploratory work in these areas. However, park superintendent Philetus W. Norris (1877–82) found artifacts in Yellowstone and sent them to the Smithsonian Institution in Washington, D.C. Today, archeologists study environmental change as a tool for understanding human uses of areas such as Yellowstone.

Approximately 1,900 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 ~700 B.P.

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

Highlights of Yellowstone’s History

- People have been in Yellowstone more than 11,000 years, as shown by archeological sites, trails, and oral histories.
- Although Sheep Eaters are the most well-known group of Native Americans to use the park, many other tribes and bands lived in and traveled through what is now Yellowstone National Park prior to and after European American arrival.
- European Americans began exploring in the early 1800s.
- Osborne Russel recorded early visits in the 1830s.
- First organized expedition explored Yellowstone in 1870.
- Yellowstone National Park established in 1872.
- Railroad arrived in 1883, allowing easier visitor access.
- The U.S. Army managed the park from 1886 through 1918.
- Automobiles allowed into the park in 1915, making visits easier and more economical.
- National Park Service created, 1916
- First boundary adjustment of the park made in 1929.
- “Leopold Report” released in 1963; its recommendations changed how wildlife is managed in the park.
- 1970: New bear management plan 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.

Archaic Period (7,000–1,500 B.P.)

7,000 B.P.

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

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

3,000 B.P.

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

1,500 B.P.

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

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

The Little Ice Age

Climatic evidence has already confirmed the Yellowstone area experienced colder temperatures during what is known as the Little Ice Age—mid-1400s to mid-1800s. Archeological evidence indicates fewer people used this region during this time, although more sites dating to this period are being discovered. Campsites appear to have been used by smaller groups of people, mostly in the summer. Such a pattern of use would make sense in a cold region where hunting and gathering were practical for only a few months each year.

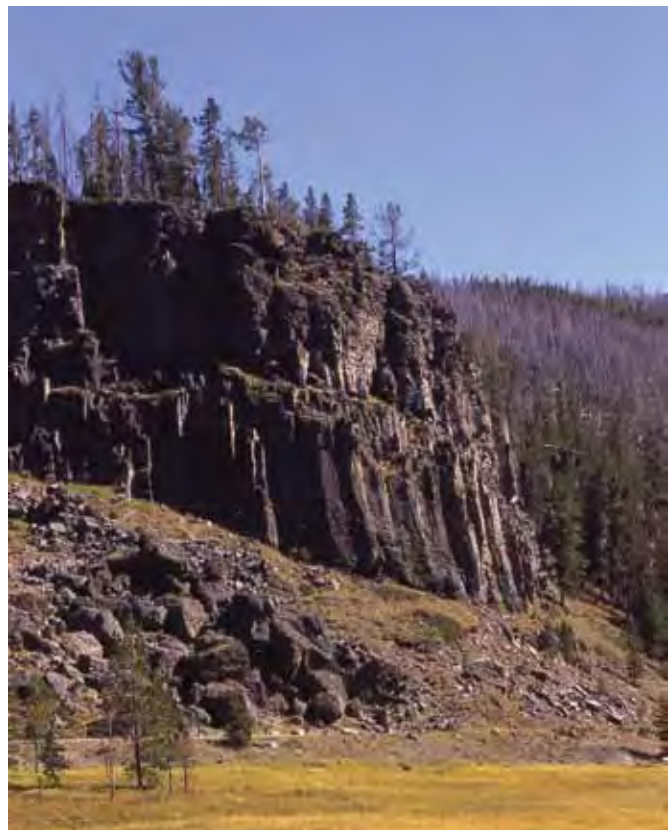
Historic Tribes

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

The Crow occupied the country generally east of the park, and the Blackfeet occupied the country to the north. The Shoshone, Bannock, and other tribes of the plateaus to the west traversed the park

annually to hunt on the plains to the east. Other Shoshonean groups hunted in open areas west and south of Yellowstone.

In the early 1700s, some tribes in this region began to acquire the horse. Some historians believe the horse fundamentally changed lifestyles because tribes could now travel faster and farther to hunt bison and other animals of the plains.



Obsidian Cliff, a source of obsidian valued highly by native cultures, as seen from the Grand Loop Road between Mammoth and Norris. The site was designated a National Historic Landmark in June 1996.

1400

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

1450

Little Ice Age begins.

1600s

North American tribes in the southwest begin acquiring horses in the mid- to late 1600s. Ancestors of the Crow may have come into Yellowstone during this time.

1700s

Lakota Sioux begin exploring the Yellowstone area.

late 1700s

Fur traders travel the rivers into the Yellowstone region. Tribes in the Yellowstone area begin using horses.

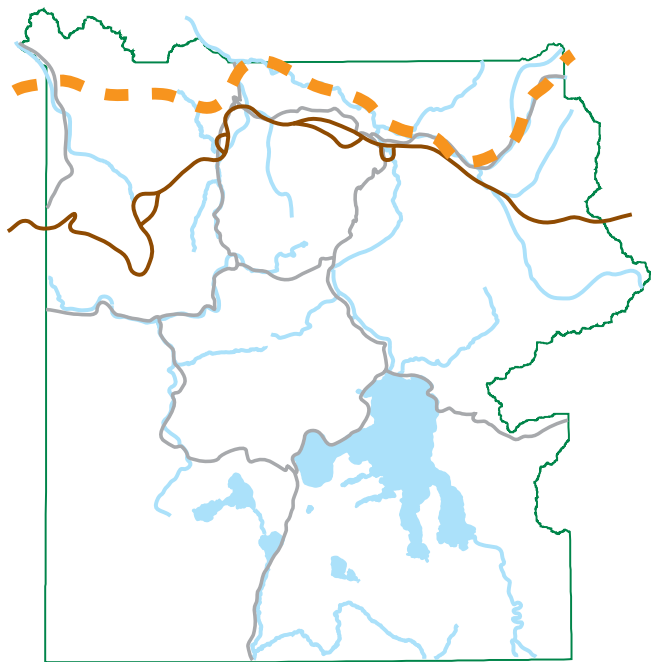
C.E. = Common Era (replaces A.D.)

The “Sheep Eaters”

Some groups of Shoshone who adapted to a mountain existence chose not to acquire the horse.

These included the Sheep Eaters, or Tukudika, who used their dogs to transport food, hides, and other provisions.

Sheep Eaters acquired their name from the bighorn sheep whose migrations they followed. Bighorn sheep were a significant part of their diet, and they crafted the carcasses into a wide array of tools and implements. For example, they soaked sheep horn in hot springs to make them pliable for bows. They traded these bows, plus clothing and hides, to other tribes.



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

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

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

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

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

Osborne Russell wrote a book about fur trapping in and around Yellowstone around 1820-1830.

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.

1800–1860 C.E.

1804–1806	1807–1808	1812	1820s	1834–1835	1840s	1850s	1860
The Lewis and Clark Expedition passes within 50 miles of Yellowstone.	John Colter explores part of Yellowstone.	The War of 1812 begins.	Trappers return to Yellowstone area.	Trapper Osborne Russell encounters Sheep Eaters in Lamar Valley.	Trapper era ends.	Little Ice Age ends, climate begins to warm.	First organized expedition attempts but fails to explore the Yellowstone Plateau.

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 “Discover” Yellowstone

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

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



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.



Wickiups provided temporary shelter for some Native Americans while they were in Yellowstone. None are known to remain standing.

of a friend who said their journey was “the next thing to suicide” because of “Indian trouble” along the way. From Bozeman, they traveled down the divide between the Gallatin and Yellowstone rivers, crossed the mountains to the Yellowstone and continued into the present park. They observed Tower Fall, the Grand Canyon of the Yellowstone—“this masterpiece of nature’s handiwork”—continued past Mud Volcano to Yellowstone Lake, then south to West Thumb. From there, they visited Shoshone Lake and the geyser basins of the Firehole River. The expedition updated an earlier explorer’s map (DeLacy, in 1865), wrote an article 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).

1861	1862	1865	1869	1870	1871	1872	1877	1883
Civil War begins.	Gold strike northwest of Yellowstone.	Civil War ends.	Folsom–Cook–Peterson Expedition.	Washburn–Langford–Doane Expedition; Old Faithful Geyser named.	First Hayden Expedition.	Yellowstone National Park Protection Act establishes the first national park.	Nez Perce (Nee-me-poo) flee U.S. Army through Yellowstone.	Northern Pacific Railroad reaches the North Entrance of the park.

The explorers traveled to Tower Fall, Canyon, and Yellowstone Lake, followed the lake's eastern and southern shores, and explored the Lower, Midway, and Upper geyser basins (where they named Old Faithful). They climbed several peaks, descended into the Grand Canyon of the Yellowstone, and attempted measurements and analyses of several of the prominent natural features.

The 1871 Hayden Expedition

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

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

1872—Birth of a National Park

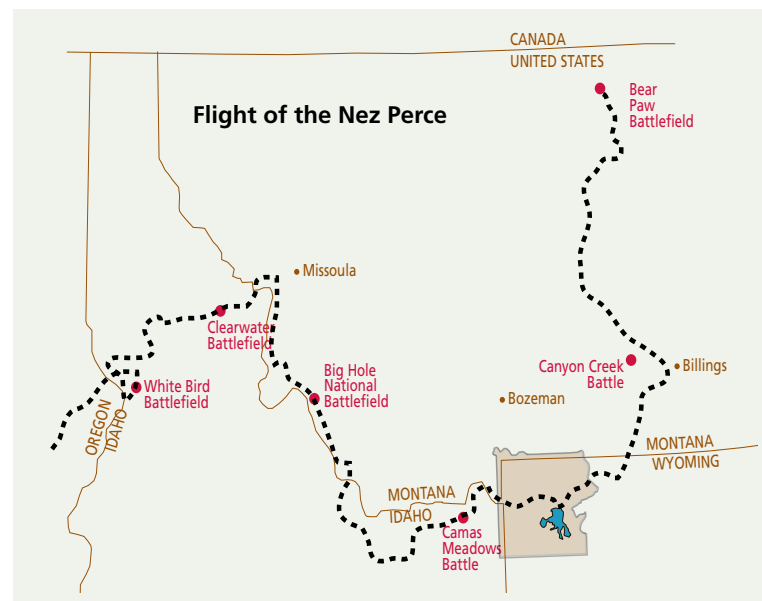
The crowning achievement of Yellowstone's explorers was helping to save Yellowstone from private development. They promoted a park bill in Washington in late 1871 and early 1872 that drew upon the precedent of the Yosemite Act of 1864, which reserved Yosemite Valley from settlement and entrusted it to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

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

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



1886	1894	1903	1906	1908	1915	1916	1918	1929
The U.S. Army arrives to administer the park. They stay until 1918.	Poacher Ed Howell captured; National Park Protection Act (Lacey Act) passed.	President Theodore Roosevelt dedicates arch at the North Entrance in Gardiner.	The Antiquities Act provides for the protection of historic, prehistoric, and scientific features on, and artifacts from, federal lands.	Union Pacific train service begins at West Yellowstone.	Private automobiles are officially admitted to the park.	The National Park Service Organic Act establishes the National Park Service.	U.S. Army turns over park management to the National Park Service.	President Hoover signs first law changing park's boundary.

authorized appropriations “to protect, preserve, and improve the Park.”

Norris constructed roads, built a park headquarters at Mammoth Hot Springs, hired the first “game-keeper,” and campaigned against hunters and vandals. Much of the primitive road system he laid out remains as the Grand Loop Road. Through constant exploration, Norris also added immensely to geographical knowledge of the park.

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

Norris fell victim to political maneuvering and was removed from his post in 1882. He was succeeded by three powerless superintendents who could not protect the park. Even when ten assistant superintendents were authorized to act as police, they failed to

stop the destruction of wildlife. Poachers, squatters, woodcutters, and vandals ravaged Yellowstone.

1886—The Army Arrives

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

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

The most persistent menace came from poachers, whose activities threatened to exterminate animals such as the bison. In 1894, soldiers arrested a man named Ed 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

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 U.S. Army. Settlers were moving into their homeland and the U.S. Government was trying to force them onto a reservation. At Big Hole, Montana, many of their group, including women and children, were killed in a battle with the Army. The remainder of the group continued fleeing, and entered Yellowstone National Park on August 23. During the two weeks they crossed the park, the Nez Perce encountered 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 into Canada, but after fierce fighting and a siege, the rest of the band surrendered on October 5. This is where it is believed Chief Joseph said, “From where the sun now stands, I will fight no more forever.” The 1,170-mile flight had ended.

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

1932

President Hoover expands the park again.

1933

Civilian Conservation Corps established, works in Yellowstone through 1941.

1934

NPS Director's Order prohibits killing predators.

1935

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

1948

Park receives one million visitors.

1949

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

1955

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

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.

1916—The National Park Service Begins

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

Act, creating the National Park Service.

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



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



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

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.)

1959

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

1963

The Leopold Report is issued.

1966

Thermus aquaticus discovered in a Yellowstone hot spring.

1970

New bear management plan begins, which includes closing open-pit dumps in park.

1971

Overnight winter lodging opens in park.

1975

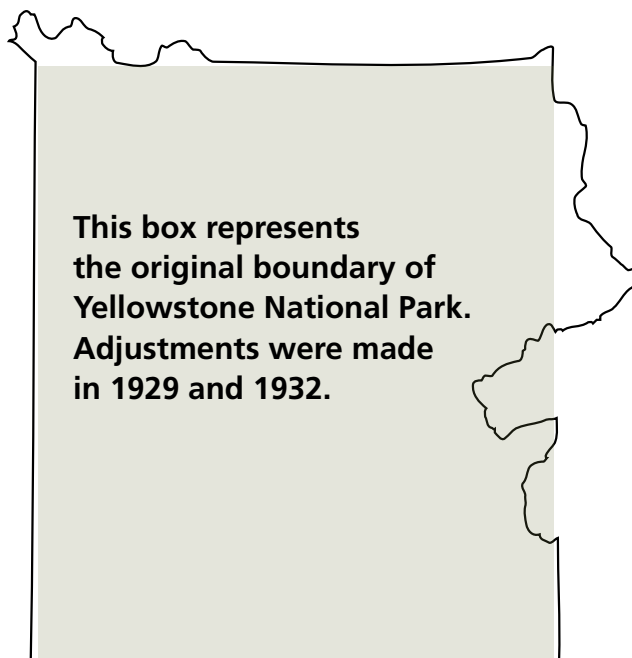
Grizzly bear listed as threatened species in the lower 48 states.

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

Efforts to exploit the park also expanded during this time. Water users, from the town of Gardiner to the potato farmers of Idaho, wanted the park's water. Proposals included damming the southwest corner of the park—the Bechler region. The failure of these schemes confirmed that Yellowstone's wonders were so special that they should be forever preserved from exploitation.

The 1940s

World War II drew away employees, visitors, and money from all national parks, including Yellowstone. The money needed to maintain the park's facilities, much less construct new ones, was directed to the war effort. Among other projects, the road from Old Faithful to Craig Pass was unfinished.



The National Park Service Organic Act

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

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

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

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

Mission 66

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

In Yellowstone, Canyon Village was developed as part of Mission 66. 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.

From Managed to "Natural"

Until the mid-1960s, park managers actively managed the elk and bison of Yellowstone. Elk population

1988

Public Law 100-443 protects hydrothermal features in national parks from geothermal development on adjacent federal lands; Summer of Fire: more than 790,000 acres affected by fires in Yellowstone.

1991

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

1994

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

1995

Wolves are restored to the park.

1996

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

1998

The National Parks Omnibus Management Act is passed.

limits were determined according to formulas designed to manage livestock range. When elk reached those limits, park managers “culled” or killed the animals to reduce the population. Bison were likewise heavily managed.

In 1963, a national park advisory group, comprised of prominent scientists, released a report recommending parks “maintain biotic associations” within the context of their ecosystem, and based on scientific research. Known as the Leopold Report, this document established the framework for park

management still used today throughout the National Park System. By adopting this management philosophy, Yellowstone went from an unnatural managing of resources to “natural regulation”—today known as Ecological Process Management.

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

Associated Tribes of Yellowstone National Park



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

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

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 & 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.

Involving Native Americans

Yellowstone National Park has 26 associated tribes. Some have evidence of its ancestral presence in 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 1994, as part of a pilot

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

A Decade of Environmental Laws

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

The 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.

Preserving the Park's History

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

Archeological Sites

More than 1,600 prehistoric sites exist in the park. The oldest known site is on the shore of Yellowstone Lake, and is eroding. Rather than stopping that natural process, archeologists excavated the site in 2000 and 2002. They found evidence of people camping and hunting as well as performing domestic chores. They probably used this Yellowstone site in the summer while hunting bear, deer, bighorn, and rabbits, and perhaps making tools and clothes. Archeologists speculate these early park visitors may have made rafts to visit islands in Yellowstone Lake due to the discovery of 3,000 B.P. artifacts on the islands.

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.

Construction Dates for Other Park Buildings

Lake General Store 1920	Old Faithful Lower General Store 1897, 1921 addition
Lake Ranger Station 1922–23	Old Faithful Upper General Store 1929–30
Mammoth Chapel 1912–13	South Entrance Ranger Station Duplex 1928
Mammoth Gas Station 1920	Tower General Store 1932
Mammoth Post Office 1932	West Thumb Ranger Station 1925; now an information station
Old Faithful Gas Station (Lower) 1920, 1925	

Yellowstone's Cultural Resources

- More than 300 ethnographic resources (animals, plants, sites)
- Approximately 1,900 prehistoric and historic Native American archeological sites and historic European American archeological sites
- More than 2 dozen sites, landmarks, and districts listed on the National Register of Historic Places; many more eligible for listing
- More than 900 historic buildings
- 1 National Historic Trail
- Museum collection of more than 379,000 cultural objects and natural science specimens available to researchers
- Archives containing millions of historic documents
- Thousands of books and periodicals available to the public; plus manuscripts and rare books available to historians and other researchers
- 90,000 historic photographs used by staff, scholars, authors, and filmmakers

Ethnographic Resources

Yellowstone National Park has more than 300 ethnographic resources identified by tribal peoples. These include: animals such as bison; plants; hydrothermal areas; mineral paints from hydrothermal areas; Yellowstone Lake; vision questing sites; obsidian, rendezvous sites; and hunting sites.

Historic Structures and Districts

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.

Roosevelt Arch (1903)

The Roosevelt Arch rises in the North Entrance Road Historic District and is part of the Fort Yellowstone Historic Landmark District. This soaring stone structure was conceived by U.S. Engineer Hiram Chittenden; Robert Reamer may have contributed

to the design, and architect N.J. Ness also worked on it. President Theodore Roosevelt placed the cornerstone for the arch in 1903. The top of the arch is inscribed with a line from the Yellowstone National Park Act of 1872: “For the benefit and enjoyment of the people.”

Old Faithful Inn & Historic District (1903–1904)

Most people who step into the Old Faithful Inn for the first time stop as their eyes follow thick rustic logs up to the soaring peak of the ceiling. Robert Reamer designed this National Historic Landmark, which opened in 1904. It is the centerpiece of the Old Faithful Historic District. Nearby, the Old Faithful Lodge is a result of numerous changes made until 1928 when the lodge reached its present configuration.

The Buffalo Ranch (1906)

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

Mammoth Hot Springs/Fort Yellowstone (1909)

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



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



Madison Museum.

Roosevelt Area (1920)

Diners at Roosevelt Lodge (President Theodore Roosevelt had camped nearby) view much the same landscape seen by visitors when the lodge opened in 1920. The area is registered as the Roosevelt Lodge Historic District.

Trailside Museums (1929–1932)

Four trailside museums were built in Yellowstone and reflect a concept that a national park is itself a museum, that an interpretive structure should blend in with its surroundings and that its exhibits should explain but not substitute for the park experience.



Left to right: Lake Hotel, Buffalo Ranch, and Old Faithful Inn.

Yellowstone on the National Register of Historic Places

This is a partial list.

National Historic Landmark District

- Fort Yellowstone

National Historic Landmarks

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

National Register Historic Districts

- Lake Fish Hatchery
- Mammoth Hot Springs
- North Entrance Road
- Old Faithful Area
- Roosevelt Lodge

National Historic Sites

- Lake Hotel
- Lamar Buffalo Ranch
- Obsidian Cliff Kiosk
- Queen's Laundry Bath House
- Mammoth Post Office

a gateway to the Norris Geyser Basin. Visitors first glimpse the area's hydrothermal features from a breezeway.

The Madison Museum, overlooking the junction of the Gibbon and Firehole rivers, features many elements associated with National Park Rustic: stone and wood-shingled walls, and rafters of peeled logs. Built in 1930, it now serves as an information station and bookstore.

The Fishing Bridge Museum, built in 1932, retains many original exhibits as an example of early National Park Service displays. On the south side of the museum, visitors can cross a flagstone terrace overlooking Yellowstone Lake and descend steps to the shore.

Lodging No Longer Standing

Marshall's Hotel, which stood near the present-day intersection of Fountain Flats Drive and Grand Loop Road, was built in 1880 and was the second hotel in the park. Later renamed the Firehole Hotel, it was razed in 1895.

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

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.

The museums here are well-known examples of the architectural style, National Park Rustic (also called "parkitecture").

The Old Faithful Museum was the first trailside museum in Yellowstone, and the only one no longer standing. It opened in 1929 to acclaim for its quality materials and construction, and for the way it blended into its surroundings.

The Norris Museum, built in 1930, still serves as

Historic Designations

National Register of Historic Places

The National Register of Historic Places is the Nation's official list of cultural resources worthy of preservation. Authorized under the National Historic Preservation Act of 1966, the National Register is part of a national program to coordinate and support public and private efforts to identify, evaluate, and protect our historic and archeological resources. Properties listed in the Register include districts, sites, buildings, structures, and objects

that are significant in American history, architecture, 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

National Historic Landmarks are nationally significant historic places

designated by the Secretary of the Interior because they possess exceptional value or quality in illustrating or interpreting the heritage of the United States. Today, fewer than 3,500 historic places bear this national designation. The National Historic Landmarks program draws upon the expertise of National Park Service staff who evaluate potential landmarks and work to preserve existing landmarks.

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.

Historic Artifacts and Documents

Objects and written records document the history and science of the park, changes in perception and meaning over time, and the interaction between people and nature. Ranging from geologic and natural history specimens to Native American and European American cultural materials, the historic collections document the park from pre-history through the present.

Preserving and providing access to Yellowstone's historic collections was made easier with the opening of the Heritage and Research Center (HRC) in Gardiner, Montana in 2005. The state-of-the-art facility provides secure, environmentally controlled storage for the fragile materials as well as dedicated space for research use. Open to the public, researchers at the HRC range from local high school students working on term papers to tourists re-tracing an ancestor's visit and from park staff developing interpretive programs or researching climate change to filmmakers preparing a miniseries for PBS. Webpages relating to the collections may be accessed at www.nps.gov/yell/historyculture/collections.htm.

Archives

The Yellowstone National Park archives house records that document 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 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, and oral histories.

The Yellowstone National Park archives are an affiliated archive of the National Archives and Records Administration (NARA), which allows permanent federal records created by the park's administration to remain in Yellowstone instead of being transferred to the National Archives as is the norm. 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 archives webpage.

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)

authorizes the creation of the National Register of Historic Places and gives extra protection to national historic landmarks and properties in the national register. National parks established for their historic value automatically are registered; others, such as Yellowstone, must nominate landmarks and properties to the register.

The Archeological and Historic Preservation Act (1974)

provides for the preservation of significant scientific, historic, and archeological material and data that might be lost or destroyed by federally sponsored projects. For example, federal highway projects in Yellowstone include archeological surveys.

The Archeological Resources Protection Act (1979)

provides for the preservation and custody of excavated materials, records, and data.

The Native American Graves Protection and Repatriation Act (1990)

assigns ownership or control of Native American human remains, funerary objects, and sacred objects of cultural patrimony to culturally affiliated Native American groups.

American Indian Religious Freedom Act (AIRFA)

protects and preserves American Indian access to sites, use and possession of sacred objects, and the freedom to worship through ceremonials and traditional rites.

Executive Order 13007

guarantees access to and ceremonial use of Indian sacred sites by Indian religious practitioners to ensure that these sites not adversely affected.

Library

The Yellowstone Research Library serves the park staff, volunteers and members of the general public with year-round open hours Tuesday through Friday, 9 am to 4 pm. The collection consists of over 20,000 books, magazines, articles, pamphlets and AV materials related to the history, culture, geology, animals and plants of Yellowstone National Park. The entire collection is cataloged online through the Wyoming Library Databases consortium (<http://wyld.state.wy.us>) and most publications can be requested through Interlibrary Loan from a local public or university library.

Museum

Yellowstone has one of the largest collections in the National Park Service, with more than 5.3 million items. The largest belongs to Edison National Historic Site, which contains more than 6 million items. Yellowstone's collections document the cultural and natural history of the world's first national park and the conditions of its resources. The collections grow continuously with the addition of archeological and natural science objects, important donations, and occasional purchases. The 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 snowmobiles.

The Legacy of Yellowstone

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

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

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

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

Touring the Park



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

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

These visitors carried home unforgettable memories of experiences and sights, and they wrote hundreds of accounts of their trips. They recommended the tour to their friends, and each year more 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.



The Greater Yellowstone Ecosystem is one of the largest intact temperate-zone ecosystems on Earth today.

Greater Yellowstone Ecosystem

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

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

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

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

The distribution of rocks and sediments in the park also influences the distribution of flora and fauna. The volcanic rhyolites and tuffs of the Yellowstone Caldera are rich in quartz and potassium feldspar, which form nutrient-poor soils. Thus, areas of the park underlain by rhyolites and tuffs generally are characterized by extensive stands of lodgepole

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

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

Biodiversity and Processes

Biological Diversity

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

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

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

Other unique life forms are protected here, too. Various species of microorganisms are 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. Photo-synthesis, 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 hydro-thermal 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.

Greater Yellowstone Ecosystem Basics

- 12–18 million acres; 18,750–28,125 square miles (see map, next page, for why it varies)
- States: Wyoming, Montana, Idaho
- Encompasses state lands, two national parks, portions of six national forests, three national wildlife refuges, Bureau of Land Management holdings, private and tribal lands
- Managed by state governments, federal government, tribal governments, and private individuals
- One of the largest elk herds in North America
- Largest free-roaming, wild herd of bison in U.S.
- One of few grizzly populations in contiguous U.S.
- Rare sightings of wolverine and lynx

In Yellowstone National Park:

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

Management Challenges

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



These whitebark pine trees grow in the andesitic soils on Mount Washburn.

Decomposers—bacteria, fungi, other microorganisms—link all that dies with all that is alive.

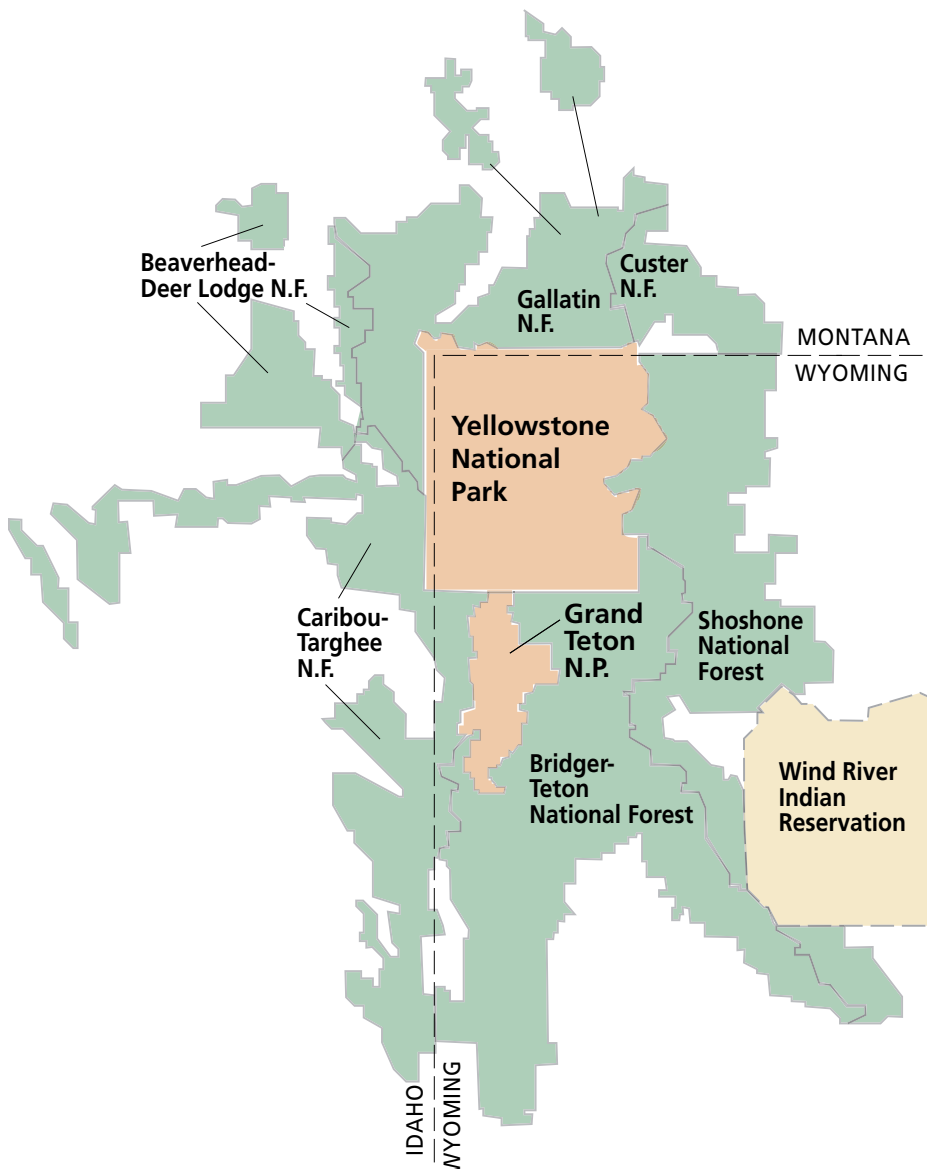
The ecosystem is constantly changing and evolving. A wildland fire is one example of such an integral, dynamic process. Fires rejuvenate forests on a grand scale. Fires rejuvenate forests on a grand scale. Some species of plants survive the intense burning to resprout. Some cones of lodgepole pines pop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

Complexity

Increasing Community Complexity

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

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



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



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

Intricate Layers

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

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

Trophic Cascades

Scientists in Yellowstone have been exploring the hypothesis that wolf restoration is causing changes in predator/prey/vegetation relationships—what ecologists call a “trophic cascade.” Most researchers agree that wolves have caused elk to change their behavior. For example, elk don’t linger in willow or aspen areas. Some researchers say this behavioral change is the reason why recent willow growth has been strong. Not all scientists agree with this conclusion. However, if wolves are the main factor in willow increase, they could also be indirectly increasing riparian bird habitat and improving fish habitat.

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

Balancing Nature?

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

Consider the northern Yellowstone elk herd, which has been declining. The recovery of the wolf occurred simultaneously with increased grizzly bear and mountain lion populations, increased human hunting of elk (especially female or “antlerless”) north of the park, and an extended drought. Computer models prior to wolf recovery predicted a decline in elk, but did not incorporate these other factors, and the decline has exceeded predictions. Populations of prey species that share their habitat with more rather than fewer species of predators are now thought to fluctuate around lower equilibria.

The elk populations of Yellowstone will continue to adjust to the pressures and opportunities they face, as will their wild neighbors, large and small.

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

Winter in Yellowstone

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

Animal Behavioral Adaptations

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

Animal Morphological/Physical Adaptations

- Mammals molt their fur in fall. Incoming guard hairs are longer and protect the underfur. Additional underfur grows each fall and consists of short, thick, often wavy hairs designed to trap air. A sebaceous (oil) gland, adjacent to

each hair canal, secretes oil to waterproof the fur. Mammals have muscular control of their fur, fluffing it up to trap air when they are cold and sleeking it down to remove air when they are warm.

- River otters' fur has long guard hairs with interlocking spikes that protect the underfur, which is extremely wavy and dense to trap insulating air. Oil secreted from sebaceous glands prevents water from contacting the otters' skin. After emerging from water, they replace air in their fur by rolling in the snow and shaking their wet fur.
- Snowshoe hares, white-tailed jackrabbits, long-tailed weasels, and short-tailed weasels turn white for winter. White provides camouflage but may have evolved primarily to keep these animals insulated as hollow white hairs

contain air instead of pigment.

- Snowshoe hares have large feet to spread their weight over the snow; martens and lynx grow additional fur between their toes to give them effectively larger feet.
- Moose have special joints that allow them to swing their legs over snow rather than push through snow as elk do.
- Chickadees' half-inch-thick layer of feathers keeps them up to 100 degrees warmer than the ambient temperature.

Biochemical/Physiological Adaptations

- Mammals and waterfowl exhibit counter-current heat exchange in their limbs that enables them to stand in cold water: cold temperatures cause surface blood vessels to constrict, shunting blood into deeper veins that lie close to arteries. Cooled blood returning from extremities is warmed by arterial blood traveling towards the extremities, conserving heat.
- At night, chickadees' body temperature drops from 108°F to 88°F, which lessens the sharp gradient between the temperature of their bodies and the external temperature. This leads to a 23 percent decrease in the amount of fat burned each night.
- Chorus frogs tolerate freezing by becoming

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



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.

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.

Research in the Park

Before and after its inception, Yellowstone has attracted scientists as a unique outdoor laboratory for research. For example, dozens of comprehensive studies were completed in the 20 years following the 1988 fires. According to Monica Turner, speaking at the 9th Biennial Scientific Conference, “The 1988 fires presented an unprecedented opportunity to study the landscape-scale ecological effects of an infrequent natural disturbance—a large, severe fire in this case—in an ecological system minimally affected by humans.” A similar flurry of research began with the restoration of wolves in 1995 and continues today. This active volcanic ecosystem also fuels a wide variety of geologic studies. Many of these scientific studies have ramifications far beyond Yellowstone National Park.

In 2010, approximately 200 permits were issued for research in the park. Current research examples include:

- Determining if willow growth is related to changes in climate, elk populations, or hydrology.
- Monitoring plant and animal species that may be affected by climate change.
- Using tree-ring data, pollen records, and charcoal evidence to understand past climate patterns.
- Using earthquake monitoring stations to detect the numerous daily tremors in the Yellowstone region, and studying the patterns to develop an understanding of the geodynamics of Yellowstone's hotspot.
- Surveying rare and unusual plants (such as mosses, liverworts, lichens) and aquatic species.
- Monitoring the effects of human recreation on wildlife, air quality, and wilderness soundscapes.
- Studying the ecology and life-history strategies

Words to Know

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

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

Rime Frost forms when supercooled water droplets contact an object and freeze in place.

Hoar Frost forms when water vapor sublimates onto a surface. (Sublimation means changing from ice to vapor or vapor to ice without going through a water state.) Hoar frost occurs when night temperatures are very low.

of nonnative plants and aquatic organisms to better understand how to eradicate those that threaten native communities.

- Understanding how large-scale fires affect carbon cycling on our planet.
- Collecting thermophiles—microorganisms that can live in extreme environments—from hydrothermal features to study their heat-resistant enzymes, which may help in producing biofuels, decontaminating toxic waste, and assisting other organisms with heat tolerance.

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

Challenges

Ecosystem Management Challenges

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

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

- **Heat:** Volcanic activity drives the ecosystem; wild fire influences the species that live here; and political heat also affects decisions.
 - **Space:** The GYE spans different climate regimes and vegetation zones; crosses multiple jurisdictional boundaries; and is the last remaining large native ecosystem in the contiguous United States.
- The park's geographic location also attracts humans who want to occupy increasing amounts of space in the ecosystem. This leads to habitat modification, which poses a serious threat to both biodiversity and to ecosystem processes. For example, when homes are built close to wilderness boundaries, they fragment habitats and isolate populations of plants and animals, cutting them off from processes necessary for survival.

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

Time also refers to how this ecosystem changes and at what pace. What are the intervals between

The Yellowstone Volcano Observatory

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

University of Utah, and Yellowstone National Park.

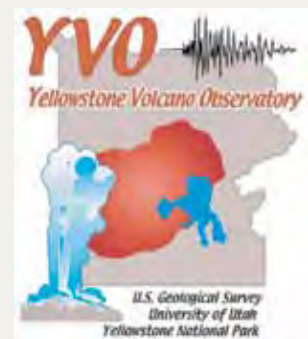
The principal goals of YVO include:

- Strengthening the monitoring system for tracking earthquake activity, uplift and subsidence, and changes in the hydrothermal (hot water) system;
- Assessing the long-term potential hazards of volcanism, earthquakes, and explosive hydrothermal activity in the Yellowstone region;
- Enhancing scientific understanding of active geologic and hydrologic processes occurring

beneath Yellowstone and in the surrounding region of the Earth's crust; and

- Communicating new scientific results, the current status of Yellowstone's activity, and forecasts of potential hazardous hydrothermal explosions or volcanic eruptions to Yellowstone National Park staff, the public, and local, state, and federal officials.

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



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

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.

BioBlitz: Fast Search for Species

In August 2009, more than 120 scientists, citizen scientists, students, and park staff participated in Yellowstone's first “BioBlitz”—an effort to document species at one point in time in one location. Such documentation can serve as a benchmark of environmental conditions. The Yellowstone BioBlitz took place during 24 hours in the Mammoth Hot Springs area of the park. Scientists reported finding 1079 species, including:

373 plant species, including a newly discovered grass to Yellowstone

86 mushroom species (two newly discovered to Yellowstone)

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

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

45 different lichens, including a species newly discovered to Yellowstone

13 mollusk species, possibly one newly discovered to the park

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



Greater Yellowstone Coordinating Committee

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

Currently, the GYCC is helping to develop a science agenda for the next 10–12 years. In 2009, federal agency managers, scientists from the U.S. Geological Survey and from universities met to identify the external drivers threatening to dramatically alter the GYE: climate change, land-use change, and invasive species. 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 GYE; how will climate change and land-use change affect invasive species and their management?

As a first step to understanding climate change impacts, the GYCC 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.



The physical landscape of Yellowstone National Park is the result of many geological forces.

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.

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.

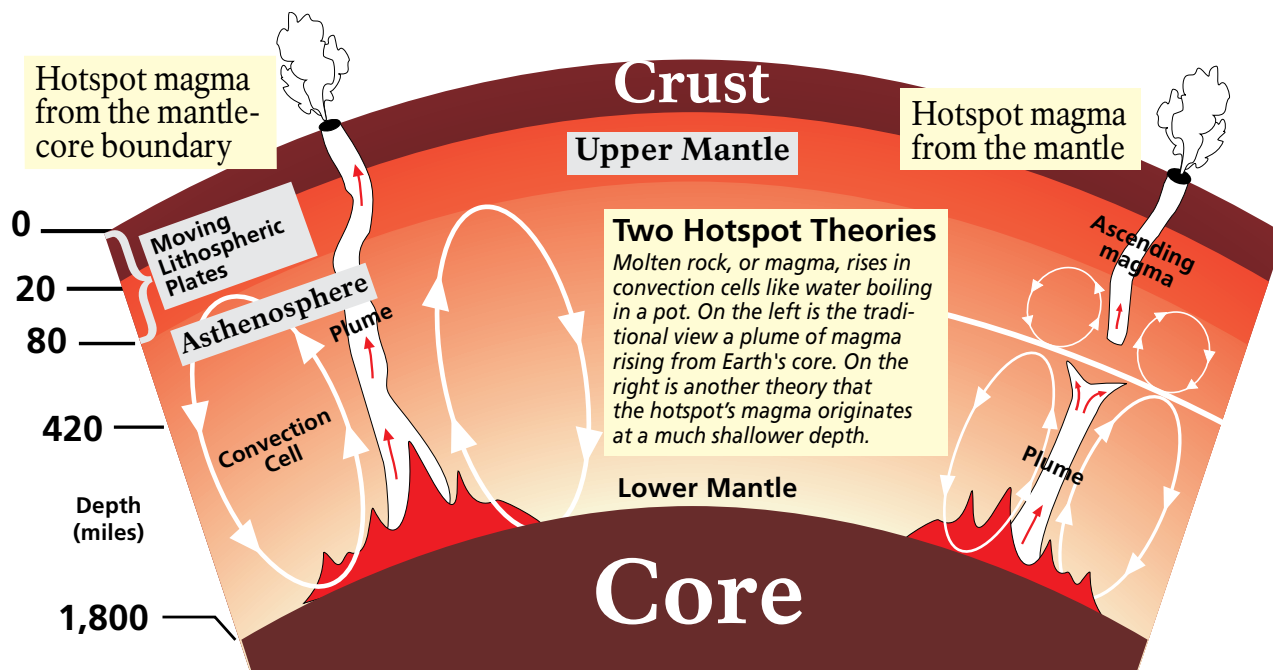
The Earth is frequently depicted as a ball with a central core surrounded by concentric layers that culminate in the crust or surface layer. The distance from the Earth's surface to its center or core is approximately 4,000 miles. The core of the earth is divided into two parts. The mostly iron and nickel 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 lithosphere (crust and upper mantle) 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 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

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.



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

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.

Volcano

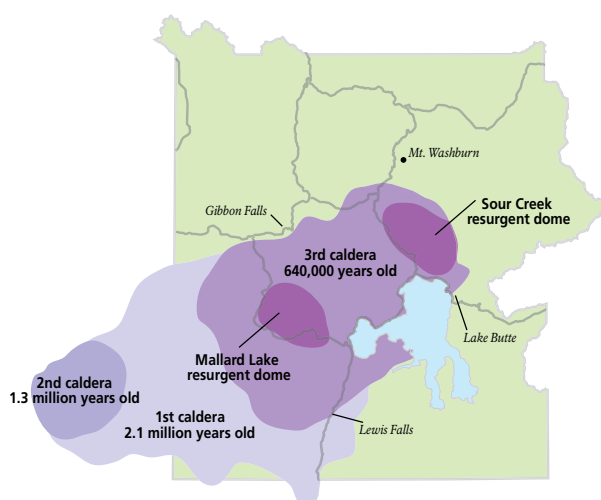
Most of Earth's history (from the formation of the earth 4.6 billion years ago to approximately 542 million years ago) is known as the Precambrian time. Rocks of this age are found in northern Yellowstone and in the hearts of the Teton, Beartooth, Wind River, and Gros Ventre ranges. During the Precambrian and

the subsequent Paleozoic and Mesozoic eras (542 to 66.5 million years ago), the western United States was covered at times by oceans, sand dunes, tidal flats, and vast plains. Near the end of the Mesozoic, mountain-building processes created the Rocky Mountains.

During the Cenozoic era (approximately the last 66.5 million years of Earth's history), widespread mountain-building, volcanism, faulting, and glaciation sculpted the Yellowstone area. The Absaroka Range along the park's north and east sides was formed by numerous volcanic eruptions about 50 million years ago. This period of volcanism is not related to the present Yellowstone volcano.

Approximately 30 million years ago, vast expanses of the West began stretching apart along an east-west axis. This stretching process increased about 17 million years ago and continues today, creating the modern Basin and Range topography (north-south mountain ranges with long north-south valleys) characterizing much of the West—including around Yellowstone.

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



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

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

body of magma. About 2.1 million years ago, the movement of the North American plate brought the Yellowstone area into proximity with the shallow magma body. This volcanism remains a driving force in Yellowstone today.

Magma and Hotspots

Magma (molten rock from Earth's mantle) has been close to the surface in Yellowstone for more than 2 million years. Its heat melted rocks in the crust, creating a magma chamber of partially molten, partially solid rock. Heat from this shallow magma caused 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 Yellowstone created the Yellowstone Caldera, 30 by 45 miles in size. A much smaller eruption approximately 174,000 years ago created what is now the West Thumb of Yellowstone Lake. In between and after these eruptions, lava has 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

Yellowstone Geologic History

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

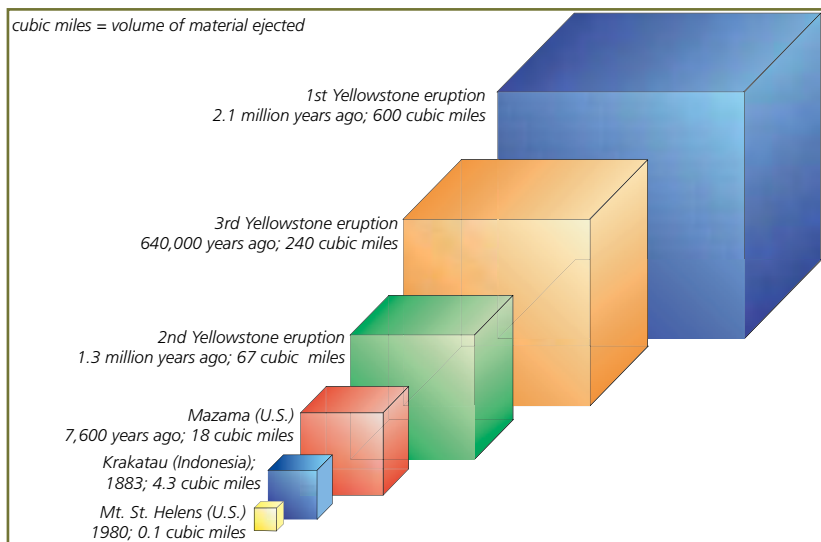
542 to 66 Ma	Area covered by inland seas
50 to 40 Ma	Absaroka volcanics
30 Ma to present	"Basin and Range" forces creating Great Basin topography
16 Ma	Volcanics begin again in present day Nevada and Idaho
2.1 Ma	1st Yellowstone eruption
1.3 Ma	2nd Yellowstone eruption
640 ka	3rd Yellowstone eruption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

floor lifts up or subsides, too, but not as much as the domes. In the past century, the net result has been to tilt the caldera floor toward the south. As a result, Yellowstone Lake's southern shores have subsided and trees stand in water.

Future Volcanic Activity

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

The most likely activity would be lava flows, such as those that occurred after the last major eruption. 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.



Volume comparison of volcanic eruptions.

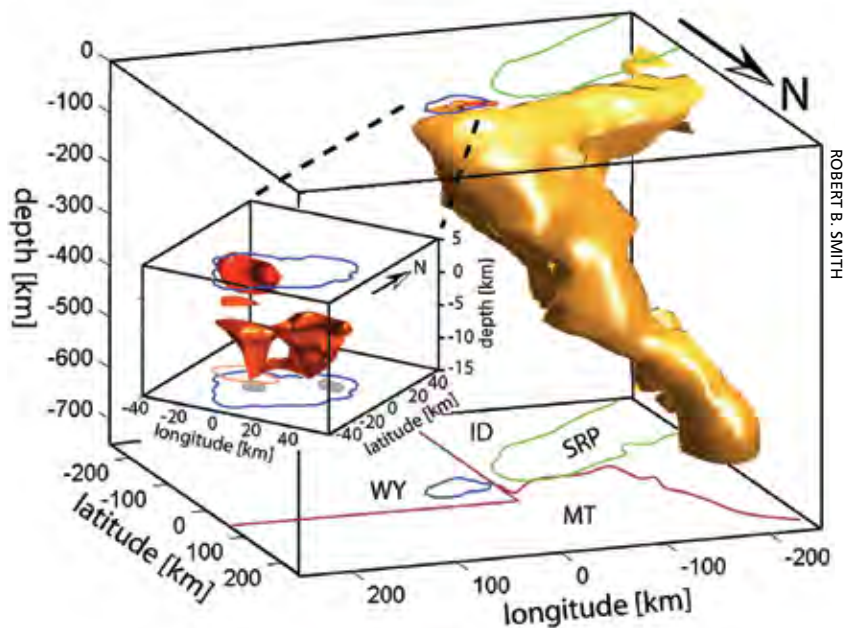
Hydrothermal Systems

Yellowstone's hydrothermal features would not exist without the underlying magma body that releases tremendous heat. They also depend on sources of water, such as 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



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.

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.

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, much as it does with depth in the ocean. Increased pressure exerted by the enormous weight of the overlying

water prevents the water from boiling. As the water rises, steam forms. Bubbling upward, steam expands as it nears the top of the water column. 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.

Hydrothermal Features



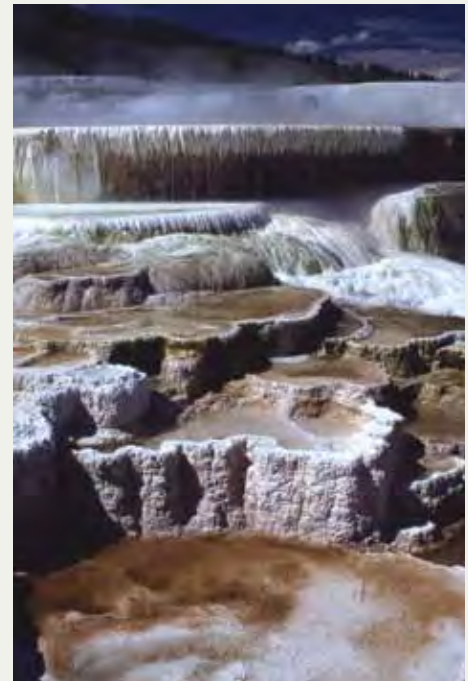
Fumaroles or steam vents, are the hottest hydrothermal features in the park. The limited amount of water flashes into steam before reaching the surface. At places like Roaring Mountain (above), the result is a loud hissing of steam and gases.



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.

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 U.S. Geological Survey and a private company, Eastern Oceanics, surveyed the bottom of Yellowstone Lake using high-resolution, multi-beam swath sonar imaging, seismic reflection profiling, and a ROV. The survey confirmed the northern half of the lake is inside the 640,000-year-old Yellowstone Caldera and mapped previously unknown features such as large hydrothermal explosion craters, siliceous spires, hundreds of hydrothermal vents and craters, active fissures, and gas pockets. 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 explosions formed craters at Mary Bay and Turbid Lake. Spires may form similarly to black smoker chimneys, which are hydrothermal features associated with oceanic plate boundaries.

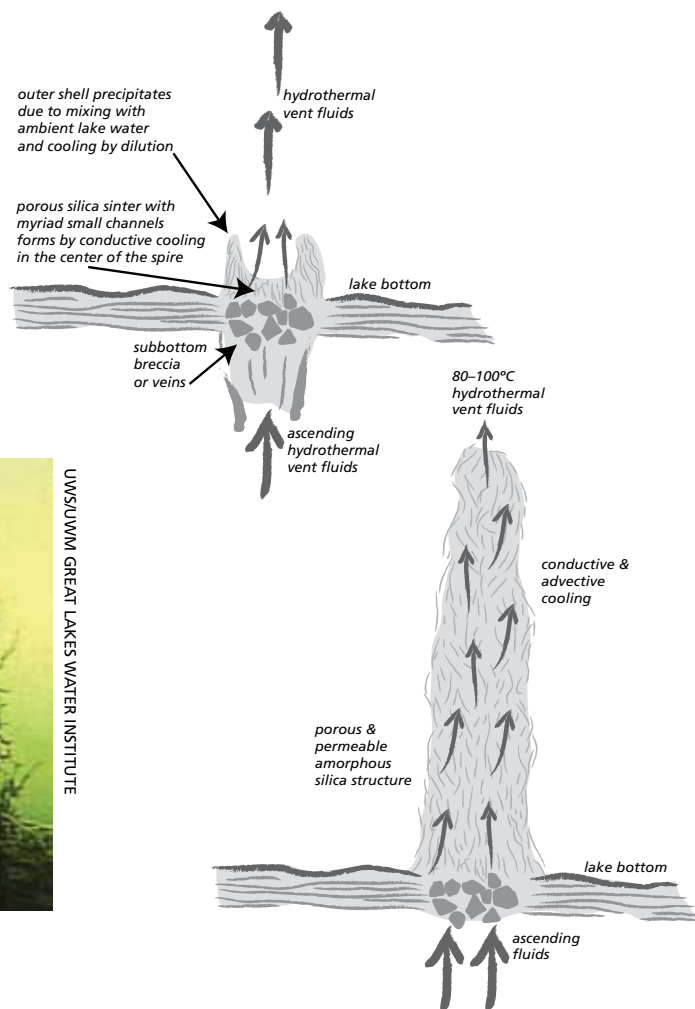


Spire Analysis

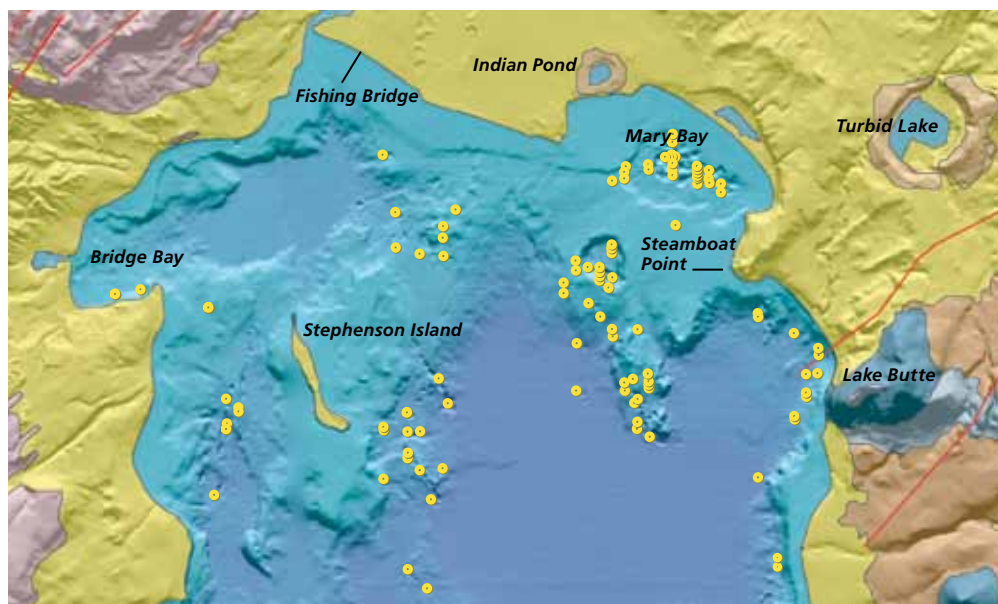
With the cooperation of the National Park Service, scientists from the University of Wisconsin–Milwaukee collected pieces of spires and a complete small spire for study by several teams. They conducted a CAT scan of the spire, which showed structures seeming to be conduits, perhaps for hydrothermal circulation.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

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

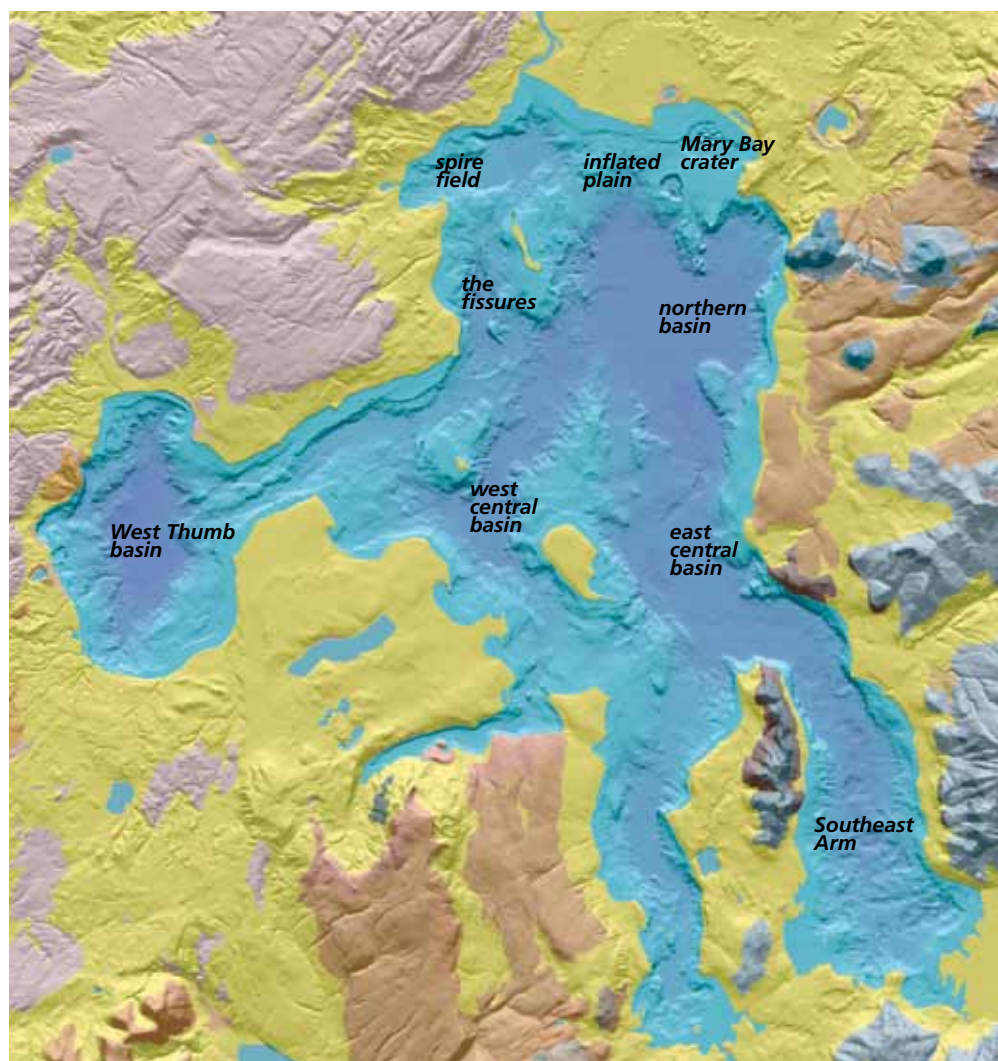
Both research projects expanded our understanding of the geological forces at work beneath Yellowstone Lake. Additional study of the spires and other underwater features will continue to contribute to our understanding of the relationship between these features and the aquatic ecosystem.



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 LeHardys 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.



USGS/ LISA MORGAN



USGS/ LISA MORGAN

Opposite: Initial spire growth (top), a mature spire (bottom), and a photo of a Bridge Bay spire. Illustrations adapted from originals by Yellowstone National Park researcher and US Geological Survey research geologist Lisa Morgan.

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.

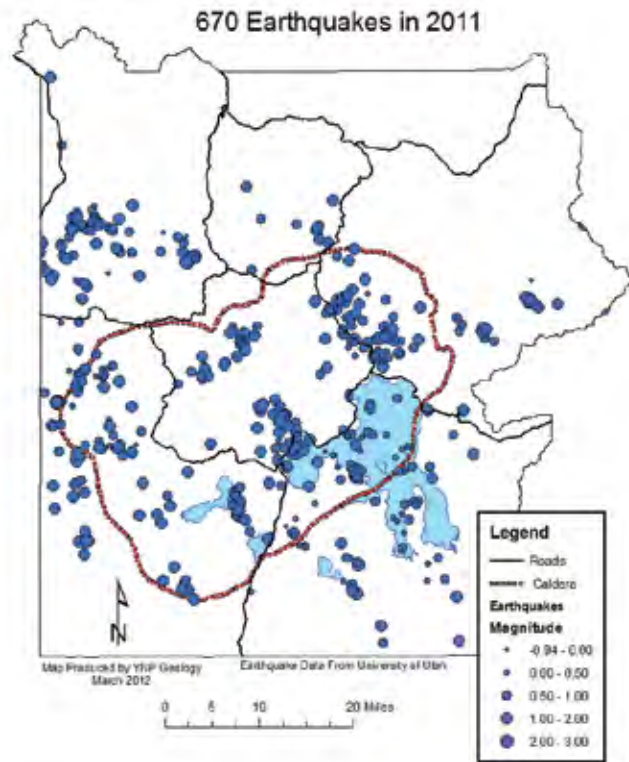
In Yellowstone, earthquakes help to maintain hydrothermal activity by keeping the “plumbing” system open. Without periodic disturbance of relatively small earthquakes, the small fractures and conduits that supply hot water to geysers and hot springs might be sealed by mineral deposition. Some earthquakes 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

Scales of Magnitude

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



Approximately 670 earthquakes occurred in Yellowstone National Park in 2011. Blue dots = earthquakes. Red dotted line = Yellowstone Caldera. Real-time data about earthquakes in Yellowstone National Park is available at www.seis.utah.edu, a website maintained by the University of Utah Seismograph Stations.

geology around and beneath Yellowstone. The energy from earthquakes travels through hard and molten rock at different rates. Scientists can “see” the sub-surface 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.

Glaciers

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

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.

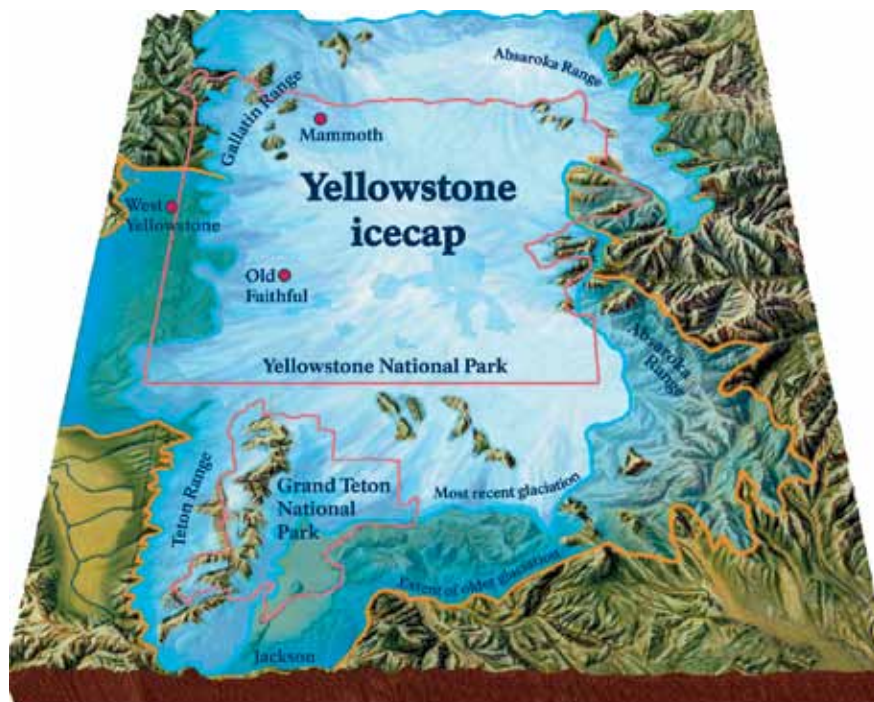
Yellowstone and much of North America have experienced numerous periods of glaciation during the last two million years. Succeeding periods of glaciation have destroyed most surface evidence of previous glacial periods, but scientists have found evidence of them in sediment cores taken on land and in 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 varies 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 period, glaciers advanced and retreated from the Beartooth Plateau, scouring the landscape we know today as the northern range. Glacial dams backed up water over Hayden Valley that deposited glacial sediment. Such dams also backed up water over Lamar Valley; when the dams lifted, catastrophic floods helped to form the 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 the magmatic activity beneath Yellowstone



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

had pushed up the area to a higher elevation with colder temperatures and more precipitation than the surrounding land.

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 (570 million to 66 million years ago) can be seen in the Gallatin Range and Mount Everts. Sedimentary rocks in Yellowstone tend to erode more easily than the Precambrian rocks.

Weathering breaks down earth materials from large sizes to small particles, and happens in place. The freeze/thaw action of ice is one type of weathering common in Yellowstone. Agents of erosion—wind, water, ice, and waves—move weathered materials from one place to another.

When erosion takes place, sedimentation—the deposition of material—also eventually occurs. Through time, sediments are buried by more sediments and the material hardens into rock. This rock is eventually exposed (through erosion, uplift, and/or faulting), and the cycle repeats itself. Sedimentation and erosion are “reshapers” and “refiners” of the



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.

landscape—and they also expose Yellowstone’s past life as seen in fossils like the petrified trees.

Fossils

Paleobotany

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

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

The first fossil plants from Yellowstone were collected by the early Hayden Survey parties. In his 1878 report, Holmes made the first reference to Yellowstone’s fossil “forests.”

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; Titanotheres (type of rhinoceros) tooth and mandible found on Mt. Hornaday in 1999.

Remember:

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



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

Frequently Asked Questions: Volcanic Geology

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 (right) 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 a supervolcano?

Some scientists consider Yellowstone to be a “super-volcano,” 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/.

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

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

If Old Faithful Geyser quits, 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.

Frequently Asked Questions: Hydrothermal Geology

Why are geysers in Yellowstone?

Yellowstone's volcanic geology provides the three components for geysers and other hydrothermal features: heat, water, and a natural "plumbing" system. Magma beneath the surface provides the 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 Artist Paintpots.

The largest group of mudpots can be found at Mud Volcano, at the southern end of Hayden Valley.

What is the most active thermal area in the park?

Norris Geyser Basin is the hottest, oldest, and most dynamic of Yellowstone's active hydrothermal areas. The highest temperature yet recorded in any Yellowstone hydrothermal area was measured in a scientific drill hole at Norris: 459°F just 1,087 feet below the surface. Norris shows evidence of having had hydrothermal features for at least 115,000 years. The features change often, with frequent disturbances from seismic activity and water fluctuations. Norris is so hot and dynamic primarily because it sits at the intersection of three major faults, two of which intersect with a ring fracture from the Yellowstone Caldera eruption 640,000 years ago.

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

Terrace Mountain, near Mammoth Hot Springs, may be a dormant thermal area dated as 406,000 years old. New studies indicate that Terrace Mountain may be cold water travertine, potentially making Norris the oldest dated thermal area at 115,000 years old.

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

Yellowstone National Park's thermal areas cannot be tapped for geothermal energy because such use could destroy geysers and hot springs, as it has done in other parts of the world.

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

Dogs do not seem to recognize the difference between hot and cold water. Dogs have died diving into hot springs. They also disturb wildlife and are prohibited from all park trails. In the few places pets are permitted, they must be leashed at all times. Ask at a visitor center where you can walk a pet.

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

YES. Geyser basins are constantly changing. Boiling water surges just under the thin crust of most geyser basins, and many people have been severely burned when they have broken through the fragile surface. Some people have died.

Why can't I smoke in the geyser basins?

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

Were Native Americans afraid of geysers?

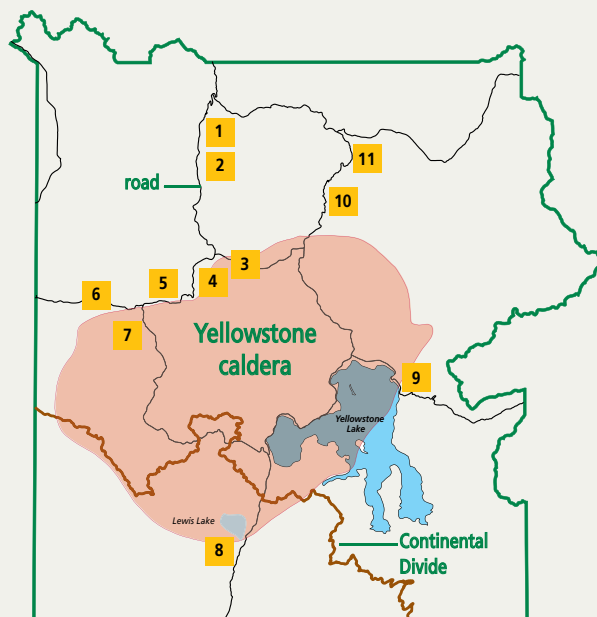
Native Americans in general were not afraid of geysers. Many of the associated tribes of Yellowstone say their people have used the park as a place to live, to collect food and other resources, and as a passage through to the bison hunting grounds of the Great Plains. Archeologists and historians have also uncovered ample evidence that people lived in and visited Yellowstone for thousands of years before historic times.

Frequently Asked Questions: Glacial Geology

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 era, called the Pinedale, glaciers flowed down from the Beartooth Plateau and other high country, following river corridors such as the Lamar, Yellowstone, and Madison. An ice cap also formed.

Where to see volcanic flows



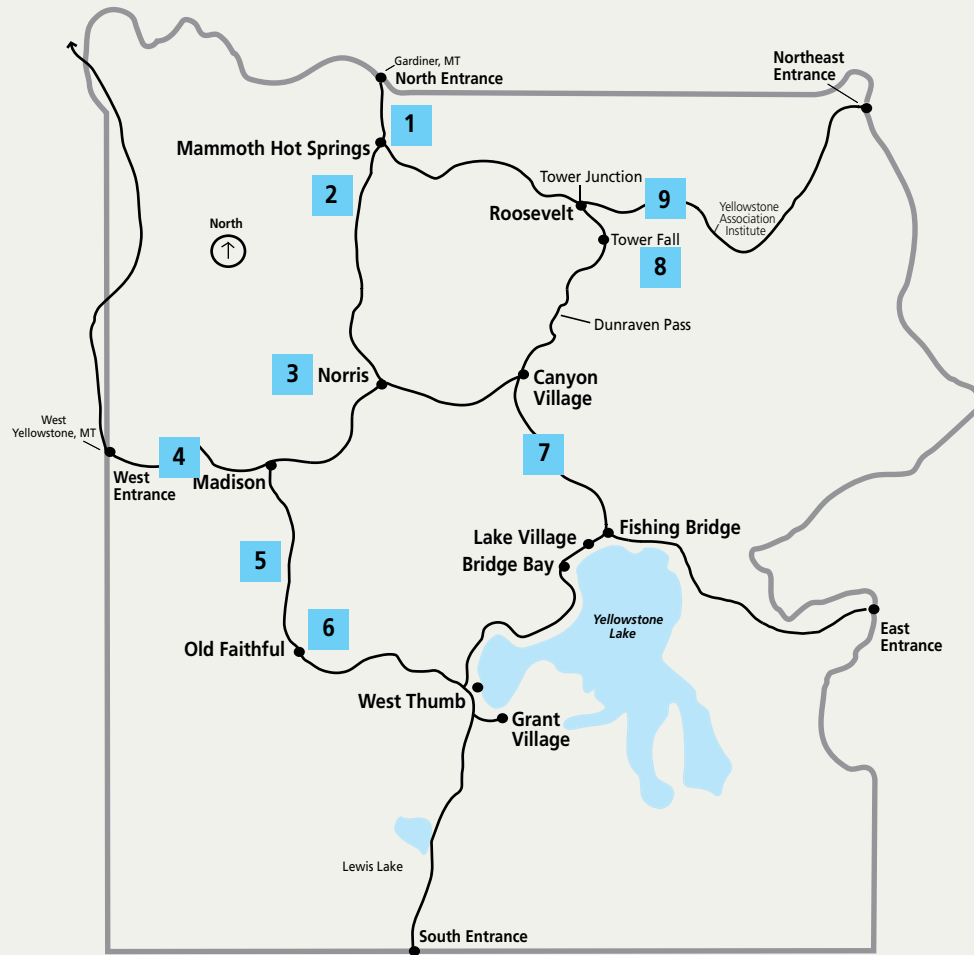
- | | |
|---|--|
| 1. Sheepeater Cliff: columnar basalt | 7. Firehole Canyon: lava |
| 2. Obsidian Cliff: lava | 8. Lewis Falls: Near caldera rim |
| 3. Virginia Cascades: ash flow | 9. Lake Butte: On edge of caldera, overall view of caldera |
| 4. Gibbon Falls: Near caldera rim | 10. Washburn Hot Springs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

(11) Between Tower Fall and Tower Junction

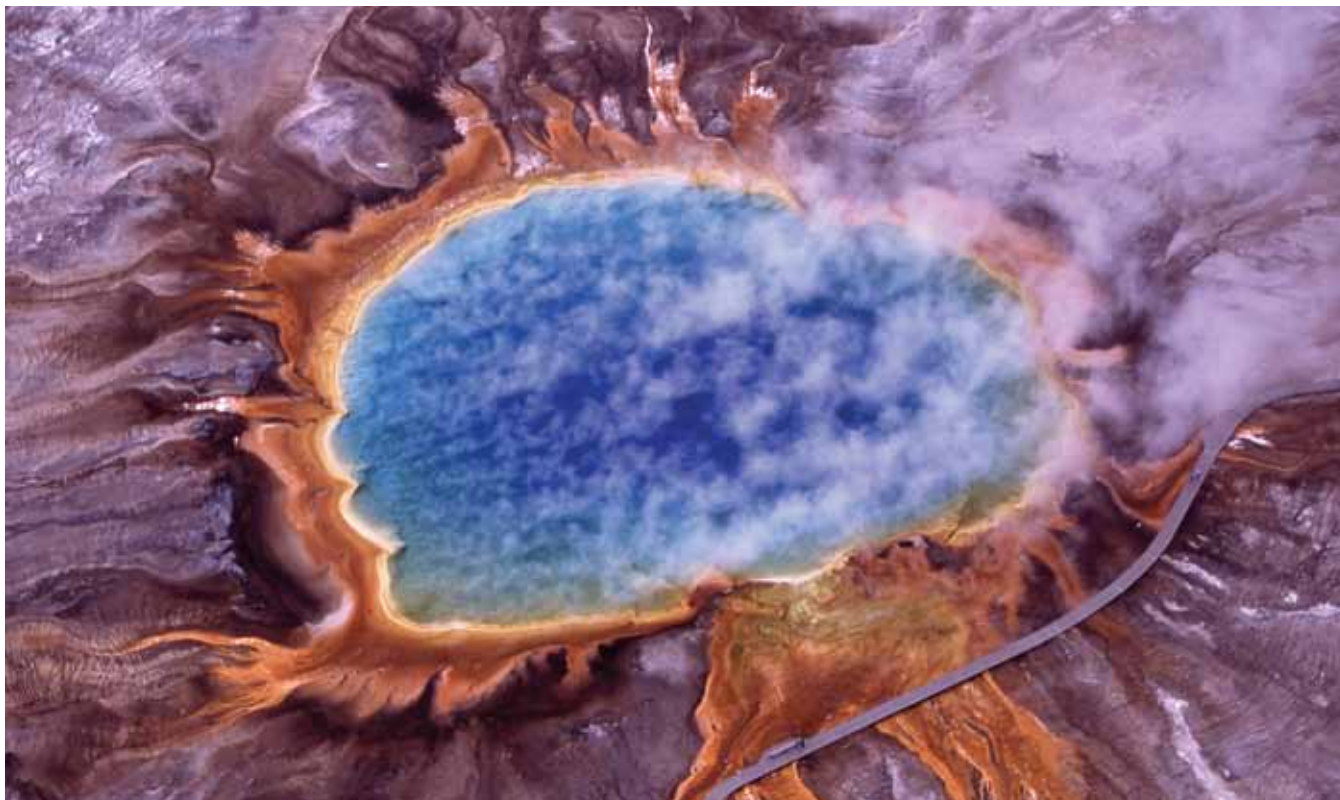
(1) Sheepeater Cliff

(7) Firehole Canyon

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.
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: The top of Sepulcher peaked above the Pinedale ice.
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 are thermal kames.
6. Upper Geyser Basin: Glacial deposits underlying this and other area geyser basins store the water necessary for geysers to occur and allow the water to percolate up from depth.
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.



Grand Prismatic Spring at Midway Geyser Basin is habitat for thermophiles, or heat-loving microscopic organisms.

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:

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.

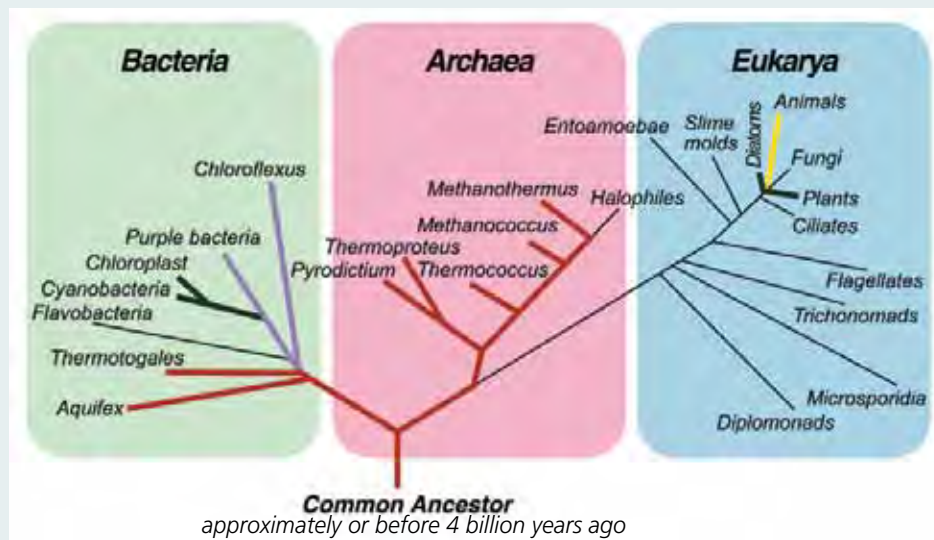
Bacteria (Bacterium): Single-celled microorganisms without nuclei, varying in shape, metabolism, and ability to move.

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 the 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.

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

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

Today, many scientists study Yellowstone's thermophiles. Some of these microbes are similar to the first life forms capable of photosynthesis—using

sunlight to convert water and carbon dioxide to oxygen, sugars, and other byproducts. These life forms, called cyanobacteria, began to create an atmosphere that would eventually support human life. Cyanobacteria are found in some of the colorful mats and streamers of Yellowstone's hot springs.

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.

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

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.

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

CAROLYN DUCKWORTH






Norris Geyser Basin is one of the best places to see thermophilic algae.



The travertine terraces in Mammoth Hot Springs host thermophilic bacteria.

Thermophilic Bacteria in Yellowstone National Park

Name		pH and Temperature	Description	Location
Cyanobacteria: <i>Calothrix</i> <i>Oscillatoria</i> <i>Leptolyngbya</i> <i>Spirulina</i> <i>Synechococcus</i>		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	<ul style="list-style-type: none"> • Mammoth Hot Springs • Upper, Midway, and Lower geyser basins • West Thumb
Green nonsulfur bacteria: <i>Aquifex</i> <i>Chloroflexus</i> <i>Thermus</i>		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	<ul style="list-style-type: none"> • Mammoth Hot Springs • Upper, Midway, and Lower geyser basins • West Thumb • <i>Thermus</i> sp. at Norris, especially at Cistern Spring
Sulfur-oxidizing bacteria: <i>Aquificales</i> 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	<ul style="list-style-type: none"> • 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.

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 photo-synthesize, 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.

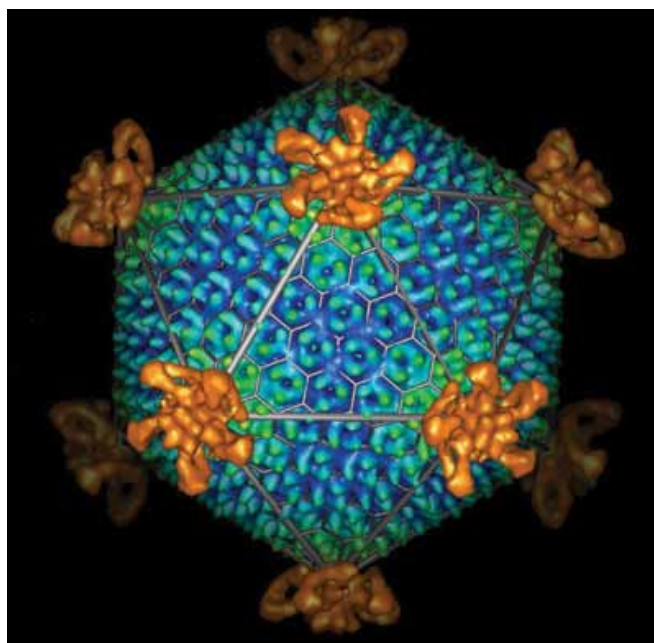
Individual bacteria may be rod or sphere shaped, but they often join end to end to form long strands called filaments. These strands help bind thermophilic mats, forming a vast community or mini-ecosystem. Other groups of bacteria form layered structures, which look like tiny towers, that can trap sand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

Thermophilic Archaea

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



This virus parasitizes *Sulfolobus*.

THERMAL BIOLOGY INSTITUTE, MONTANA STATE UNIVERSITY

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.

Thermophilic Archaea 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	<ul style="list-style-type: none"> In many of Yellowstone's hydrothermal features
<i>Sulfolobus acidocaldarius</i> is the species most often isolated	pH 2–3, ideal <90°C (194°F)	Color: none Metabolism: chemosynthesis; oxidizes sulfur and sulfur compounds into sulfuric acid Form: spherical with lobes	<ul style="list-style-type: none"> Mud Volcano Norris, especially Congress Pool Roaring Mountain

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.



Top: Ephyrid flies lay eggs in pink-orange mounds, sometimes on the firm surfaces of the mats.

Middle: The fungi *Curvularia proturberata* lives in the roots of hot springs panic grass.






Bottom: Waving streamers of *Zygogonium* are easy to see in Porcelain Basin.

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	<ul style="list-style-type: none"> 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 	<ul style="list-style-type: none"> In many of Yellowstone’s hydrothermal features
Unnamed	Acidic Boiling	<ul style="list-style-type: none"> 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 	<ul style="list-style-type: none"> Unnamed pool near Midway Geyser Basin
Unnamed	Acidic Boiling	<ul style="list-style-type: none"> Parasitizes the archaeum, <i>Sulfolobus</i> 	<ul style="list-style-type: none"> Norris, Congress Pool

THERMAL BIOLOGY INSTITUTE, MONTANA STATE UNIVERSITY

Thermophilic Eukarya found in Yellowstone National Park

Name		pH and Temperature	Description	Location
Algae				
<i>Cyanidium caldarium</i>		pH 0.5–3 <56°C (133°F)	Color: bright green Metabolism: photosynthetic Form: coating on top of Formations; mats	<ul style="list-style-type: none"> Roaring Mountain Norris, both basins
<i>Zygogonium</i>		pH 2–3 35°C (96°F)	Color: dark brown or purple Metabolism: photosynthetic Form: filaments and mats	<ul style="list-style-type: none"> Norris, especially Porcelain Basin
Protozoa				
<i>Naegleria</i> (amoeba)		Warm Alkaline	Predator; can infect humans when ingested through nose	<ul style="list-style-type: none"> Huckleberry Hot Springs Boiling River
<i>Vorticella</i> (ciliate)			Consumer; single-celled ciliate (feathery appendages swirl water, bringing prey)	<ul style="list-style-type: none"> Obsidian Creek
<i>Euglenids Mutablis</i>		pH 1–2 <43°C (109°F)	Single-celled; photosynthetic; moves by waving one or two strands called flagella	
<i>Fungi (Curvularia protuberata)</i>		≤65°C (149°F) with panic grass <55°C (131°F) without	Grows in roots of hot springs panic grass (<i>Dichanthelium lanuginosum</i>), enabling both to survive high temperatures; the plant also produces sugars that the fungus feeds on	
Ephydrid fly (<i>Ephydra</i> sp.)		>pH 2 <43°C (109°)	Nonbiting insect that eats microscopic algae as larvae and adult; prey for spiders, beetles, dragonflies, killdeer	<ul style="list-style-type: none"> Norris, especially Porcelain Basin Upper Geyser Basin, especially Geyser Hill Mammoth Hot Springs
Ross's bentgrass (<i>Agrostis rossiae</i>)		38°C (100°F)	One of Yellowstone's three endemic plant species; may bloom in winter; dries out in summer's hot air temperatures	<ul style="list-style-type: none"> 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	<ul style="list-style-type: none"> Obsidian Creek

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

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.

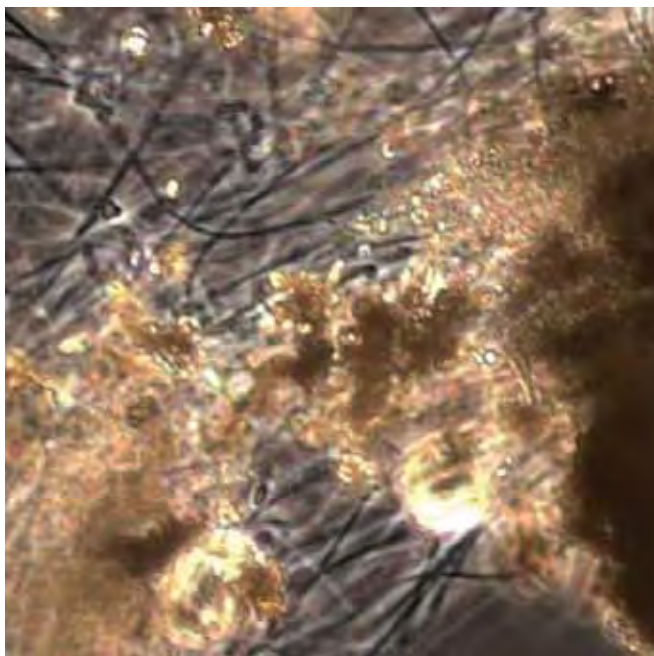
Thermophilic eukarya include one form that is dangerous to humans: *Naegleria*, a type of amoeba, that can cause disease and death in humans if inhaled through the nose.

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 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 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



Top: Structures formed by the bacteria *Thermocrinis*;

Middle: 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.

Bottom: Millions of individual microbes can connect into long strands called filaments, shown here with the help of a microscope;

TOP LEFT AND CENTER: THERMAL BIOLOGY INSTITUTE; MONTANA STATE UNIVERSITY




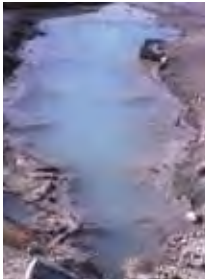

CAROLYN DUCKWORTH



CAROLYN DUCKWORTH

Elk and bison 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			
	<ul style="list-style-type: none"> pH 7–11 (alkaline) underlain by rhyolitic rock water rich in silica, which forms sinter and geyserite deposits 	<ul style="list-style-type: none"> >75°C (167°F), bacteria and archaea >75°C (167°F), <i>Thermocrinis</i> and other bacteria form streamers of pink, yellow, orange, or gray <75°C (167°F), <i>Synechococcus</i>, <i>Lyptolyngbya</i>, and <i>Calothrix</i> (cyanobacteria) plus <i>Roseiflexus</i> (filamentous green bacterium) form mats that line cooler hot springs and runoff channels 	<ul style="list-style-type: none"> Pink, yellow, orange, gray filaments—<i>Thermocrinis</i> 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			
	<ul style="list-style-type: none"> pH 0–5 (acidic) underlain by rhyolite rock 	<ul style="list-style-type: none"> >75°C (167°F), <i>Sulfolobus</i>, an archaeum, and viruses that parasitize <i>Sulfolobus</i> >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), <i>Zygogonium</i>, other algae, and fungi form mats in runoff channels 	<ul style="list-style-type: none"> Pink–pinkish-orange mats and streamers—<i>Thermus aquaticus</i> and other <i>Thermus</i> sp. Green streamers and mats—<i>Cyanidium</i> Orange—iron and/or arsenic, perhaps oxidized by thermophiles Gray, muddy pools—<i>Sulfolobus</i>
Mammoth Hot Springs			
	<ul style="list-style-type: none"> pH 6–8 (neutral to slightly acidic) underlain by ancient limestone deposits water rich in calcium carbonate and sulfur 	<ul style="list-style-type: none"> 66–75°C (151–167°F), <i>Aquificales</i> (bacteria) filaments near hot springs vents <66°C (151°F), <i>Chloroflexus</i> (green nonsulfur bacteria) and cyanobacteria mats, and filamentous bacteria streamers <58°C (136°F), <i>Chromatium</i> (bacteria) form dark mats (uncommon) 25–54°C (77–129°F), <i>Chlorobium</i> (bacteria) mats; <i>Calothrix</i> streamers; <i>Synechococcus</i> 	<ul style="list-style-type: none"> Orange—<i>Chloroflexus</i> and cyanobacteria in summer Green—<i>Chloroflexus</i> and cyanobacteria in winter; <i>Chlorobium</i> in cooler water Cream—filamentous bacteria

Note: Photos by Carolyn Duckworth.

their environments. The information here pertains to some of the microbe communities most easily seen in Yellowstone.

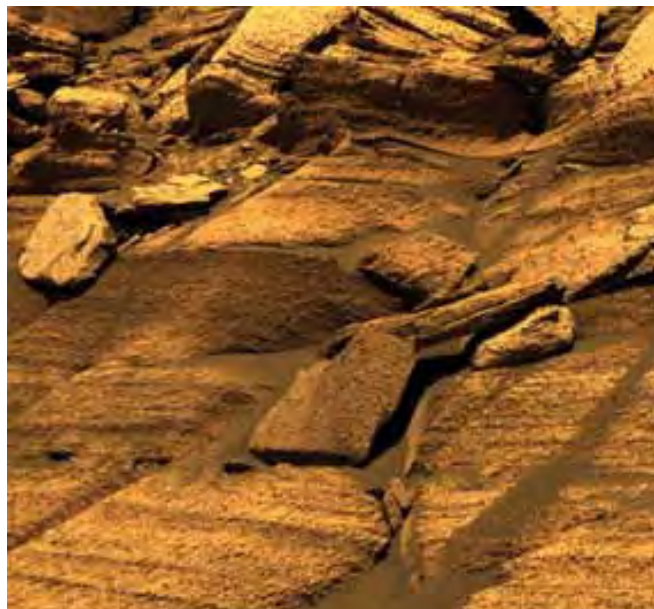
Millions of individual microbes can connect into long strands called filaments. Some bacteria (photo left) and algae form thin and delicate structures in fast moving water such as the runoff channels of hot springs and geysers. Other microbes form thick, sturdy structures in slower water or where chemical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

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

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

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

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

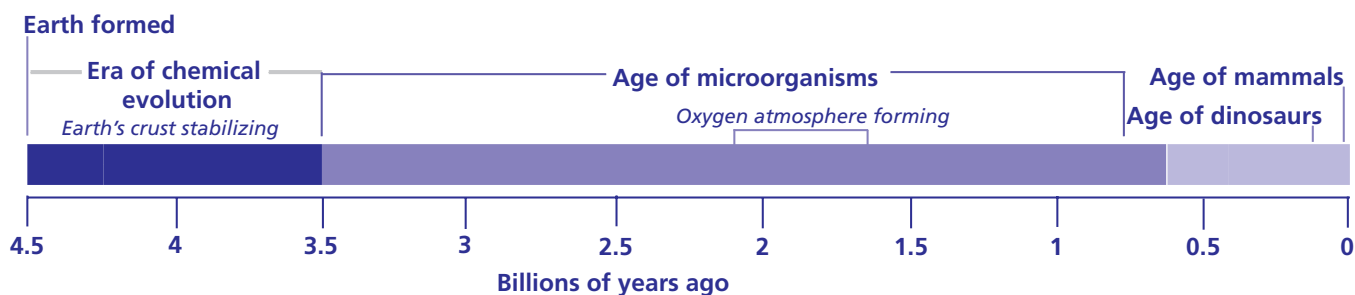


NASA/JPL

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.

What's the Connection?

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



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 iron in the water, forming the orange community.

Communities

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 this water. The bacterial filaments form mats, in which the mineral is captured. The iron may also be caught on the bacteria as the microbes move about within the mat. An olive green color indicates where the orange iron and green bacteria are enmeshed. Darker streaks indicate the presence of manganese. Scientists think the bacterial concentration may contribute to the iron concentration at the Chocolate Pots, where the iron is one hundred times more concentrated than at other neutral hydrothermal features.

Communities formed by thermophilic microbes sustain communities of larger organisms within Yellowstone's hydrothermal areas. 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 the shift of heat beneath the Earth, these communities change through common and strange processes. Biologists continue to discover more about the

individuals involved in thermophilic communities, and ecologists continue to follow the threads of these intricate webs.

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, 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.



Arrowleaf balsamroot

Vegetation

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

The vegetation of the park is interrelated with the geology of the park. The region's caldera explosions catastrophically destroyed vegetation. In addition, glaciers significantly altered the region. Today, the roughly 1,150 native species of flowering plants in the park represent the species able to either persist in the area or recolonize after glaciers, lava flows, and other major disturbances. Unlike southwestern Wyoming

Vegetation Overview

- Vegetation in Yellowstone is typical of the Rocky Mountains.
- Elements of the Great Plains and Great Basin floras mix with Rocky Mountain vegetation in the vicinity of Gardiner and Stephen's Creek.
- The interaction of climate and geologic substrate controls distribution of vegetation in the park.
- Disturbances—fire, floods, insects, disease—occur periodically, affecting portions of the park.
- Hydrothermal areas support unique plant communities and rare species.
- Lodgepole pine alone comprises 80% of the forest canopy.
- Six other conifer tree species: whitebark pine, Engelmann spruce, subalpine fir, Douglas-fir, Rocky Mountain juniper, limber pine.
- Deciduous trees include quaking aspen and cottonwood.
- Shrubs include common juniper, sagebrush (many species), Rocky Mountain maple.
- Wildflowers number in the hundreds.
- Three endemics—Ross' bentgrass, Yellowstone sand verbena, Yellowstone sulfur wild buckwheat.
- More than 210 exotics.

Management

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



CAROLYN DUCKWORTH

Fringed gentian grows in wetlands.

or central Idaho, the Greater Yellowstone region has few endemic vascular plant species, primarily in the eastern portion of the Absaroka Mountains outside of Yellowstone. Within Yellowstone, only three endemics occur, Yellowstone sand verbena (*Abronia ammophila*), Ross's bentgrass (*Agrostis rossiae*), and Yellowstone sulfur wild buckwheat (*Eriogonum umbellatum* var. *cladophorum*).

Major Types

Montane Forests

Forests cover roughly 80 percent of the park. Miles and miles of lodgepole pine forest characterize the park, especially within the Yellowstone Caldera. Extensive areas of forest dominated by subalpine fir and Engelmann spruce are also present, especially in areas such as the Absaroka Range that are underlain by andesites. These species can also be common in the understory where the canopy is entirely composed of lodgepole pine. Through time, in the absence of fire and in non-rhyolitic soil, subalpine fir and Engelmann spruce can replace the lodgepole pine, leading to a canopy dominated by these species. In rhyolitic soils, which are poor in nutrients needed

Finding Wetlands

Here are a few wetlands locations near roads:

- **Northeast Entrance Road**, beginning east of Yellowstone Picnic Area: listen for frogs in spring, look for sandhill cranes throughout the Lamar Valley
- **Firehole Lake Road**: listen for frogs and look for elephant's head flowers where the road begins
- **Dunraven Pass area**: look for abundant wildflowers in high elevation wetlands near the road
- **Norris Geyser Basin, Back Basin**: near Puff 'n' Stuff Geyser, look for dragonflies
- **All thermal areas**: look for ephydrid flies, thermophiles, and other life forms

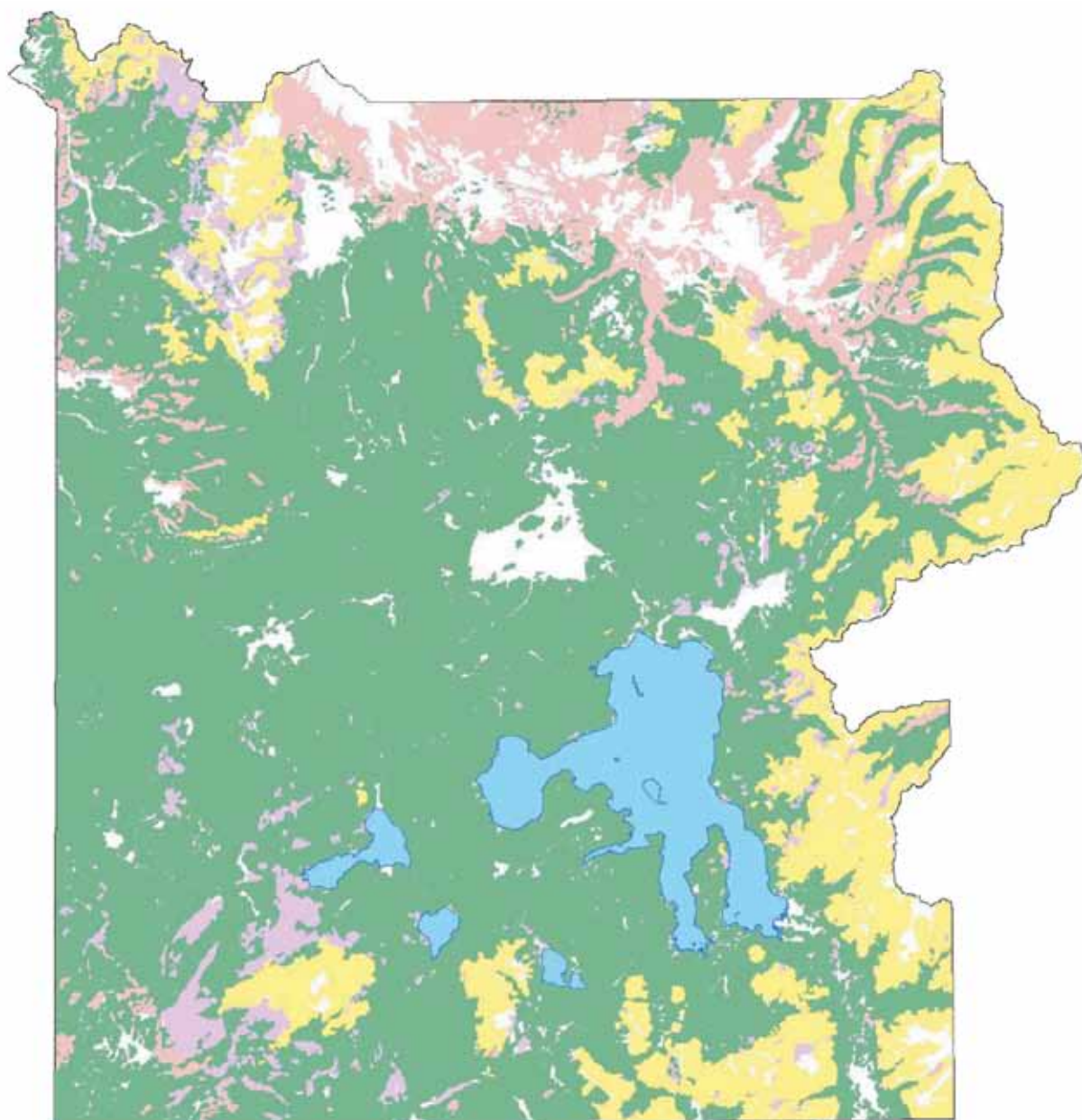
by fir and spruce, lodgepole pine remains dominant. At higher elevations such as the Absaroka Mountains and the Washburn Range, whitebark pine becomes a significant component of the forest. In the upper subalpine zone, whitebark pine, Engelmann spruce, and subalpine fir often grow in small areas separated by subalpine meadows. Wind and dessication cause distorted forms known as krumholtz where most of the "tree" is protected below snow.

Douglas-fir Forests

Douglas-fir forests occur at lower elevations, especially in the northern portion of the park. The thick bark of Douglas-fir trees allows them to tolerate low-intensity fire. Some of the trees in these forests are several hundred years old and show fire scars from a succession of low intensity ground fires. In contrast, lodgepole pine trees have very thin bark and can be killed by ground fires.

Understory Vegetation

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



Map of vegetation 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.

Douglas-fir forests

Associated with the Lamar, Yellowstone, and Madison river drainages below 7,600 feet.

Often less than 20 inches annual precipitation.

More frequent historic fire interval (25–60 year) than other forest types in the park.

Spruce-fir forests

Engelmann spruce and subalpine fir dominate older forests.

Usually found on moist and/or fertile substrates.

Climax forests underlain by andesitic soils.

Whitebark pine forests

Major overstory component above 8,400 feet.

Major understory component of lodgepole-dominated forests from 7,000 to 8,400 feet.

Seeds are ecologically important food for a variety of wildlife species.

Non-forest

Includes grasslands, sagebrush, alpine meadows, talus, and hydrothermal environments.

Encompasses the moisture spectrum from dry sagebrush shrublands to wet alpine meadows.

Provides the winter and summer forage base for ungulates.

Other types not shown on map

Aspen—found in small clones interspersed among the sagebrush/forest ecotone (transition zone) along the Yellowstone, Madison, and Snake river drainages.

Wetland—includes various grass, forb, rush, sedge, and woody species.

Riparian—typically streamside vegetation includes cottonwoods, willows, and various deciduous shrubs.

Sagebrush-steppe

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

Wetlands

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

Hydrothermal Communities

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

Effects of Disturbances

The park's vegetation appears at first glance to be static and unchanging, but must, in fact, respond to change. Hydrothermal plant communities demonstrate in very short periods of time that change is fundamental in any natural system. In a few days, the ground can heat up, perhaps triggered by an earthquake, and kill plants, while an adjacent area may be turning cooler, allowing plants to invade a previously inhospitable place. The vegetation of the park today reflects the effects of many different types of natural disturbance such as forest fire, floods, landslides, insect infestations, blowdowns, and the changing climate.

Major Types of Trees in Yellowstone National Park

Lodgepole pine (*Pinus contorta*)

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

Limber pine (*P. flexilis*)

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

Whitebark pine (*P. albicaulis*)

- Grows above 7,000 feet
- Needles in groups of five
- Purple-brown cones produce important food for squirrels, bears, Clark's nutcrackers
- Up to 75 feet tall

Engelmann spruce (*Picea engelmannii*)

- Often along creeks, or wet areas

- Sharp, square needles grow singly

- Cones hang down and remain intact, with no bract between scales

- Up to 100 feet tall

Subalpine fir (*Abies lasiocarpa*)

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

Douglas-fir (*Pseudotsuga menziesii*)

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

Rocky Mountain juniper (*Juniperus scopulorum*)

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

Cottonwood (*Populus* spp.)

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

Quaking aspen (*Populus tremuloides*)

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



Lodgepole pine in Yellowstone National Park

Trees

Lodgepole Pine

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

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

Like all conifers, lodgepole pines have both male and female cones. The male cones produce huge quantities of yellow pollen in June and July. This yellow pollen is often seen in pools of rainwater around the park or at the edges of lakes and ponds. The lodgepole’s female cone takes two years to mature. In the first summer, the cones look like tiny, ruby-red miniature cones out near the end of the branches. The next year, after fertilization, the cone starts rapidly growing and soon becomes a conspicuous green. The female cones either open at maturity releasing the seeds, or remain closed—a condition called serotiny—until subjected to high heat such as a forest fire. These cones remain closed and hanging

on the tree for years until the right conditions allow them to open. Within a short period of time after the tree flashes into flame, the cones open up and release seeds over the blackened area, effectively dispersing seeds after forest fires. Trees without serotinous cones (like Engelmann spruce, subalpine fir, and Douglas-fir) must rely on wind, animals, or other agents to carry seeds into recently burned areas.

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

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

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

Insects and Fungus Threaten the Trees of Yellowstone

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

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



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

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

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

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

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

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

Blister rust is a disease caused by a fungus, *Cronartium ribicola*. It 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.

Only Here

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

Endemics

Ross's Bentgrass (*Agrostis rossiae*)

Ross's bentgrass grows only in the geyser basins along the Firehole River and at Shoshone Lake. This species seems to require locations providing the right combination of moisture and warmth that create a natural greenhouse. The temperature within an inch of the surface under a patch of this grass is usually about 100°F. As a result, this grass is one of the first plants to green up in warm pockets of geyserite—sometimes as early as January.

Ross's bentgrass rarely grows taller than six inches and more typically only 2–3 inches. Another diagnostic characteristic of Ross's bentgrass is that the inflorescence (flower) never completely opens up. Flowers may be present in February and March, but the plants typically do not produce viable seed that early. Full bloom occurs in late May and early June. As soon as temperatures rise in the early summer, the plants dry out due to the sun's heat from above and the thermal heat from below. Ross's bentgrass is already dead and hard to find by July.

Any plant growing in thermal areas must be able to deal with constant change. A successful plant in the geyser basins must be able to shift location relatively easily as one major thermal change or several changes could eradicate the entire population. Apparently, Ross's bentgrass deals with this problem efficiently. Its seed dispersal mechanism probably includes traveling on the muddy hooves of bison and elk who inhabit thermal areas during the winter. Exotic species, such as cheat grass, pose the only known threat; as they spread in thermal areas, they eventually may outcompete Ross's bentgrass.

Exotic Species

- More than 210 exotic plant species in the park.
- Resource managers target the most invasive species for control or removal.
- Species include (common names): dalmation toadflax, spotted knapweed, Canada thistle, ox-eye daisy, houndstongue, leafy spurge.

Yellowstone Sand Verbena (*Abronia ammophila*)

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

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

Yellowstone Sulfur Wild Buckwheat (*Eriogonum umbellatum* var. *cladophorum*)

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

Managing Invasive Plants

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

Exotic plants can displace native plant species and change the nature of vegetation communities. These changes can profoundly effect the entire ecosystem. For example, exotics unpalatable to wildlife may replace preferred native plants, leading to changes in

grazing activity. In turn, this stresses plants not adapted to grazing.

Controlling all the exotic species, some well-established, is unrealistic. The park focuses control action on species posing the most serious threat or those most likely to be controlled.

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



Dalmatian toadflax

Dalmatian toadflax (*Linaria dalmatica*)

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

Spotted knapweed (*Centaurea maculosa*)

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

Canada thistle (*Cirsium arvense*)

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

Ox-eye daisy (*Leucanthemum vulgare*)

- Mammoth and Madison areas.
- Can become dominant in meadows, is unpalatable to elk and other wildlife.
- Control efforts have substantially curtailed infestation; monitoring and evaluation continue.

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.

Restoring Native Plants

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

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

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



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

Fire

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

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

Fire can limit trees in the grasslands of Yellowstone, such as the Lamar and Hayden valleys.

Fire in Yellowstone

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

Factors Affecting Size and Severity

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

Topography

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

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

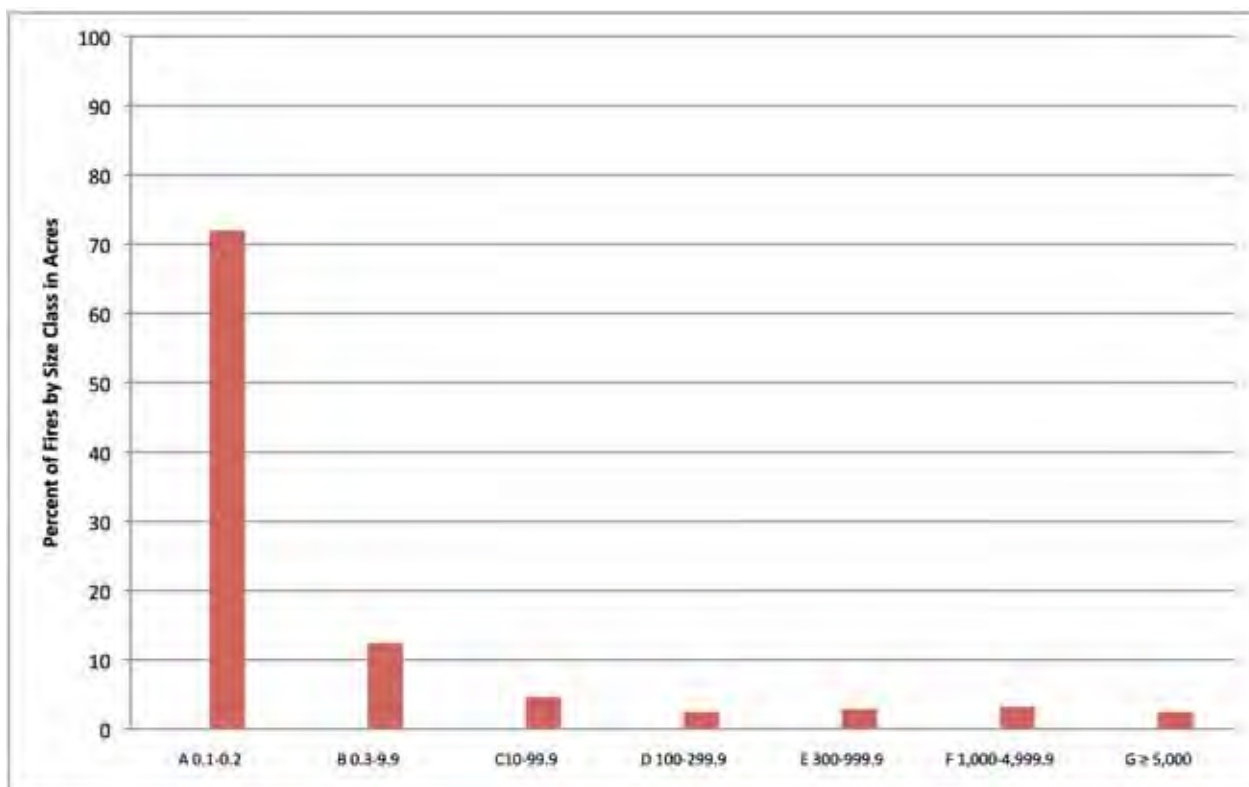


The Greater Yellowstone Ecosystem is a fire-adapted ecosystem.

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.

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

Lodgepole pines produce two types of cones, one of which opens and releases seeds after being heated to at least 113°F. These fire-dependent cones—called serotinous—ensure seedlings become established after a fire. Lodgepole seedlings need an open canopy that allows plenty of sun through. This happens only if mature trees in a lodgepole stand



Percent of fires in Yellowstone National Park, 2001–2010, by size class. Some fires burn with extreme fire behavior and rapid rates of spread. These large, fast moving fires send plumes of smoke thousands of feet into the air and receive much of the public's attention. These large fires (>100 acres) occur less than 11 percent of the time. Seventy-two percent of fires that occur in this park are less than 0.2 acres and another 12 percent range from 0.3 to 9.9 acres. These smaller, less intense fires play a role in this ecosystem by helping to thin out smaller trees and brush and boost the decay process that provides nutrients to the soil.

are periodically thinned by disease, insects, fire, or other natural agents. Such disturbances create a landscape more diverse in age, which reduces the probability of disease or fire spreading through large areas.

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

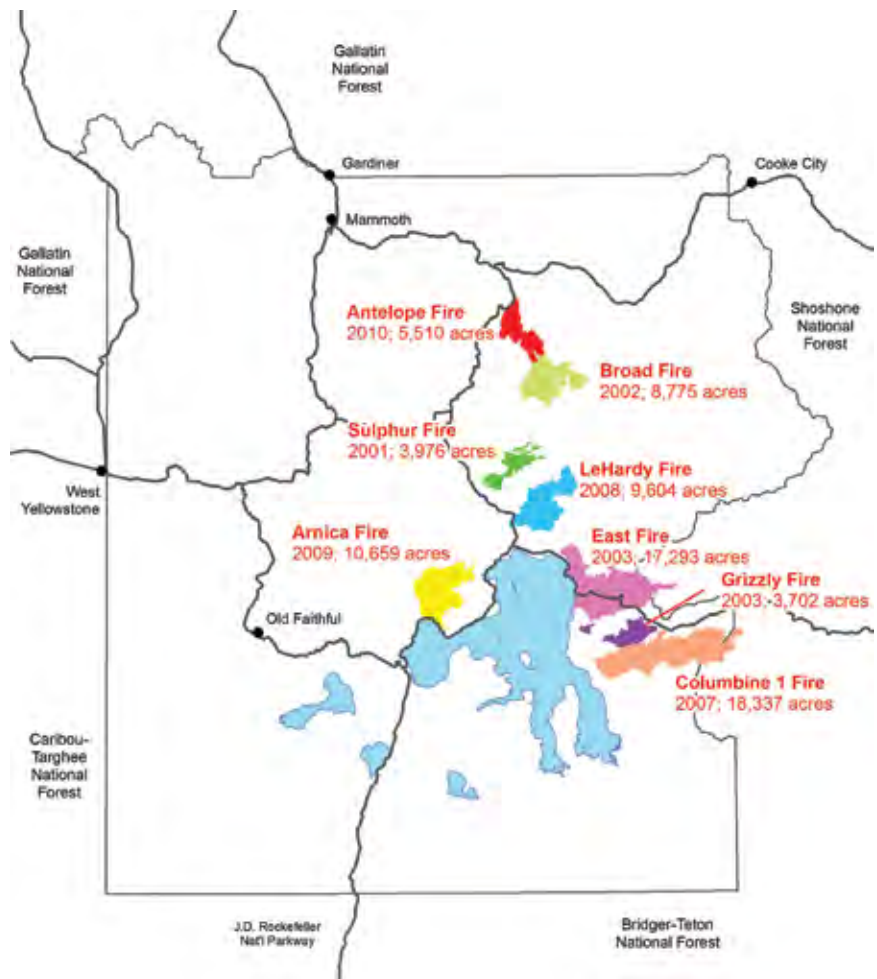
Fire suppression alters these natural conditions. Landscape diversity diminishes, and plant community structure and composition change. Diseases and insect infestations spread over greater areas, litter and deadfall accumulate, and minerals remain locked up or are more slowly released.

Fire Behavior

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

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

Ongoing research in Yellowstone is also showing that forests experiencing stand-replacing fires can then affect fire behavior for up to 200 years. As a fire encounters the previously burned forest, its intensity and rate of spread decrease. In some cases, the fire moves entirely around the burned area. Thus, fire managers have another tool for predicting fire behavior: They can compare maps of previous



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

stand-replacing fires with a current fire's location to predict its intensity and spread.

Managing Fire

Fire suppression in Yellowstone National Park began with the arrival of the U.S. Army, which was placed in charge of protecting the park in 1886. The Army, which was in Yellowstone until 1918, successfully extinguished some fires, though the effect of their efforts on overall fire frequency or extent of fires cannot be fully determined. Their efforts are detectable on the northern range, where fire suppression allowed more trees to become established.

Post World War II

Reliable and consistent fire suppression began when modern airborne firefighting techniques became available after World War II. Fire suppression continued until 1972. In that year, Yellowstone and several

other national parks initiated programs allowing some natural fires to run their courses. Two back-country areas in the park totaling 340,000 acres were designated as locations where natural fires could burn.

In 1976, the park's program expanded to 1,700,000 acres. Shortly thereafter, Yellowstone National Park and Bridger-Teton National Forest entered into a cooperative program allowing naturally caused fires in the Teton Wilderness to burn across the boundary between the two federal units.

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

Late 20th Century Reviews

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



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.

History

- For the first 100 years of the park's existence, managers believed fires had to be extinguished to preserve park resources.
- Scientific research revealed:
 - fires have occurred in Yellowstone for as long as there has been vegetation to burn
 - fire plays a role in creating the vegetation patterns of the landscape
 - fire is a part of the ecosystem that park managers want to preserve
 - suppressing fires alters the natural landscape and diminishes diversity.
- 1972, Yellowstone began using natural fire management.
- Between 1972 and 2005, 397 natural, unsuppressed fires burned 66,354 acres—mostly in 3 dry years: 1979, 1981, 1988. (In 1988, natural fires were allowed to burn in early summer.)
- The fires of 1988 brought about management changes, as did subsequent major fire seasons in this region.

Current Fire Management Policy

Yellowstone National Park follows guidelines of the 2009 Federal Wildland Fire Policy, which allows firefighters to manage fires for multiple objectives.

Yellowstone National Park's fire management plan of 1992.

Other major revisions occurred to the park's fire management plan in 2004.

Fire Management Today in the Greater Yellowstone Ecosystem

Today, 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 fire-fighters 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 but threatened visitor travel, power lines, and Lake Village.

Wildland fire is a great example of interagency cooperation and coordination. Federal agencies, state and local governments, and private contractors all play a role in managing fire here the park. For example, the NPS relies on Forest Service smoke-jumpers to monitor or fight the park's remote fires. In return, the NPS sends its helicopter or engine to the Silver Gate or Cooke City areas, which are located on or adjacent to the Gallatin and Shoshone national forests. Since 2009, the park's wildland engine has been staffed by both NPS and Forest Service firefighters. Programmable radios ensure communication between NPS and Forest Service dispatch, which improves firefighter safety. The NPS 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.

The 1988 Fires

The spring of 1988 was wet until June, when hardly any rain fell. Park managers and fire behavior specialists expected that July would be wet, though, as it had been historically. They allowed 18 lightning-caused fires to burn after evaluating them, according to the fire management plan. Eleven of these fires burned themselves out, behaving like many fires had in previous years.

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

Because of the extremely dry conditions, after July 15 no new natural fires were allowed to burn except those started adjacent to existing fires and that were clearly going to burn into existing fires. Even so, within a week the fire acreage in the park doubled to about 17,000 acres. After July 21, all fires—including those started naturally—were fully suppressed as staffing would allow. (Human-caused fires had been suppressed from the beginning.) On July 27, during a visit to Yellowstone, the Secretary of the Interior reaffirmed that all fires would be fought, regardless of their origin.



Helicopters are used to control the spread of fire.

Fighting the Fires

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

Accepted firefighting techniques were often ineffective because fires spread long distances by “spotting,” a phenomenon in which wind carries embers across unburned forest to start spot fires ahead of the main fire. In the severe conditions of 1988, fires were spotting up to a mile and a half ahead—jumping roads, rivers, even the Grand Canyon of the Yellowstone River.

Fires often moved two miles per hour, with common daily advances of five to ten miles. The fast movement, coupled with spotting, made direct attacks on the fires impossibly dangerous, as fire crews could easily be overrun or trapped between a main fire and its outlying spot fires. Even during the night, fires could not be fought. Typically, wildfires “lie down” at night as humidity increases and temperature decreases. But in 1988, the humidity remained low at night, and fire fighting was complicated by the

The 1988 Fires

Statistics

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

Fighting the Fires

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

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 area, and most major park developments—and a few surrounding communities—had been evacuated at least once as fires approached within a few miles. The fire suppression efforts involved many different federal and state agencies, including the armed forces. At the height of the fires, ten thousand people were involved. This was the largest such cooperative effort undertaken to that date in the United States.

Confusion in the Media

The Yellowstone fires of 1988 received more national attention than any other event in the history of

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.

Percent of Normal Rainfall, Mammoth Hot Springs

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

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



Clockwise from top left: Firefighters worked to prevent historic structures like the Old Faithful Inn (left) and Mammoth Hotel (right) from burning; Fires burn in a mosaic pattern; The Yellowstone fires of 1988 received more media attention than any other event in the history of national parks up to that time; More than \$120 million was spent fighting the fires in the greater Yellowstone area.

the “Yellowstone Park Fire;” they referred to these fires as part of the park’s natural fire program, which was not true; and they often oversimplified events and exaggerated how many acres had burned. In Yellowstone National Park itself, the fires affected—but did not “devastate”—793,880 acres or 36 percent of total park acreage.

A number of major fires started outside the park. These fires accounted for more than half of the total acres burned in the greater Yellowstone area, and included most of the fires that received intensive media attention. The North Fork Fire began in the Targhee National Forest and suppression attempts began immediately. The Storm Creek Fire started as a lightning

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

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

hopelessness of stopping fires and concentrated their efforts on protecting developed areas.

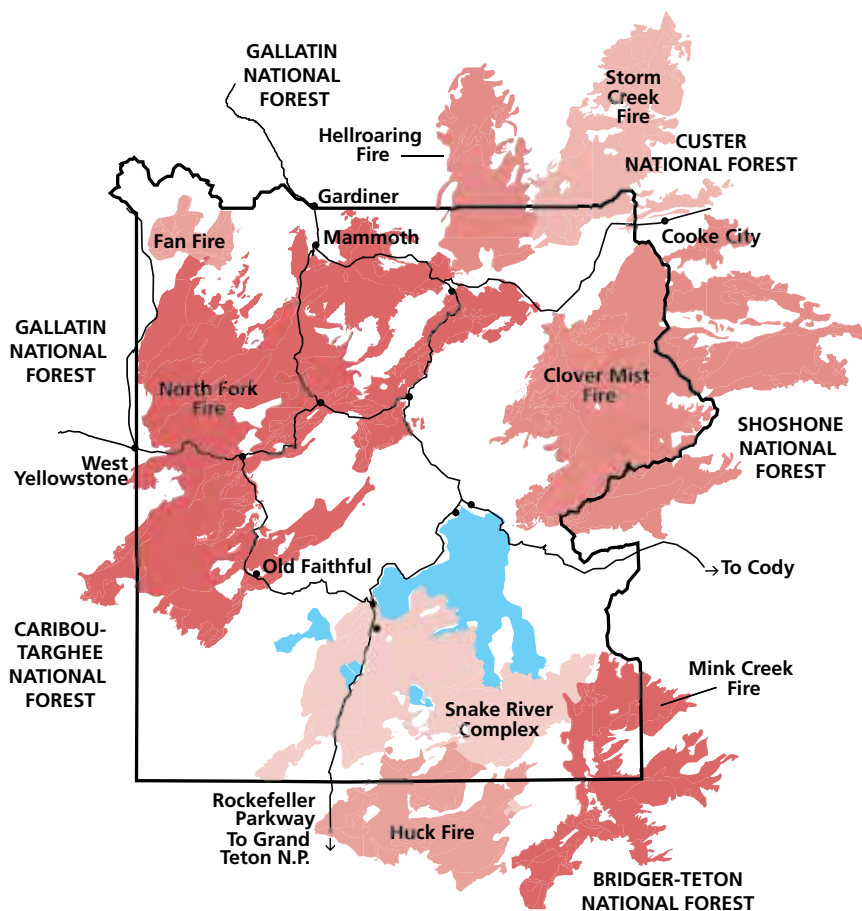
The most unfortunate public and media misconception about the Yellowstone firefighting effort may have been that human beings can always control fire. These fires could not be controlled; their raw, unbridled power cannot be over-emphasized. Firefighters were compelled to choose their fights very carefully,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

Post-fire Response and Ecological Consequences

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

Scientists wanted to monitor the ecological processes following these major fires. The National Park Service cooperated with other agencies and independent researchers and institutions in developing comprehensive research directions for this unparalleled scientific opportunity. Observations began while the fires were still burning, when it was apparent that the fires did not annihilate all life forms in their paths.

Burning at a variety of intensities, the fires killed many lodgepole pines and other trees, but did not kill



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

Burned Area within Yellowstone National Park

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

Data from the Geographic Information Systems Laboratory, Yellowstone National Park, 1989.

Table adapted, *Yellowstone in the Afterglow: Lessons From the Fires*, Mary Ann Franke, 2000.

most other plants; they merely burned the tops, leaving roots to regenerate. Temperatures high enough to kill deep roots occurred in less than one-tenth of one percent of the park. Only under logs and in deep litter accumulations, where the fire was able to burn for several hours, did lethal heat penetrate more



Wildlife continued to use burned areas after the fires.



deeply into the soil. Where water was available, new plant growth began within a few days. In dry soils, the rhizomes, bulbs, seeds, and other reproductive tissues had to wait until soil moisture was replenished the following spring.

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

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

After the 1988 Fires

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

Soils

Fertile soils with good water-holding capacity that have a dense, diverse vegetation before the fire were likely to respond quickly after the fire with a variety of species and nearly complete cover. Some soils in Yellowstone supported little vegetation before the fires and have continued to have little since then. Areas that appear barren and highly erosive did not necessarily become that way because of fire.

Trees

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

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

The density of lodgepole pine seedlings in burned areas after the 1988 fires varied, depending on factors such as fire severity, elevation, abundance of serotinous cones (which require fire to open), and seedbed characteristics. Density ranged from 32 seedlings per acre in a high-elevation stand with no serotinous cones to 769,000 seedlings per hectare in a low-elevation stand in which nearly half the trees had serotinous cones.

About 24 percent of the park's whitebark pine forest burned in 1988. This affects grizzly bears, for which whitebark pine seeds are an important food in fall. Seeds not consumed by grizzlies remain in caches of red squirrels and Clark's nutcracker. These buried seeds and the hardiness of whitebark pine seedlings on exposed sites give this tree an initial advantage in large burned areas over conifers dependent on wind to disperse seeds. However, this slow-growing and long-lived tree is typically more than 50 years old before producing cones. The young trees may die before reproducing if the interval between fires is too short or if faster-growing conifers overtake them. By 1995, whitebark pine seedlings had appeared in all 275 study plots, though density was not significantly different between burned and unburned sites.



Some soils responded quickly after the fires, but others may continue to support little vegetation.

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

shrub height. But the fires indirectly helped protect some of these young trees: the trunks of fallen trees keep elk from reaching some young aspen.

Other Vegetation

The regrowth of plant communities began as soon as the fire smoke cleared and moisture was available, which in some sites was within days. In dry soils, the seeds had to wait until moisture was replenished the following spring. New seedlings grew even in the few areas where the soil had burned intensely enough to become sterilized. Within a few years, grasslands had largely returned to their pre-fire appearance. Sagebrush also recovered rapidly.

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

Wildlife

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

After the 1988 Fires

What Did NOT Happen

Many predictions were made about the 1988 fires' long-term consequences for visitation, wildlife, and vegetation. However, the following have not come to pass:

- ✗ A long-term drop in park visitation.
- ✗ Flooding downstream of the park because of increased runoff on bare slopes.
- ✗ A decline in fish populations because increased erosion silted up the water.
- ✗ An increase in fish populations in smaller streams where deforestation and loss of shade could result in warmer water and higher nutrient levels.
- ✗ More rapid invasion of non-native plants into burned areas and corridors cleared as fire breaks.
- ✗ An increase in lynx following a boom in snowshoe hares as a result of changes in forest structure.
- ✗ An increase in the elk population because of improved forage.
- ✗ A decline in the endangered grizzly bear population because of smaller whitebark pine seed crops.
- ✗ Another big fire season in Yellowstone because of all the fuel provided by so many dead and downed trees.

What DID Change

These changes have been caused entirely or in part by the fires of 1988:

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

The most recent research was presented September 2008 at the 9th Biennial Scientific Conference on the Greater Yellowstone Ecosystem, “The ‘88 Fires: Yellowstone & Beyond.” Proceedings at www.nps.gov/yell/naturescience/upload/88fires.pdf

Elk mortality rose to about 40 percent in the winter of 1988–89, but scientists are unsure how much of this was due to reduced forage because of the fires. (At least 15 percent of the deaths were due to hunting seasons outside the park.) Even without the fires, several factors would probably have led to high elk mortality that winter:

summer drought, herd density, hunting harvest, and winter severity. The greatest impact of the fires would therefore be on the quantity and quality of forage available to elk in subsequent years. A two-year study following the fires found that the forage quality of three types of grasses was better at burned sites than unburned sites.

Of the 38 grizzly bears wearing radio transmitters when the fires began, 21 had home ranges burned by one

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

Rodents probably had the highest fire-related mortality of any mammals. Although many could escape the fires in burrows, others died of suffocation as the fires came through. They also were more exposed to predators because they had lost the cover of grasses and other plants. But, because of their capacity to have multiple litters with many young per year, rodents quickly repopulated burned areas.

Most birds were not directly harmed by the fires and some benefited. For example, raptors hunted rodents fleeing the fires. But young osprey that were still in their nests died. Post-fire habitat changes

helped some birds. Cavity-nesting birds, such as Barrow's goldeneye, flickers, and bluebirds had many dead trees for their nests. Robins and flickers found ants and worms more easily. Boreal owls, however, lost some of the mature forests they need.

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”

Aquatic Resources

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

About a quarter of the Yellowstone Lake and Lewis Lake watersheds and half of the Heart Lake watershed burned to some extent, but no significant changes were observed in nutrient enrichment, plankton production, or fish growth afterward. No apparent streambank erosion or other changes occurred

that affected cutthroat trout spawning habitat, nor did the number of spawning streams decline. No discernible fire-related effects have been observed in the fish populations or the angling experience in the six rivers that have been monitored regularly since 1988.

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

Conclusion

In the first years after a major fire, new vistas appear while the lush growth of new, young trees emerges from the burned ground. Today, more than twenty years after the 1988 fires, those young trees are renewed forests, once again filling in vistas. Some visitors still feel that the Yellowstone they knew and loved is gone forever. But Yellowstone is not a museum—it is a functioning ecosystem in which fire plays a vital role.



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).

Frequently Asked Questions: The Fires of 1988

How much of the park burned in 1988?

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

How were weather conditions different than in previous years?

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

Could the fires have been put out?

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

detected. Despite the largest firefighting effort in the history of the nation, weather finally contained the fires when snow fell in September.

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

After the fires of 1988, a national policy review team examined the national fire policy again, and concluded that natural fire policies in national parks and wilderness areas were basically sound. It also recommended improvements that were incorporated into the National Park Service's fire policy of June 1990 and into Yellowstone National Park's fire management plan of 1992.

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.

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

Why doesn't the park remove burned trees?

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



Yellowstone National Park is home to the largest concentration of mammals in the lower 48 states. Here, bison and elk graze on the northern range.

Wildlife

Mammals

Mammals In Yellowstone National Park

Yellowstone is home to the largest concentration of mammals in the lower 48 states.

- 67 different mammals live here, including many small mammals.
- >600 grizzly bears live in the Greater Yellowstone Ecosystem.
- Black bears are common.
- Gray wolves were restored in 1995. About 100 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.
- Non-native mountain goats have colonized northern portions of the park.

Mammals of Yellowstone National Park

Species	Habitat	Estimated Park Population
<i>Order Carnivora</i>		
Family Ursidae		
Black Bear (<i>Ursus americanus</i>)*	forests, meadows	common
Grizzly Bear (<i>Ursus arctos horribilis</i>)*	forests, meadows	±150 in the park; ±600 in Greater Yellowstone Ecosystem
Family Canidae		
Coyote (<i>Canis latrans</i>)*	forests, meadows, grasslands	common
Gray Wolf (<i>Canis lupus</i>)*	forests, meadows	±100 in the park
Fox (<i>Vulpes vulpes</i>)*	meadows	common
Family Felidae		
Bobcat (<i>Lynx rufus</i>)*	forests, rocky areas	may be widespread
Cougar (<i>Puma concolor</i>)*	mountains, rocky areas	14–23
Lynx (<i>Lynx canadensis</i>)*	subalpine forests	few
Family Pcyonidae		
Raccoon (<i>Procyon lotor</i>)	rivers, cottonwoods	rare
Family Mephitidae		
Striped Skunk (<i>Mephitis mephitis</i>)	riparian to forest	rare
Family Mustelidae		
Badger (<i>Taxidea taxus</i>)	sagebrush	common
Fisher (<i>Martes pennanti</i>)	forests	rare, if present

Species	Habitat	Estimated Park Population
Marten (<i>Martes martes</i>)**	coniferous forests	common
Mink (<i>Mustela vison</i>)	riparian forests	occasional
River Otter (<i>Lutra canadensis</i>)**	rivers, lakes, ponds	common
Long-tailed Weasel (<i>Mustela frenata</i>)**	willows to spruce/fir forests	common
Short-tailed Weasel (ermine) (<i>Mustela erminea</i>)**	willows to spruce/fir forests	common
Wolverine (<i>Gulo gulo</i>)**	alpine, coniferous forests	rare
<i>Order Artiodactyla</i>		
Family Cervidae		
Elk (Wapiti) (<i>Cervus elaphus</i>)*	meadows, forests	10,000 in summer
Moose (<i>Alces alces shirasi</i>)*	riparian, forests	<200
Mule Deer (<i>Odocoileus hemionus</i>)*	forests, grasslands, shrub lands	2,300–2,500
White-tailed Deer (<i>O. virginianus</i>)*	forests, grasslands, shrub lands	occasional
Family Bovidae		
Bison (<i>Bison bison</i>)*	meadows, grasslands	±3,900
Bighorn Sheep (<i>Ovis canadensis</i>)*	cliffs, mountain slopes	250–275
Mountain Goat (non-native) (<i>Oreamnus americanus</i>)	alpine meadows, rocky slopes	175–225
Family Antilocapridae		
Pronghorn (<i>Antilocapra americanus</i>)*	sagebrush, grasslands	200–300
<i>Order Chiroptera</i>		
Family Vespertilionidae		
Big Brown Bat (<i>Eptesicus fuscus</i>)	roost in buildings, other sheltered areas	common
Fringe-tailed bat (<i>Myotis thysanodes</i>)	roost in cliffs, large snags	uncommon
Hoary Bat (<i>Lasiurus cinereus</i>)	roost in trees	uncommon
Little Brown Bat (<i>M. lucifugus</i>)	roost in caves, buildings, trees	common
Long-eared Bat (<i>M. evotis</i>)	roost in cliffs, buildings	uncommon
Long-legged Bat (<i>M. volans</i>)	roost in tree cavities, cliffs, buildings	common
Silver-haired bat (<i>Lasionycteris noctivagans</i>)	roost in trees, including snags	common
Western small-footed Bat (<i>M. ciliolabrum</i>)	roost in rocky areas, caves	rare, if present
Townsend's Big-eared Bat (<i>Corynorhinus townsendii</i>)	roost in caves	uncommon
Yuma Bat (<i>M. yumanensis</i>)	roost in caves, buildings, trees	rare, if present
<i>Order Lagomorpha</i>		
Family Leporidae		
Snowshoe Hare (<i>Lepus americanus</i>)**	forests, willows	common
White-tailed Jackrabbit (<i>Lepus townsendii</i>)	low elevation sagebrush, grasslands	common
Desert Cottontail (<i>Sylvilagus audubonii</i>)	shrub lands	common
Mountain Cottontail (<i>S. nuttallii</i>)	shrub lands	common
Family Ochotonidae		
Pika (<i>Ochotona princeps</i>)**	rocky slopes	common

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

* indicates a species described in the species accounts

** indicates a species described on under "Small Mammals," alphabetized by their common name on this list.

Mammals: Small Mammals

Species accounts appear in alphabetical order by their common name. Numerous small mammals live in Yellowstone National Park. The park's interpretive rangers chose the following species to describe because visitors are likely to see them or inquire about them.

Golden-mantled Ground Squirrel (*Spermophilus lateralis*)



©ZACHERY ZDINAK

Identification

- 9–12 inches long, 7.4–11 ounces.
- Adult head and shoulders are reddish-brown, their “mantle.”
- Often mistaken for a least chipmunk (described below); distinguished by larger size, more robust body, shorter tail, and stripes that do not extend onto the sides of the head.

Habitat

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

Behavior

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

Least Chipmunk (*Tamius minimus*)



©ZACHERY ZDINAK

Identification

- 7.5–8.5 inches long, 1.2 ounces.
- Smallest member of the squirrel family; one of three chipmunk species in the park.
- Alternating light and dark stripes on its back and sides, outermost stripe on the sides is dark; underside tends to be white and tail has black-tipped hairs with a reddish undertone.
- Often mistaken for golden-mantled ground squirrel (described above); distinguished by smaller size, longer tail, and lateral stripes that extend onto the sides of the head.

Habitat

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

Behavior

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

Long-tailed Weasel (*Mustela frenata*)

Identification

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

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*)



©ZACHERY ZDINAK

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 4 litters of 2–10 young per year.

Pika (*Ochotona princeps*)



©ZACHERY ZDINAK

Identification

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

Habitat

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

Behavior

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

Pocket Gopher (*Thomomys talpoides*)



©ZACHERY ZDINAK

Identification

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

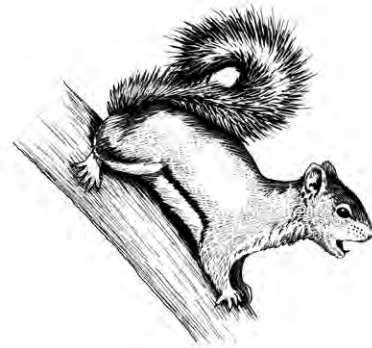
Habitat

- Only range restriction seems to be topsoil depth, which limits burrowing.
- Preyed upon by owls, badgers, grizzly bears, coyotes, weasels, and other predators.
- Snakes, lizards, ground squirrels, deer mice, and other animals use their burrows.
- In the top 6–8 inches below the surface they forage for forbs, some grasses and underground stems, bulbs and tubers.

Behavior

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

Red Squirrel (*Tamiasciurus hudsonicus*)



©ZACHERY ZDINAK

Identification

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

Habitat

- Spruce, fir, and pine forests; young squirrels found in marginal aspen habitat.
- Eat conifer seeds, terminal buds of conifer

trees, fungi, some insects; sometimes steal young birds from nests.

- Preyed on by coyotes, grizzly bears, hawks.

Behavior

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

River Otter (*Lutra canadensis*)



©ZACHERY ZDINAK

Identification

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

Habitat

- Most aquatic member of weasel family; generally found near water.
- Eat crayfish and fish; also frogs, turtles, sometimes young muskrats or beavers.

Behavior

- Active year-round.
- Breed in late March through April; one litter of two young per year.
- Females and offspring remain together until next litter; may temporarily join other family groups.
- Can swim underwater up to 6 miles per hour and for 2–3 minutes at a time.
- Not agile or fast on land unless they find snow or ice, then can move rapidly by alternating

hops and slides; can reach speeds of 15 miles per hour.

- Mostly crepuscular but have been seen at all times of the day.
- May move long distances between water bodies.

Short-tailed Weasel (Ermine) (*Mustela erminea*)



©ZACHERY ZDINAK

Identification

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

Habitat

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

Behavior

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

Snowshoe Hare (*Lepus americanus*)



©ZACHERY ZDINAK

Identification

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

Habitat

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

Behavior

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

Notes

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

Uinta Ground Squirrel (*Spermophilus armatus*)

Identification

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

Habitat

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

Behavior

- Hibernate as early as mid-July through March.
- Breed in early spring; one litter of 6–8 young per year.
- Young, after they leave the burrow, are vulnerable to long-tailed weasels and hawks.
- During cool spring weather, Uinta ground squirrels active at all times of day, as the weather warms activity more limited to morning, late afternoon, and evening.
- During winter, Uinta ground squirrels are sometimes active near the Albright Visitor Center and hotel at Mammoth Hot Springs. Perhaps they are aroused from hibernation due to ground temperatures rising as hydrothermal activity increases in the vicinity. No one knows for sure.

Wolverine (*Gulo gulo*)

Identification

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

Habitat

- Found in high-elevation conifer forests and alpine tundra; rarely seen.
- Eat burrowing rodents, birds, eggs, beavers, squirrels, marmots, mice, and vegetation

(including whitebark pine nuts); chiefly a scavenger in winter, but has also been known to take large prey such as deer or elk.

Behavior

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

Research

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

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.

Yellow-bellied marmot (*Marmota flaviventris*)



©ZACHERY ZDINAK

Identification

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

Habitat

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

Mammals: Bear, Black

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

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

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

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

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

After fertilization, the barely developed blastocyst (egg) does not immediately implant in the uterus, a process called “delayed implantation.” If the bear is healthy when she dens for the winter, implantation



A black bear and her cub of the year in Yellowstone National Park.

and development will begin; if not, her body will abort the blastocyst. Total gestation time is 200 to 220 days, but only during the last half of this period does fetal development occur.

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

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

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

Black Bears in Yellowstone National Park

Number in Yellowstone

common

Where to see

Tower and Mammoth areas, most often.

Behavior & Size

- Males weigh 210–315 pounds, females weigh 135–200 pounds; adults stand about 3 feet at the shoulder.
- May live 15–30 years.
- Home range: male, 6–124 square miles, female, 2–45 square miles.
- Can climb trees; adapted to life in

forest and along forest edges.

- Food includes rodents, insects, elk calves, cutthroat trout, pine nuts, grasses and other vegetation.
- Mates in spring; gives birth the following winter to 1–3 cubs.
- Considered true hibernators.

History

Like grizzlies, used to be fed at dumps within the park.

- For years, black bears were fed by visitors from vehicles.

- Both of these actions resulted in bears losing fear of humans and pursuing human food, which resulted in visitor injuries, property damage, and the need to destroy “problem bears.”

Management Status

- Study began in 2000 to find out how black bears fit into the mix of northern range predators; twelve black bears have been radio-collared.

Mammals: Bear, Grizzly

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

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

It is commonly said that grizzly bears cannot climb trees. This is not true, especially when the bears are small. As grizzlies grow larger and their claws grow longer, they have a harder time climbing. Stories that bears cannot swim or run downhill are also untrue. Grizzlies can swim, run up and downhill, and sprint up to 40 miles per hour.

Bears are generally solitary, although they may tolerate other bears when food is plentiful. Mating season occurs from mid-May to mid-July, and bears may mate with multiple partners during a single season. Females do not breed until at least age 4 or 5. Bears experience “delayed implantation,” meaning that the embryos do not begin to develop until late November or December. This appears to be a strategy allowing the mother bear to save up energy until entering her winter den, where the cubs are born in late January or February. A litter of one to three cubs is common, litters of four cubs occur occasionally.



A grizzly bear in Yellowstone National Park.

Male bears take no part in raising cubs and may pose a threat to younger bears. A mother grizzly will usually keep her cubs with her for two winters following their birth, after which time she (or a prospective suitor) chases the subadult bears away so she can mate again. Female cubs frequently establish their home range in the vicinity of their mother, but male cubs must disperse farther in search of a home.

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

Grizzly Bears in Yellowstone National Park

Number in Yellowstone

±150 with home ranges wholly or partially in park; 541–663 in Greater Yellowstone Ecosystem.

Where to see

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

Behavior & Size

- Males weigh 300–700 pounds, females weigh 200–400 pounds; adults stand about 3 1/2 feet at the shoulder.
- May live 15–30 years.
- Home range: male, 813–2,075

square miles, female, 309–537 square miles.

- Agile; can run up to 35–40 mph.
- Can climb trees but curved claws and weight make this difficult.
- Adapted to life in forest and meadows.
- Food includes rodents, insects, elk calves, cutthroat trout, roots, pine nuts, grasses, and large mammals.
- Mates in spring; gives birth the following winter; 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 GYE.

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

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

- adult males
- lone adult females, females with two-year-old cubs; females with yearlings
- females with cubs of the year
- subadults of either sex

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

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



© ZACHERY ZDINAK

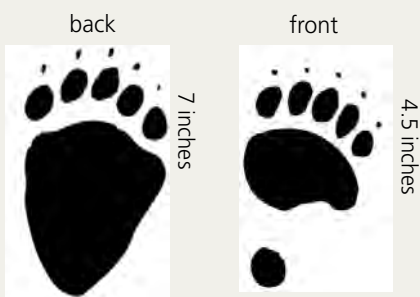
Grizzly bear

Compare Black Bears and Grizzly Bears

Black Bear



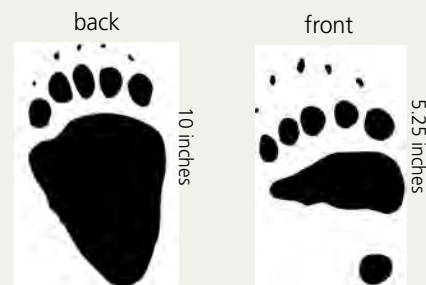
- Rump higher than shoulders.
- No shoulder hump



Grizzly Bear



- Rump lower than shoulders.
- Shoulder hump present.



Mammals: Beaver

Since 1979, park staff has periodically surveyed riparian habitat in Yellowstone to determine current presence and distribution of beavers (*Castor canadensis*). These surveys confirmed that beavers live throughout Yellowstone National Park but are concentrated in the southeast (Yellowstone River delta area), southwest (Bechler area), and northwest portions (Madison and Gallatin rivers) of the park. They are also making a comeback in the northern range due to new willow growth and because they were reintroduced nearby in the Gallatin National Forest. These areas are likely important habitat because of their waterways, meadows, and the presence of preferred foods such as willow, aspen, and cottonwood.

Beavers, however, are not restricted to areas that have their preferred foods. Essentially no aspen exist in most areas where beaver sign is most abundant, such as in the Bechler River. The same is true in other areas where beavers periodically live, such as Heart Lake, the lower Lamar River and Slough Creek area, Slide Lake, and the lower Gardner River. In these areas, beavers use willows for construction and for food. Where their preferred plants are few or absent, beavers may cut conifer trees and feed on submerged vegetation such as pond lilies.

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



A beaver in Yellowstone National Park

Like wolves, beavers live in family groups, which are called colonies. Fewer than five percent of mammals live organized like this. Male and female beavers look alike—thick brown fur, paddle-shaped tail, weigh 30–60 pounds, and are 35 to 40 inches long, including tail. When hunched over their food, beaver can resemble round rocks.

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

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

Beaver in Yellowstone National Park

Number in Yellowstone

Estimate: There were 112 colonies counted in Yellowstone during Fall 2011. Colonies can range from two to 14 animals. Six is considered average. This number reflects little change in population from previous years.

Where to see

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

Behavior & Size

- Crepuscular: active in evening and morning
- If live on rivers, may build bank dens instead of lodges.
- One lodge may support 6–13 beavers that are usually related; this group is called a colony.
- 35–40 inches long, including tail.
- Weighs 30–60 pounds.
- Average life span: 5 years.

Other Information

- Beavers are native to Yellowstone.
- Yellowstone's beavers escaped most of the trapping that occurred in the 1800s due to the region's inaccessibility.

Mammals: Bighorn Sheep

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

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

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

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

Although they are sure-footed in a steep and rocky environment, bighorns do have accidents. They fall



Bighorn sheep in Yellowstone National Park

off cliffs, slip on ice, and can become caught in avalanches. In Yellowstone, they also have been struck by lightning and hit by automobiles.

Population and Management

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

Researchers have also studied bighorn sheep habitat use and the effect of human activity along the Gardiner–Mammoth road. About 65 percent of all sheep observations occur atop McMiner Bench of Mt. Everts.

Bighorn Sheep in Yellowstone National Park

Number in Yellowstone

250–275

Where to See

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

Behavior and Size

- Adult male (ram) up to 300 pounds, including horns that can weigh 40 pounds.

- Average life span: males, 9–12 years; females 10–14 years.
- Adult female (ewe) up to 200 pounds.
- Both sexes have horns.
- Feed primarily on grasses; forage on shrubby plants in fall and winter.
- Mating season begins in November.
- One to two lambs born in May or June.

Management

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

Mammals: Bison

The bison is the largest land mammal in North America. Bulls are more massive in appearance than cows, and more bearded. For their size, bison are agile and quick, capable of speeds in excess of 30 mph. Each year, bison injure park visitors who approach too closely.

Bison are sexually mature at age 2. Although female bison may breed at these younger ages, older males (>7 years) participate in most of the breeding. In Yellowstone, their life span averages 12–15 years; a few individuals live as long as 20 years. Both sexes have horns, those of the cow being slightly more curved and slender than the bull's.

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 1/2 months, single reddish-brown calves are born in late April and May.



A bison in Yellowstone National Park

Calves can keep up with the herds about 2–3 hours after birth and they are well protected by their mothers and other members of the herd. However, wolves and grizzly bears have killed bison calves.

Wolves and grizzly bears are the only large predators of adult bison. Scientists have also recently seen grizzly bears hunting bison successfully. Dead bison provide an important source of food for scavengers and other carnivores.

Many insects feed upon the bison, and bison will rub against trees, rocks, or in dirt wallows in an attempt to get rid of insect pests. Birds such as the magpie “ride” a bison to feed on insects in its coat. The cowbird will also follow close behind a bison, feeding on insects disturbed by its steps.

Bison in Yellowstone National Park

Number in Yellowstone

approximately 3,900

Where to see

- Year-round: Hayden and Lamar valleys.
- Summer: grasslands of the park.
- Winter: hydrothermal areas and along the Madison River.

Behavior & Size

- Male (bull) weighs up to 2,000 pounds, female (cow) weighs up to 1,000 pounds.
- May live 12–15 years.
- Feed primarily on grasses and sedges.
- Mate in late July through August; give birth to one calf in late April or May.
- Can be aggressive, are agile, and can run up to 30 miles per hour.
- Two subpopulations: Northern Range and Hayden Valley.

History

- Yellowstone National Park is the only place in the lower 48 states to have a continuously free-ranging bison population since prehistoric times.
- In the 1800s, market hunting, sport hunting, and the U.S. Army nearly caused the extinction of the bison.
- By 1902, poachers reduced Yellowstone's small herd to about two dozen animals.
- The U.S. Army, who administered Yellowstone then, protected these bison from further poaching.
- Bison from private herds augmented the native herd.
- For decades, bison were intensively managed due to belief that they, along with elk and pronghorn, were over-grazing the park.
- By 1968, intensive manipulative management (including herd reductions) of bison ceased.

Migration

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

History

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

European American settlers moving west during the 1800s changed the balance. Market hunting, sport hunting, and a U.S. Army campaign in the late 1800s nearly eliminated bison. Yellowstone was the only place in the contiguous 48 states where wild, free-ranging bison persisted. The U.S. Army, which administered Yellowstone at that time, protected these few dozen bison from poaching as best they could. The protection and recovery of bison in Yellowstone is one of the great triumphs of American conservation.

Managing Bison

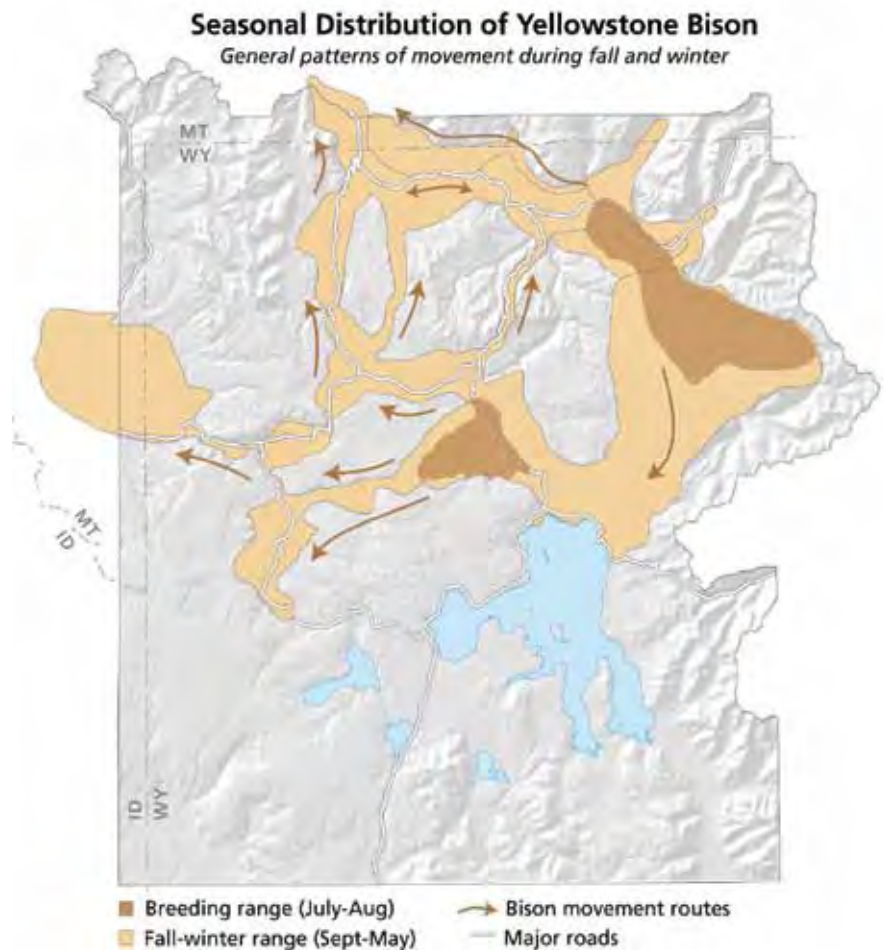
Despite protection, Yellowstone's bison were reduced by poaching to less than two dozen animals in 1902. Fearing the demise of the wild herd,

Bison or 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.

the U.S. Army brought 21 bison from ranches to Yellowstone. In 1906–07, the Buffalo Ranch in Lamar Valley was constructed to manage these bison and increase their numbers. This herd grew to more than 1,000 animals; the park's small native bison herd in Pelican Valley also slowly increased. In the 1930s, the introduced bison were allowed to move freely and intermingle with the native bison. The park's bison 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.

In 1968, managers stopped manipulating bison populations and allowed natural ecological processes to operate. As their population grew, bison began to



©2009, UNIVERSITY OF OREGON, ATLAS OF YELLOWSTONE

move outside the park. Conflicts with humans began to occur. Bison can be a threat to human safety and can damage fences, crops, landscaping, and other private property. And, of significant concern to livestock producers, some Yellowstone bison are infected with the disease brucellosis.

Because of brucellosis, bison generally are not welcome outside the park even though other ungulates that may also harbor the brucellosis organism are. Since the 1980s, this issue has grown steadily into one of the most heated and complex of Yellowstone's resource issues.

Mammals: Cats, Bobcat and Lynx

The cats of Yellowstone are seldom seen and little known.

Bobcat (*Lynx rufus*)



©ZACHERY ZDINAK

Number in Yellowstone

Unknown, but generally widespread.

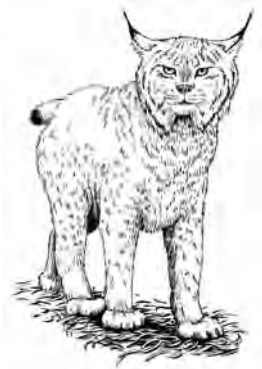
Where to see

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

Behavior and Size

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

Lynx (*Lynx canadensis*)



©ZACHERY ZDINAK



FRED PAULSEN

In December 2007, Fred Paulsen, a Xanterra 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.

Number in Yellowstone

Few; 112 known observations.

Where to see

- Very rarely seen.
- Typical habitat: cold conifer forests.

Behavior and Size

- Adult: 16–35 pounds, 26–33 inches long.
- Gray brown fur with white, buff, brown on throat and ruff; tufted ears; short tail; hind legs longer than front.
- Distinguish from bobcat: black rings on tail are complete; tail tip solid black; longer ear tufts; larger track.
- Wide paws with fur in and around pads; allows lynx to run across snow.
- Track: 4–5 inches.
- Solitary, diurnal and nocturnal.
- Eats primarily snowshoe hares, especially in winter; also rodents, rabbits, birds, red squirrels, and other small mammals, particularly in summer.

Research

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

Mammals: Cats, Cougar



©ZACHERY ZDINAK

The cougar (*Puma concolor*), also called the mountain lion, is among the largest cats in North America. (The jaguar, which occurs in New Mexico and Arizona, is larger.) Cougars live throughout the park in summer, but few people ever see them. The northern range of Yellowstone is prime habitat for cougars because snowfall is light and prey always available. Cougars follow their main prey as they move to higher elevations in summer and lower elevations in the winter.

Adult male cougars are territorial and may kill other adult males in their home range. Male territories may overlap with several females. In non-hunted populations, such as in Yellowstone, the resident adult males living in an area the longest are the dominant males. These males sire most of the litters within a population; males not established in the same area have little opportunity for breeding.

Although cougars may breed and have kittens at any time of year, most populations have a peak breeding and birthing season. In Yellowstone, males and females breed primarily February through May.

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.

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.

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

Cougar in Yellowstone National Park

Number in Yellowstone

14–23 resident adults on the northern range; others in park seasonally.

Where to see

Seldom seen.

Behavior and size

- Adult males weigh 140–165 pounds; females weigh about 100 pounds; length, including tail, 6.5–7.5 feet.
- Average life span: males, 8–10 years; females, 12–14 years.
- Preferred terrain: rocky breaks and

forested areas that provide cover for hunting prey and for escape from competitors such as wolves and bears.

- Prey primarily on elk and mule deer, plus porcupines and other small mammals.
- Bears frequently displace cougars from their kills.
- Male cougars may kill other male cougars within their territory.
- Adult cougars and kittens have been killed by wolves.

- Litters range from 2–3 kittens; 50% survive first year.

Interaction with humans

Very few documented confrontations between cougars & humans have occurred in Yellowstone.

If a big cat is close by: Stay in a group; carry small children; make noise. Do not run, do not bend down to pick up sticks. Act dominant—stare in the cat's eyes and show your teeth while making noise.

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.

Yellowstone's cougars are not hunted within the park. Thus, their life span may be 12–14 years for females and 8–10 years for males. Cougars living in areas where they are hunted have much shorter life spans.

In Yellowstone, cougars prey upon elk (mostly calves) and deer. They stalk the animal then attack, aiming for the animal's back and killing it with a bite to the base of the skull or the throat area.

A cougar eats until full, then caches the carcass for later meals. Cougars spend an average of 3–4 days consuming an elk or deer and 4–5 days hunting for the next meal. Cougars catch other animals—including red squirrels, porcupines, marmots, grouse, and moose—if the opportunity arises.

Cougars are solitary hunters who face competition for their kills from other large mammals. Even though a cached carcass is harder to detect, scavengers and competitors such as bears and wolves sometimes find it. In Yellowstone, black and grizzly bears will take over a cougar's kill. Coyotes will try, but can be killed by the cougar instead. Wolves displace cougars from approximately 6 percent of their elk carcasses.

Management History

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

In 1987, the first cougar ecology study began in Yellowstone National Park. The research documented population dynamics of cougars in the northern Yellowstone ecosystem inside and outside the park boundary, determined home ranges and habitat requirements, and assessed the role of cougars as a predator.



TONI K. RUTH, HORNOCKER WILDLIFE INSTITUTE & WILDLIFE CONSERVATION SOCIETY

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

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

Very few cougar/human confrontations have occurred in Yellowstone. However, observations of cougars, particularly those close to areas of human use or residence, should be reported.



Mammals: Coyote

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

Often mistaken for a wolf, the coyote is about one-third the wolf's size with a slighter build. Its coat colors range from tan to buff, sometimes gray, and with some orange on its tail and ears. Males are slightly larger than females.

During the 20th century, coyotes partially filled the niche left vacant after wolves were exterminated from the park. In Yellowstone, they live in packs or family groups of up to 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 scent-marks (urine and feces) to communicate their location, breeding status, and territorial boundaries.

Until 1995, coyotes faced few predators in Yellowstone other than cougars, who will kill coyotes feeding on cougar kills. After wolves were restored,



Coyotes (right) are smaller than wolves (left).

however, dozens of coyote pups and adults were been killed by wolves—primarily when feeding on other animals killed by wolves. On the northern range, wolves caused a 30–50 percent reduction in coyote population density through direct mortality and changes in coyote denning behaviors and success. Researchers see some evidence now that coyotes on the northern range have adapted to wolves and their population has recovered.

Coyotes also face threats from humans. They quickly learn habits like roadside feeding. This may lead to aggressive behavior toward humans and can increase the risk of the coyote being hit by a vehicle. Several instances of coyote aggression toward humans have occurred here, including a few attacks.

Park staff scare unwary coyotes from visitor-use areas with cracker-shell rounds, bear repellent spray, or other negative stimuli. Animals that continue to pose a threat to themselves or to humans are killed. Signs, interpretive brochures, and park staff continue to remind visitors that coyotes and other park wildlife are wild and potentially dangerous and should never be fed or approached.

Coyote in Yellowstone National Park

Number in Yellowstone

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

Where to see

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

Behavior & Size

- Weigh 25–35 pounds, 16–20 inches high at the shoulder.
- Average life span 6 years; up to 13 years in the park.
- Home range: 3–15 square miles.

- Primarily eat rodents, birds, insects, carrion, elk calves, some adult elk.
- 4–8 pups are born in April in dens; emerge in May.
- Killed by wolves, mountain lions.

Management

- Like other predators, coyotes were often destroyed in the early part of the 20th century because they sometimes preyed on livestock.
- Coyotes continued to thrive because their adaptability enabled them to compensate for the destruction efforts.

- Elimination of wolves probably resulted in high coyote population densities; wolves' absence opened a niche that coyotes could partially occupy in Yellowstone.
- NPS staff monitors coyotes and uses cracker-shell rounds, pepper spray, or other negative stimuli to discourage coyotes that have lost their wariness of humans.

Mammals: Deer

Mule deer are common in Yellowstone, living throughout the park in almost all habitats; white-tailed deer are uncommon, restricted to streamside areas of the northern range.

Mule deer (*Odocoileus hemionus*)



Number in Yellowstone

Summer: 2,300–2,500

Winter: less than 100

Where to see

- Summer: throughout the park.
- Winter: North Entrance area.

Behavior and Size

- Male (buck): 150–250 pounds; female (doe): 100–175 pounds; 3 1/2 feet at the shoulder.
- Summer coat: reddish; winter coat: gray-brown; white rump patch with black-tipped tail; brown patch on forehead; large ears.
- Males grow antlers from April or May until August or September; shed them in late winter and spring.
- Mating season (rut) in November and December; fawns born late May to early August.
- Lives in brushy areas, coniferous forests, grasslands.
- Bounding gait, when four feet leave the ground, enables it to move more quickly through shrubs and rock fields.
- Eats shrubs, forbs, grasses; conifers in spring.
- Predators include wolf, coyote, cougar, bear.

About Mule and White-tailed Deer

Mule deer and white-tailed deer can be told apart by their coloration, antler shape, tail, behavior, and where they live.

All species of deer use their hearing, smell, and sight to detect predators such as coyotes or cougars. They probably smell or hear the approaching predator first; then may raise their heads high and stare hard, rotating ears forward to hear better. If a deer hears or sees movement, it flees.

White-tailed Deer (*O. virginianus*)

Number in Yellowstone

Scarce

Where to see

Along streams and rivers in northern part of the park.

Behavior and Size

- Adults 150–250 pounds; 3 1/2 feet at the shoulder.
- Summer coat: red-brown; winter coat: gray-brown; throat and inside ears with whitish patches; belly, inner thighs, and underside of tail white.
- Waves tail like a white flag when fleeing.
- Males grow antlers from May until August; shed them in early to late spring.
- Mating season (rut) peaks in November; fawns born usually in late May or June.
- Eats shrubs, forbs, grasses; conifers in spring.
- Predators include wolf, coyote, cougar, bear.



Mammals: Elk

Elk (*Cervus elaphus*) are the most abundant large mammal found in Yellowstone. European American settlers used the word “elk” to describe the animal, which is the word used in Europe for moose (causing great confusion for European visitors). The Shawnee word “wapiti,” which means “white deer” or “white-rumped deer,” is another name for elk. The North American elk is considered the same species as the red deer of Europe.

Bull elk are probably the most photographed animals in Yellowstone, due to their huge antlers. Bull elk begin growing their first set of antlers when they are about one year old. Antler growth is triggered in spring by a combination of two factors: a depression of testosterone levels and lengthening daylight. The first result of this change is the casting or shedding of the previous year’s “rack.” Most bulls drop their antlers in March and April. New growth begins soon after.

Growing antlers are covered with a thick, fuzzy coating of skin commonly referred to as “velvet.” Blood flowing in the skin deposits calcium that makes the antler. Usually around early August, further hormonal changes signal the end of antler growth, and the bull begins scraping the velvet off, polishing and sharpening the antlers in the process.

The antler growing period is shortest for yearling bulls (about 90 days) and longest for healthy, mature bulls (about 140 days). Roughly 70 percent of the antler growth takes place in the last half of the period, when the antlers of a mature bull will grow 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.



A bull (adult male) elk in Yellowstone National Park.

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

Elk in Yellowstone National Park

Number in Yellowstone

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

Where to see

- Summer: Gibbon Meadows, Elk Park, and Lamar Valley.
- Autumn, during “rut” or mating season: northern range, including Mammoth Hot Springs; Madison River.
- Winter: migrate south to the Jackson Hole Elk Refuge in Jackson, Wyoming, or north to the northern range and around Gardiner, Montana; <100 year-round along the Firehole and Madison rivers.

Behavior and Size

- Male (bull) weighs about 700 pounds and is about 5 feet high at the shoulder; female (cow) weighs about 500 pounds and is slightly shorter; calf is about 30 pounds at birth.
- Average life span: 13–18 years.
- Bulls have antlers, which begin growing in the spring and usually drop in March or April.
- Feed on grasses, sedges, other herbs and shrubs, bark of aspen trees, conifer needles, burned bark, aquatic plants.
- Mating season (rut) in September and October; calves born in May to late June.

Antlers

Antlers are usually symmetrical and can occur on female elk.

- 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.

other intensely, and wrestle for dominance. While loud and extremely strenuous, fights rarely cause serious injury. The weaker bull ultimately gives up and wanders off.

Calves are born in May and June. They are brown with white spots and have little scent, providing them with good camouflage from predators. They can walk within an hour of birth, but they spend much of their first week to ten days bedded down between nursings. Soon thereafter they begin grazing with their mothers, and join a herd of other cows and calves. Up to two-thirds of each year's calves may be killed by predators. Elk calves are food for black and grizzly bears, wolves, coyotes, cougars, and golden eagles. Female elk can live 17–18 years. Rare individuals may live 22 years.

Habitat

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



A young elk calf in Yellowstone National Park.

The northern range, with more moderate temperatures and less snowfall than the park interior, can support large numbers of wintering elk. The northern Yellowstone herd is one of the largest herds of elk in the United States. The herd winters in the area of the Lamar and Yellowstone river valleys from Soda Butte to Gardiner, Montana. It also migrates outside of the park into the Gallatin National Forest and onto private lands.

Only one herd lives both winter and summer inside the park. The Madison–Firehole elk herd (less than 100 animals) has been the focus of a research study since November 1991. Researchers are examining how environmental variability effects ungulate reproduction and survival. Prior to wolf restoration, the population was naturally regulated by severe winter conditions to a degree not found in other, human-hunted elk herds. The elk are also affected by high fluoride and silica levels in the water and plants they eat, which affect enamel formation and wear out teeth quickly—thus shortening their lives. The average life span is 13 years; elk on the northern range live approximately 18 years. Information gained in this study will be useful in comparing unhunted and hunted elk populations.

Researchers also examined elk use of areas burned in the wildfires of 1988. They found that elk ate the bark of burned trees. Fires had altered the chemical composition of lodgepole pine bark, making it more digestible and of higher protein content than live bark. While the burned bark was not the highest quality forage for elk, it is comparable to other low-quality browse species. Researchers speculate that elk selected burned bark because it was readily available above the snow cover in winter.



Mammals: Fox

The red fox (*Vulpes vulpes*) has been documented in Yellowstone since the 1880s. In relation to other canids in the park, red foxes are the smallest. Adult foxes weigh 9–12 pounds; coyotes average 28 pounds in Yellowstone; and adult wolves weigh closer to 100 pounds. Red foxes occur in several color phases, but they are usually distinguished from coyotes by their reddish yellow coat that is somewhat darker on the back and shoulders, with black “socks” on their lower legs. “Cross” phases of the red fox (a dark cross on their shoulders) have been reported a few times in recent years near Canyon and Lamar Valley. Also, a lighter-colored red fox has been seen at higher elevations.

Foxes feed on a wide variety of animal and plant materials. Small mammals such as mice and voles, rabbits, and insects comprise the bulk of their diet. Carrion seems to be an important winter food source in some areas. The many miles of forest edge and extensive semi-open and canyon areas of the park seem to offer suitable habitat and food for foxes. They are widespread throughout the northern part of the park with somewhat patchy distribution elsewhere in the park. Foxes are more abundant than were previously thought in Yellowstone, yet they are not often seen because they are nocturnal, usually forage alone, and travel along edges of meadows and forests. During winter, foxes may increase their activity around dawn and dusk, and even sometimes in broad daylight. In late April and May, when females are nursing kits at their dens, they are sometimes more visible during daylight hours, foraging busily to get enough food for their growing offspring.

Foxes can become habituated to humans usually due to being fed. One fox in the summer of 1997 was



A fox in Yellowstone National Park.

trapped and relocated three times from the Tower Fall parking area because visitors fed it human food. The fox was relocated between 10 and 60 miles away from Tower but twice it returned. Finally the fox came to Mammoth where it was fed again and as a result was destroyed. While this story gives us interesting information about the homing instinct of fox, it also points out the importance of obeying rules to avoid inadvertently causing the death of one of Yellowstone’s animals.

A little known fact about red foxes is most of them in the lower 48 states, especially in the eastern and plains states, were introduced from Europe in the 18th and 19th centuries for fox hunts and fur farms. The foxes that survived the hunt or escaped the fur farms proliferated and headed westward. In addition to this introduced subspecies of red fox, three native subspecies exist at high elevations in the Sierra (*V. v. necator*), Cascade (*V. v. cascadenensis*), 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.

Fox in Yellowstone National Park

Number in Yellowstone

Total unknown, but not nearly as numerous as coyotes.

Where to see

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

Behavior and Size

- Adult males weigh 11–12 pounds; females weigh average 10 pounds.
- Average 43 inches long.

- Average life span: 3–7 years; up to 11 years in Yellowstone.
- In northern range, home range averages 3.75 square miles, with males having slightly larger range than females.
- Several color phases; usually red fur with white-tipped tail, dark legs; slender, long snout.
- Barks; rarely howls or sings.
- Distinguish from coyote by size, color, and bushier tail.

- Solitary, in mated pairs, or with female from previous litter.
- Prey: voles, mice, rabbits, birds, amphibians, other small animals.
- Other food: carrion and some plants.
- Killed by coyotes, wolves, mountain lions.



Foxes (right) are smaller than wolves (left) and coyotes (center).

A research project conducted between 1994–1998 determined at least two subpopulations of foxes live in the Greater Yellowstone Ecosystem. At about 7,000 feet in elevation, there seemed to be a dividing line with no geographical barriers separating these foxes. The genetic difference between these foxes was similar to mainland and island populations of foxes in Australia and their habitat use was different as well. In addition, their actual dimensions, such as ear length and hind foot length, were adapted to some degree for colder environments with deep snow and long winters.

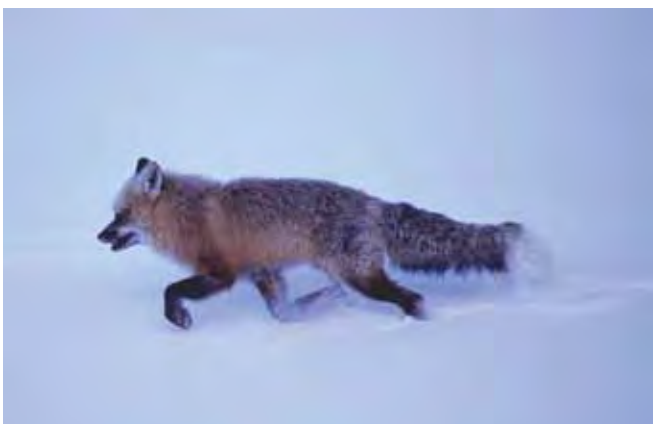
Ever since red fox sightings were first recorded in Yellowstone National Park, a novel coat color has been seen at higher elevations. This yellowish or cream color most often occurs above 7,000 feet in areas such as Cooke City and the Beartooth Plateau. Recent genetic analyses are beginning to shed light on this mysterious ‘Yellow fox of the Yellowstone,’ and new evidence is beginning to support the distinctiveness of this high elevation fox.

During the past century, especially within the past few decades, the number of fox sightings has increased greatly. This could be due to better documentation of sightings through the rare animal sighting

reports that began in 1986. In addition, an increase in visitors means more chances to see foxes. There may also be a gradual increase in the number of foxes now that the wolf has returned to Yellowstone.

Wolves and coyotes are more closely related both genetically and physically than wolves and foxes, and wolves are successfully competing with coyotes, causing a decline in the coyote population. This may have caused an increase in the number of fox sightings in core wolf areas such as the Lamar Valley.

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



A fox runs on snow in Yellowstone National Park.

Mammals: Moose



Moose (*Alces alces shirasi*) are the largest members of the deer family in Yellowstone. A male (bull) moose can weigh nearly 1,000 pounds and stand more than seven feet at the shoulder. Both sexes have long legs that enable them to wade into rivers and through deep snow, to swim, and to run fast. Despite its size, a moose can slip through the woods without a sound. Moose, especially cows with calves, are unpredictable and have chased people in the park.

Both sexes are dark brown, often with tan legs and muzzle. Bulls can be distinguished from cows by their antlers. Adults of both sexes have “bells”—a pendulous dewlap of skin and hair that dangles from the throat and has no known function.

In summer, moose eat aquatic plants like water lilies, duckweed, and burweed. But the principle staples of the moose diet are the leaves and twigs of the willow, followed by other woody browse species such as gooseberry and buffaloberry. An adult moose consumes approximately 10–12 pounds of food per day in the winter and approximately 22–26 pounds of food per day in the summer.

Some moose that summer in the park migrate in winter to lower elevations west and south of Yellowstone where willow remains exposed above the snow. But many moose move to higher elevations

(as high as 8,500 feet) to winter in mature stands of subalpine fir and Douglas-fir. Moose can also move easily in these thick fir stands because the branches prevent snow from accumulating on the ground.

Moose are solitary creatures for most of the year, except during the mating season or rut. During the rut, both bulls and cows are vocal: the cows may be heard grunting in search of a mate, and bulls challenge one another with low croaks before clashing with their antlers. A bull on the offensive tries to knock its opponent sideways. If such a move is successful, the challenger follows through with another thrust of its antlers. The weaker animal usually gives up before any serious damage is done; occasionally the opponent’s antlers inflict a mortal wound.

Bulls usually shed their antlers in late November or December, although young bulls may retain their antlers as late as March. Shedding their heavy antlers helps them conserve energy and promotes easier winter survival. In April or May, bulls begin to grow new antlers. Small bumps on each side of the forehead start to swell, then enlarge until they are knobs covered with a black fuzz (called velvet) and fed by blood that flows through a network of veins. Finally the knobs change into antlers and grow until August. The antlers are flat and palmate (shaped like a hand). Yearlings grow six to eight inch spikes; prime adult bulls usually grow the largest antlers—as wide as 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. She gives birth to one or more calves, each weighing 25–35 pounds.

A calf walks a few hours after birth and stays close to its mother. Even so, a moose calf often becomes

Moose in Yellowstone National Park

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

- Largest member of deer family.
- Adult male (bull) weighs close to 1,000 pounds; female (cow) weighs up to 900 pounds; 5 1/2 to 7 1/2 feet at the shoulder.
- Browses on willows and aquatic plants in summer; willows where available in winter or on conifers as high as 8,500 feet.

- Usually alone or in small family groups.
- Mating season peaks in late September and early October; one or two calves born in late May or June.
- Lives up to 20 years.



A moose and her calf in Yellowstone National Park.

prey for bears or wolves and less frequently for cougars or coyotes.

History

Moose were reportedly very rare in northwest Wyoming when the park was established in 1872. Subsequent protection from hunting and wolf control programs may have contributed to increased numbers. However, forest fire suppression probably was the most important factor in their population

increase because moose depend on mature fir forests for winter survival. By the 1970s, an estimated 1,000 moose inhabited the park.

The moose population declined following the fires of 1988. Many old moose died during the winter of 1988–89, probably as a combined result of the loss of good moose forage and a harsh winter. Unlike moose habitat elsewhere, northern Yellowstone does not have woody browse species that will come in quickly after a fire and extend above the snowpack to provide winter food. Therefore, the overall effect of the fires was probably detrimental to moose populations. Their current population and distribution are unknown.

Today, moose are most likely seen in the park's southwestern corner and in the Soda Butte Creek, Pelican Creek, Lewis River, and Gallatin River drainages.



Mammals: Pronghorn

The North American pronghorn (*Antilocapra americana*) is not a true antelope, which are found in Africa and southeast Asia. The pronghorn is the surviving member of a group of animals that evolved in North America during the past 20 million years. Use of the term “antelope” seems to have originated when the first written description of the animal was made during the 1804–1806 Lewis and Clark Expedition.

The pronghorn has true horns, similar to bison and bighorn sheep. The horns are made of modified, fused hair that grows over permanent bony cores, but they differ from those of other horned animals in two major ways: the sheaths are shed and grown every year and they are pronged. (A number of other horned mammals occasionally shed their horns, but not annually.) Adult males (bucks) typically have 10–16 inch horns that are curved at the tips. About 70 percent of the females (does) also have horns, but they average 1–2 inches long and are not pronged. The males usually shed the horny sheaths in November or December and begin growing the next year’s set in February or March. The horns reach maximum development in August or September. Females shed and regrow their horns at various times.

Pronghorn are easy to distinguish from the park’s other ungulates. Their deer-like bodies are reddish-tan on the back and white underneath, with a large white rump patch. Their eyes are very large, which provides a large field of vision. Males also have a



A pronghorn in Yellowstone National Park.

black cheek patch.

Females that bred the previous fall commonly deliver a set of twins in May or June. The newborn fawns are a uniform grayish-brown and weigh 6–9 pounds. They can walk within 30 minutes of birth and are capable of outrunning a human in a couple of days. The young normally stay hidden in the vegetation while the mother grazes close by. After the fawns turn three weeks old 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 National Park

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 several miles at 65 mph.
- Eat sagebrush and other shrubs, forbs, some grasses.
- Both sexes have horns; males are pronged.

History

- Prior to European American settlement of the West, pronghorn population estimated to be 35 million.
- Early in the 19th century, pronghorn abundant in river valleys radiating from Yellowstone; settlement and hunting reduced their range and numbers.

- Park management also culled pronghorn during the first half of the 20th century due to overgrazing concerns.

Research Concerns

- Pronghorn are designated species of special concern in the park.
- During 1991–1995, the population dropped approximately 50%; possible causes include predation and loss of winter range.
- This small population could face extirpation from random catastrophic events such as a severe winter or disease outbreak.

signaling the others to flee. The pronghorn is adapted well for outrunning its enemies—its oversized windpipe and heart allow large amounts of oxygen and blood to be carried to and from its unusually large lungs. Pronghorn can sustain sprints of 45–50 mph. Such speed, together with keen vision, make the adults difficult prey for any natural predator. Fawns, however, can be caught by coyotes, bobcats, wolves, bears, and golden eagles.

The pronghorn breeding season begins mid-September and extends through early October. During the rut the older males “defend” groups of females (called a harem). They warn any intruding males with loud snorts and wheezing coughs. If this behavior does not scare off the opponent, a fight may erupt. The contenders slowly approach one another until their horns meet, then they twist and shove each other. Eventually, the weaker individual will retreat. Although the fights may be bloody, fatalities are rare.

The most important winter foods are shrubs like sagebrush and rabbitbrush; they eat succulent forbs during spring and summer. They can eat lichens and plants like locoweed, lupine, and poisonvetch that are toxic to some ungulates. Their large liver (proportionately, almost twice the size of a domestic sheep’s liver) may be able to remove plant toxins from the blood stream. Grasses appear to be the least-used food item, but may be eaten during early spring when the young and tender shoots are especially nutritious.

During winter, pronghorn form mixed-sex and-age herds. In spring, they split into smaller bands of females, bachelor groups of males between 1–5 years old, and solitary older males. The small nursery and bachelor herds may forage within home ranges of 1,000 to 3,000 acres while solitary males

roam smaller territories (60 to 1,000 acres in size). Pronghorn, including three-fourths of the individuals in Yellowstone, migrate between different winter and summer ranges to more fully utilize forage within broad geographic areas.

History

During the early part of the 19th century, pronghorns ranked second only to bison in numbers, with an estimated 35 million throughout the West. The herds were soon decimated by conversion of rangeland to cropland, professional hunters who sold the meat, and ranchers who believed that pronghorns were competing with livestock for forage. Today, due to transplant programs and careful management, pronghorns again roam the sagebrush prairies in herds totaling nearly 500 thousand animals.

Pronghorn in Yellowstone have not fared as well. The park’s pronghorn population declined in the 1960s and again in the 1990s. Research in 1991 found that the average fawn life span that year was about 35 days and nearly all collared pronghorn fawns were apparently killed by coyotes. This mortality rate closely followed the decline in total fawn numbers measured during weekly surveys of the entire park. In 1999 another cooperative study was initiated to determine fawn productivity and mortality rates. Other factors include declining amount and quality of winter range as private lands are taken out of agriculture.

Research continues to search for answers to the population decline. This small population is susceptible to extirpation from random catastrophic events such as a severe winter or disease outbreak.

Mammals: Wolf

Wolves ranged widely throughout North America in pre-Columbian times. Worldwide, all wolves, except the red wolf (*Canis rufus*) of the southeastern United States, are the same species (*Canis lupus*).

Wolves are highly social animals and live in packs. In Yellowstone, packs contain from 8 to 14 individuals, with some occasionally having twice that number. Pack size varies based on the size of its main prey. The pack is a complex social family, with leaders (the alpha male and alpha female) and subordinates, each having individual personality traits and roles in the pack. Packs generally command territory that they mark by urine scenting and defend against intrusion by other wolves (individuals or packs).

Wolves consume a wide variety of prey, large and small. They efficiently hunt large prey that other predators cannot usually kill. They also compete with coyotes (and, to a lesser extent, foxes) for smaller prey. In Yellowstone, 90 percent of their winter prey is elk; 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 25 percent. That ratio reversed from 2001 to 2007. Scientists are examining why this happened and what



A wolf in Yellowstone National Park.

it means. They know that bull elk are entering winter in worse condition than before. Therefore, bulls are easier to kill than before, and one bull provides much more meat than one calf or cow.

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

Population

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

Disease periodically kills a number of pups. The first serious outbreak was 1999, then six years later in 2005. That year, distemper killed two-thirds of the pups. The next outbreak was just three years later, in 2008, when all but 22 of the pups died. This

Wolf in Yellowstone National Park

Number in Yellowstone

- 400–450 wolves in the greater Yellowstone area.
- In December 2011, there were 98 wolves counted in the park, 38 in the northern range, and 60 in the interior. Ten packs and eight breeding pairs were noted.

Where to see

- They inhabit most of the park now, look at dawn and dusk.

Behavior & Size

- 26–36 inches high at the shoulder, 4–6 feet long from nose to tail tip; males weigh 100–130 pounds,

females weigh 80–110 pounds.

- Home range 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.

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.

shortened interval concerns scientists. Infectious canine hepatitis, canine parvovirus, and sarcopic mange also have been confirmed among adult wolves, but their effect on mortality is unknown.

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

History

In the 1800s, westward expansion brought settlers and their livestock into direct contact with native predator and prey species. Much of the wolves' prey base was destroyed as agriculture flourished. With the prey base removed, wolves began to prey on domestic stock, which resulted in humans eliminating wolves from most of their historic range. (Other predators such as bears, cougars, and coyotes were also killed to protect livestock and "more desirable" wildlife species, such as deer and elk.) By the mid 20th century, wolves had been almost entirely eliminated from the 48 states.

Today, it is difficult for many people to understand why early park managers would have participated in the extermination of wolves. After all, the Yellowstone National Park Act of 1872 stated that the Secretary of the Interior "shall provide against the wanton destruction of the fish and game found within said Park." But this was an era before people, including many biologists, understood the concepts of ecosystem and the interconnectedness of species. At the time, the wolves' habit of killing prey species was considered "wanton destruction" of the animals. Between 1914 and 1926, at least 136 wolves were killed in the park; by the 1940s, wolves were rarely reported.

In the 1960s, National Park Service wildlife management policy changed to allow populations to manage themselves. Many suggested at the time that for

such regulation to succeed, the wolf had to be a part of the picture.

Also in the 1960s and 1970s, national awareness of environmental issues and consequences led to the passage of many laws designed to correct the mistakes of the past and help prevent similar mistakes in the future. One such law was the Endangered Species Act, passed in 1973. The U.S. Fish and Wildlife Service is required by this law to restore endangered species that have been eliminated, if possible. (National Park Service policy also calls for restoration of native species where possible.)

Wolves and Humans

Wolves are not normally a danger to humans, unless humans habituate them by providing them with food. No wolf has attacked a human in Yellowstone, but a few attacks have occurred in other places.

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.

Birds

Records of bird sightings have been kept in Yellowstone since its establishment in 1872; these records document 322 species of birds to date, of which approximately 148 species are known to nest in the park. This is remarkable considering the harsh conditions of the park. For many decades, the Yellowstone National Park Bird Program focused on monitoring bird species on or close to being added to the federal list of endangered species. That focus continues; plus the program is studying how two environmental changes are affecting birds: the invasion of lake trout into Yellowstone Lake and global climate change.

Birds: Raptors (birds of prey)

More than a dozen raptor species can be seen in Yellowstone. Three—peregrine falcons, bald eagles, osprey—are carefully monitored. The falcon and eagle were formerly on the federal list of endangered and threatened species. Their monitoring is required by law. The fish-eating osprey is being monitored because it is especially vulnerable as the cutthroat trout declines in Yellowstone Lake. Detailed information on all three species follows.

Yellowstone Raptor Initiative

The Yellowstone Raptor Initiative (YRI), a new research-based program, focuses on diurnal and nocturnal raptors. The YRI conducts inventories and monitoring of select raptor species to provide baseline information on breeding, abundance, and seasonal movements. The YRI complements the Yellowstone National Park Bird Program (YNP-BP) that monitors bald eagles, ospreys, and peregrine falcons.

Yellowstone supports twelve diurnal and seven nocturnal breeding raptor species. Additional species use the Yellowstone landscape during migrations and seasonal movements. Despite Yellowstone's raptor diversity, large relatively undisturbed landscape, and heightened conservation emphasis on several species, little information exists on population size, productivity, and seasonal movements other than for the raptors monitored by the YNP-BP. Golden eagles, Swainson's hawks and ferruginous hawks merit conservation concern throughout their ranges in North America.

The YRI has selected golden eagles, red-tailed hawks, Swainson's hawks, American kestrels, prairie falcons, and owls as focal species. Research goals



Park biologists invite visitors to participate in the Yellowstone Raptor Initiative by reporting any birds of prey they see, such as this young American kestrel. The report forms are available at visitor centers.

include obtaining estimates of population size and reproductive success. Because the YRI relies on citizen science to acquire valuable data on raptors in the park, raptor observation forms are available at all visitor centers and ranger stations for employee and visitor sightings. Handbooks of raptor photos and identification tips are available at all visitor centers and ranger stations.

Birds: 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, such as 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.

Trumpeter swan

This species is probably most imperiled in Yellowstone National Park. Longterm monitoring, research, and management continue.

Common loon

The park's loon population is one of the most southerly breeding populations in North America and one of the only populations breeding in Wyoming. (It is also the largest loon population in Wyoming.) Since 1987, park scientists have collected data on common loon nesting.

Colonial nesting birds (American white pelican, double-crested cormorant, Caspian tern, California gull)

These birds nest primarily on the Molly Islands in the southeast arm of Yellowstone Lake. They have been surveyed for more than 30 years, with some data going back to 1890. Currently, only the pelicans and cormorants are nesting, with low success rates. Very wet and cold late spring weather and the declining cutthroat trout population could be factors.

Songbirds and Woodpeckers

Songbirds and woodpeckers 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

Willow growth has increased in some parts of the park's northern range, for reasons still being studied. Scientists are studying how this growth might be affecting songbirds that use this habitat. They set up study plots in willow areas that are "previously tall," where the willows have "released" (grown much

taller recently), and still suppressed. So far, many bird species are using the willow communities in almost equal abundance. However, a few species—willow flycatcher, Wilson's warbler and MacGillivray's warbler—may be colonizing the newer stands.

Breeding Bird Survey (BBS)

Yellowstone National Park participates in these longterm surveys conducted throughout North America. They 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 2010, surveyors detected 2,079 individuals of 75 different species. The Mammoth route had the highest diversity of species, while the interior route had the highest number of individuals counted. The Northeast route had the lowest diversity of species and lowest number of individuals counted. Initial inspection of the data showed that cliff swallows and vesper sparrows were fewer, for unknown reasons. Identifying such trends is a primary goal of the BBS.

Forest Burn Survey

Birds that nest in cavities depend on forest fires to provide their habitat—and different species depend on different forest fire effects. For example, black-backed woodpeckers use trees that burned low to moderately severe fires for the first few years after the fire; northern flickers move into severely burned areas three years after a severe burn. The nest cavities

Bird in Yellowstone National Park

Number in Yellowstone

322 bird species have been documented in Yellowstone.

Approximately 148 of these species nest in the park.

Species of Concern

- The peregrine falcon nests here. Formerly an endangered species, it was delisted in 1999.
- The bald eagle nests here. Formerly a threatened species, it was delisted in 2007.
- One endangered bird species previously occurred in the greater Yellowstone area: the whooping crane.

- Species monitored: peregrine falcons, bald eagles, osprey, trumpeter swans, loons, colonial nesting birds (American white pelicans, double-breasted cormorants, Caspian terns), songbirds, woodpeckers

Current Management

The Yellowstone National Park Bird Program focuses on three broad programs to monitor the park's diversity of bird species: raptors (birds of prey), wetland birds, and songbirds & woodpeckers. Scientists monitor nesting of the species listed at left to gather natural history data and to identify trends. They also are researching

the effects of climate change on songbirds and cavity-nesting birds. And scientists and interpretive rangers are collaborating on a new Raptor Initiative.

Collaborations

- Partners in Flight, an international program monitoring migrant land birds in the Americas
- U.S. Fish & Wildlife Service
- U.S. Geological Survey
- Montana State and Eastern Kentucky universities
- States of Wyoming & Montana

Watching Birds 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 rough-legged hawks and bohemian waxwings, migrate here for the winter.

CAUTION: Using audio bird calls is illegal in the park.

by these and other woodpeckers are used later by chickadees, nuthatches, and bluebirds. Because fire frequency 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.

Species Descriptions

Brief descriptions of some of Yellowstone's significant bird species follow.

Peregrine Falcon (*Falco peregrinus*)

In 1962, Rachel L. Carson sounded an alarm about the irresponsible use of pesticides with her landmark book, *Silent Spring*. Among the dangers she described were the adverse effects of chemicals—particularly DDT—on the reproductive capacity of some birds, especially predatory species such as the bald eagle and peregrine falcon. Her book raised public awareness of this issue, and was one of the catalysts leading to the United States banning the most damaging pesticides.

The peregrine falcon was among the birds most affected by the toxins. It was listed on the endangered species list. Yellowstone National Park was a site for peregrine reintroductions in the 1980s, which were discontinued when the peregrine population began increasing on its own. 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.

Yellowstone National Park's relatively pristine conditions and long-term monitoring of peregrines

provides baseline information to compare against other U.S. populations. Continued monitoring is essential, not only for comparisons with other populations, but also because peregrine falcons and other raptors are reliable indicators of 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.

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.



A peregrine falcon in Yellowstone National Park.

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.
- Migrates to South America.
- Dives at high speeds (can exceed 200 mph) and strikes prey in mid-air.

2011 Status

- From April to July, biologists monitored 25 eyries in Yellowstone.
- 19 were occupied by at least one adult.
- Nesting occurred in 12 eyries; 11 pairs raised 21 young.

Bald Eagle (*Haliaeetus leucocephalus*)

Monitored since the 1980s, when the bald eagle was placed on the federal list of threatened species, Yellowstone's population of bald eagles is relatively stable. In 2007, it was removed from the federal threatened species list, and monitoring continues. Each year, 40 to 60 percent of nests succeed (produce eggs), with each successful nest producing an average of 1.42 eaglets. These statistics are slightly lower than expected for a stable and healthy population, and may be explained by the park's harsh environment, especially during the early breeding season (February–April), and the declining cutthroat trout population in Yellowstone Lake.



A bald eagle in Yellowstone National Park.

Identification

- Large, dark bird; adult (four or five years old) has completely white head and tail.
- Females larger than males, as is true with most predatory birds.
- Immature bald eagles show varying amounts of white; they can be mistaken for golden eagles.

Habitat

Habitat can be a clue to which eagle you are seeing:

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

Behavior

- Bald eagles nest in large trees close to water.
- In severe winters, eagles may move to lower elevations such as Paradise Valley, north of the park, where food is more available. On these wintering areas, resident eagles may be joined by migrant bald eagles and golden eagles.
- Feed primarily on fish and waterfowl, except in winter.
- In winter, when fish stay deeper in water, they eat more waterfowl.
- Eat carrion in winter if it is readily available.
- Form long-term pair bonds.
- Some remain on their territories year-round, while others return to their nesting sites by late winter.
- Two to three eggs (usually two) laid from February to mid-April.
- Both adults incubate the eggs, which hatch in 34 to 36 days.
- At birth, eaglets are immobile, downy, have their eyes open, and are completely dependent upon their parents for food.
- When 10–14 weeks old, they can fly from the nest.
- Some young migrate in fall to western Oregon and Washington.
- Many adults stay in the park year-round.

2011 Status

- Some eagle territories are experiencing nest instability due to large numbers of trees that are falling as a result of the 1988 fires.
- In 2011, 17 pairs of eagles nested in the park; 10

of these pairs raised 13 young.

- Although the population is relatively stable parkwide, few of the nests in the Yellowstone Lake area succeeded.
- Bald eagles, like osprey, are among the fish-eating wildlife being monitored to determine any effect from the declining cutthroat trout population.

Osprey (*Pandion haliaeetus*)

Like many other birds of prey, osprey populations declined due to pesticides in the mid-20th century. Its populations rebounded during the latter part of the 20th century. Monitored since the late 1980s, Yellowstone's population of osprey is considered relatively stable. On average, 50 percent of nests succeed (produce eggs) each year, with each successful nest producing an average of one young. These statistics are slightly lower than expected for a stable and healthy population, and may be explained by the park's harsh environment. As with bald eagles, scientists suspect that declining nest success for osprey around Yellowstone Lake is due, in part, to the decline of cutthroat trout.

Identification

- Slightly smaller than bald eagle.
- Mostly white belly, white head with dark streak through eye.
- Narrow wings with dark patch at bend.

Habitat

- Usually near lakes (such as Yellowstone Lake), river valleys (such as Hayden and Lamar valleys), and in river canyons (such as the Gardner Canyon and the Grand Canyon of the Yellowstone River).

Behavior

- Generally returns to Yellowstone in April & leaves in September.
- Builds nest of sticks in large trees or on pinacles 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.



USFWS/STEVE HILLEBRAND

An osprey in Yellowstone National Park.

2011 Status

- In Yellowstone, the osprey population fluctuates, with 31 nests producing 25 young in 2007 and a high of 100 nests and 101 fledglings in 1994.
- Overall, osprey reproduction has increased each year since 2003.
- In 2011, osprey occupied 26 nests; 13 of these breeding pairs successfully fledged 24 young. However, none of the nests in the Yellowstone Lake area succeeded.
- Osprey in Yellowstone are being monitored, along with other fish-eating wildlife, to find out if they are affected by the declining population of cutthroat trout.

Trumpeter Swan (*Cygnus buccinator*)

Trumpeter swans in North America neared extirpation in the early 1900s due to human encroachment, habitat destruction, and the commercial swan-skin trade. Small populations survived in isolated areas such as Yellowstone. Red Rock Lakes National Wildlife Refuge, west of the park, was set aside in the 1930s specifically for this species. In the 1950s, a sizeable population of swans was discovered in Alaska. Today, more than 46,200 trumpeters exist in North America. Their population in the Greater Yellowstone area (GYA) is considered stable, but the park's population is declining. In recent years, fewer than 10 swans have lived here year-round. Winter numbers vary from 60 to several hundred. Reproduction rates are low. Scientists suspect that several factors are contributing to this decline:

- loss of wetlands during an extended drought in the late 20th and early 21st centuries
- fewer trumpeter swans taking up residence in the park



A trumpeter swan in Yellowstone National Park.

- competition with swans that migrate to the park for the winter
- increased predation by coyotes & wolves

Information on the GYA resident swan and wintering swan populations dates back to 1931 and 1971, respectively. 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).

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.

Identification

- Largest wild fowl in North America.
- White feathers, black bill with a pink streak at the base of the upper mandible.

- During migration, can be confused with the tundra swan, which is smaller, 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: in 2007, 2009, and 2010, no cygnets fledged.
- Can fail to hatch eggs if disturbed by humans.
- Lay 4–6 eggs in June; cygnets fledge in late September or early October.
- Usually in pairs with cygnets in summer; larger groups in winter.

2011 Status

- Trumpeter swans are increasing in the Rocky Mountain region, stable in the Greater Yellowstone Ecosystem, but declining in Yellowstone National Park.
- Winter population in the region varies from 2,000–4,000; in the park, varies from fewer than one hundred to several hundred.
- There was no swan reproduction in 2011.
- 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.

Other Bird Species in Yellowstone National Park



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.



Sandhill cranes nest in Yellowstone each summer. Their guttural calls announce their presence long before most people see them. Their gray feathers blend in well with their grassland habitat. The all-white whooping crane, one of the world's most endangered birds, was the subject of recovery efforts in the Greater Yellowstone Ecosystem from 1975 until 2002. The last remaining whooping crane frequented the Centennial Valley of Montana (west of Yellowstone National Park). It was declared dead in the spring of 2002, marking the end of the experimental recovery efforts in Greater Yellowstone.



Ravens frequent parking lots, and have learned to unzip and unsnap packs. Some ravens have learned to follow wolves during hunts. They wait in trees or on the ground, until wolves finish at a carcass.



The dark gray American dipper 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 preening gland enable this bird to survive cold waters.



Several raven relatives live in Yellowstone, including the black-billed magpie. Like the raven, they often show up where people are eating. Do not feed them.



Cutthroat trout spawn in the Lamar Valley.

COURTESY JAY FLEMMING

Fish

Yellowstone contains one of the most significant, near-pristine aquatic ecosystems found in the United States. More than 600 lakes and ponds comprise approximately 107,000 surface acres in Yellowstone —94 percent of which can be attributed

to Yellowstone, Lewis, Shoshone, and Heart lakes. Some 1,000 rivers and streams make up approximately 2,500 miles of running water.

This may appear to be prime fish habitat, but waterfalls and other physical barriers prevent fish from colonizing the smaller headwater streams and isolated lakes. When Yellowstone became a national

Fish in Yellowstone National Park

Number in Yellowstone

- Native species: 11
 - 3 sport fish: cutthroat trout (two subspecies), Arctic grayling, mountain whitefish
 - 8 non-game fish: 4 minnows: longnose dace, speckled dace, redbreast shiner, Utah chub; 3 suckers: longnose sucker, mountain sucker, Utah sucker; mottled sculpin
- Non-native species: 5 brook trout, brown trout, lake trout, rainbow trout, lake chub

History

- When the park was established, many of its waters were fishless.
- Park waters were stocked with native and non-native fish until the

mid-1950s.

- Stocking changed the ecology of many Yellowstone waters as non-native fish displaced or interbred with native species.

Status

- By the 1960s, Yellowstone's trout populations were in poor condition and the angling experience had declined.
- By the late 1980s, native trout had recovered in some areas due to restrictions in fish harvest.
- In 2001, fishing regulations changed to require the release of all native fishes caught in park waters.
- Both subspecies of cutthroat trout are considered to be species at risk.

- Threats to the fisheries:

- Lake trout illegally introduced into Yellowstone Lake and its tributaries.
- Whirling disease now present in Yellowstone Lake, the Yellowstone and Firehole rivers, and Pelican Creek.
- New Zealand mud snails.
- Competition and hybridization with non-native rainbow trout (Slough Creek) and brook trout (Soda Butte Creek).

park, approximately 40 percent of its waters were barren of fish—including Lewis Lake, Shoshone Lake, and the Firehole River above Firehole Falls. That soon changed.

Early park managers transplanted fish into new locations, produced more fish in hatcheries, and introduced non-native species. Today, about 40 lakes have fish; the others either were not planted or have reverted to their original fishless condition.

The ranges and densities of the park's native trout and grayling were substantially altered during the 20th century due to exploitation and introduction of non-native species. Non-native species in the park include rainbow trout, brown trout, brook trout, lake trout, and lake chub.

Despite changes in species composition and distribution, large-scale habitat degradation has not occurred. Water diversions, water pollution, and other such impacts on aquatic ecosystems have rarely occurred here. Consequently, fish and other aquatic inhabitants continue to provide important food for grizzly and black bears, bald eagles, river otters, mink, ospreys, pelicans, loons, grebes, mergansers, ducks, terns, gulls, kingfishers, and herons.

The U.S. Fish and Wildlife Service maintained an aquatic research and monitoring program in the park until 1996. Since then, National Park Service fisheries managers have focused on the same objectives: to manage aquatic resources as an important part of the park ecosystem, preserve and restore native fishes and their habitats, and provide anglers with the opportunity to fish for wild fish in a natural setting.

Fishing in Yellowstone National Park

About 75,000 of the park's three million visitors fish each year. Angling is an anomaly in a park where the primary purpose is to preserve natural environments and native species in ways that maintain natural conditions. Yet fishing has been a major visitor activity here for more than 100 years. Fishing is a major industry in the Greater Yellowstone Ecosystem, and park anglers spend more than \$4 million annually on their sport. Angler groups have supported management actions, such as closing the Fishing Bridge to fishing in the early 1970s, and have helped fund research on aquatic systems.

Observing fish in their natural habitat is also a popular activity for visitors. In the 1980s and 1990s, fisheries biologists monitored non-consumptive use of aquatic resources for about a decade at Fishing Bridge and LeHardys Rapids. In 1994, approximately

Whirling Disease

Whirling disease is a parasitic infection of fish caused by a microscopic protozoan that destroys the cartilage of juvenile trout. Seriously infected fish have a reduced ability to feed or escape from predators and mortality is high.

176,400 visitors watched fish at LeHardys Rapids, where spawning cutthroat can be observed jumping the rapids. At Fishing Bridge, approximately 167,000 people watched cutthroat trout in the waters below the bridge.

Fishing Regulations

Strict regulations allow ecological processes to function with minimal interference from humans and preserve fish populations for the animals that depend on them. Complete regulations are at all ranger stations and visitor centers. In summary:

- Fishing is allowed only during certain seasons (usually late May through early November).
- A permit is required (revenue stays in the park to support park programs).
- Terminal tackle must be lead-free (lead poisoning is a serious threat to waterfowl).
- All native sport fish—cutthroat trout, Arctic grayling, and mountain whitefish—must be released.
- Lake trout must be killed if caught in Yellowstone Lake and its tributaries.
- Certain waters may be closed to protect rare or endangered species, nesting birds, or to provide undisturbed vistas.
- To protect fish, park waters may be temporarily closed to fishing when water levels are low and water temperatures are high.

Changes in Yellowstone Waters

- Historically, only Yellowstone cutthroat trout and longnose dace populated Yellowstone Lake. Today, these two species are still present, but the longnose sucker, lake chub, redbelly shiner, and lake trout have been introduced into the lake.
- Most of the Firehole River historically was fishless because Firehole Falls blocked fish from moving upstream. Today, anglers can fish for rainbow trout, brown trout, brook trout, and Yellowstone cutthroat trout in the thermally influenced stream and its tributaries.

- Historically, the Madison and Gibbon rivers (below Gibbon Falls) were inhabited by west-slope cutthroat trout, Arctic grayling, mountain whitefish, mottled sculpin, mountain sucker, and longnose dace. Today, some of those species survive (some in extremely depleted numbers) and brown trout, rainbow trout, and brook trout have been added to the mix.
- When Heart Lake was first sampled for fish, Yellowstone cutthroat trout, mountain whitefish, speckled dace, redbreasted shiner, Utah sucker, Utah chub, and the mottled sculpin were found. Lake trout are now present.
- Lewis and Shoshone lakes were historically fishless because of waterfalls on the Lewis River. Today, the lakes support lake trout, brown trout, brook trout, Utah chub, and redbreasted shiner.
- The lower Lamar River and Soda Butte Creek historically were home to Yellowstone cutthroat trout, longnose dace, longnose sucker, and mountain sucker. Today, those species persist, but native trout are threatened by hybridization with rainbow trout and competition with brook trout.

Fish: Species Descriptions

Cutthroat Trout (*Oncorhynchus clarkii*)

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

Yellowstone Cutthroat Trout (*Oncorhynchus clarkii bouvieri*)

- Includes two forms of the same subspecies: Yellowstone cutthroat (large spotted form) Snake River cutthroat (fine spotted form)
- Yellowstone cutthroat is native to the Yellowstone River, its tributaries, the Snake River, and the Falls River.
- Snake River cutthroat is native to Snake River drainage in and beyond Yellowstone and Grand Teton national parks.
- Require cold, clean water in streams or lakes.
- Spawn in rivers or streams in early May

through mid-July.

- Most important foods are aquatic insects — mayflies, stoneflies, caddisflies, etc.—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.

While the Yellowstone cutthroat trout is historically a Pacific drainage species, it has (naturally) traveled across the Continental Divide into the Atlantic drainage. One possible such passage in the Yellowstone area is Two Ocean Pass, south of the park in the Teton Wilderness. Here, it's possible for a fish to swim across the Continental Divide at the headwaters of Pacific Creek and Atlantic Creek and, thus, swim from the Pacific to the Atlantic watersheds and vice versa.

Management

Yellowstone Lake and Yellowstone River together contain the largest inland population of cutthroat trout in the world. For many years, the fish in Yellowstone Lake have been intensively monitored and studied. In the 1960s, fisheries managers determined that angler harvest was excessive and negatively impacting the fishery. Increasingly restrictive angling regulations were put into place, which helped restore cutthroat trout population numbers and age structure. Whirling disease and illegally introduced lake trout in Yellowstone Lake now pose a serious threat to the cutthroat trout population.

Westslope Cutthroat Trout (*Oncorhynchus clarkii lewisii*)

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

Management

This subspecies is at risk through interbreeding with non-native rainbow trout and transplanted Yellowstone cutthroat trout. Two genetically pure

populations of westslope cutthroat trout have been found in Yellowstone: Last Chance Creek, a tributary of Grayling Creek in the Madison River drainage, and the Oxbow/Geode Creek complex in the Yellowstone River drainage. An intensive effort is underway to restore westslope cutthroat trout in Specimen Creek, a tributary of the Gallatin River.

Arctic Grayling (*Thymallus arcticus montanus*)

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

Management

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

Mountain Whitefish (*Prosopium williamsoni*)

- Slender silver fish, sometimes confused with grayling.
- Lives in Yellowstone's rivers and streams.
- Requires deep pools, clear and clean water, and is very sensitive to pollution.
- Unlike other native fish, the whitefish spawns in the fall.
- Generally feeds along the bottom, eating aquatic insect larvae.
- Compete with trout for the same food.
- The whitefish has persisted in its native waters, unlike grayling.

Fish: Native Nongame Fish

Suckers

- Bottom-dwelling fish that use ridges on their jaws to scrape flora and fauna from rocks.
- Eaten by birds, bears, otters, and large cutthroat trout.
- Habitat distinguishes species:
 - Mountain sucker (*Catostomus*



COURTESY JAY FLEMING

Volunteer Angler Report 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.

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.

Mottled sculpin (*Cottus bairdi*)

- Lives in shallow, cold water throughout Yellowstone except in the Yellowstone River above Lower Falls and in Yellowstone Lake.
- Eats small insects, some fish and plants.
- Eaten by trout.

Minnows

- Small fish living in a variety of habitats and eating a variety of foods.
- All four species eaten by trout.
 - Utah chub (*Gila atratria*): Largest of the minnows (12 inches); native to Snake River drainage; seems to prefer slow, warm waters with abundant aquatic vegetation.
 - Longnose dace (*Rhinichthys cataractae*): Most often found behind rocks and in eddies of cold, clear waters of the Yellowstone and Snake river drainages.
 - Redside shiner (*Richardsonius balteatus*): Minnow of lakes; native to the Snake River drainage; has been introduced to Yellowstone Lake, where it might compete with native trout because its diet is similar to that of young trout.
 - Speckled dace (*Rhinichthys osculus*): Lives in the Snake River drainage.



Blotched tiger salamander in the Elk Creek drainage

Reptiles and Amphibians

Yellowstone is home for a small variety of reptiles and amphibians. Glacial activity and current cool and dry conditions are likely responsible for their relatively low species diversity. However, they are widespread in the park and often abundant at breeding or wintering sites.

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

Yellowstone provides a valuable study area; information about the status and trends of amphibians and reptiles here may shed light on declines documented in other high-elevation protected areas of the western U.S. Population declines may be caused by factors such as disease, drought or climate change, chemical contamination, non-native species, and habitat loss and fragmentation. In addition, because many amphibians and reptiles congregate to breed or overwinter, they can be adversely affected by disturbance or loss of key sites.

Reptiles and Amphibians in Yellowstone National Park

Number in Yellowstone

- Reptiles, six species: prairie rattlesnake, bull snake, valley garter snake, wandering garter snake, rubber boa, sagebrush lizard.
- Amphibians, four species: boreal toad, boreal chorus frog, Columbia spotted frog, tiger salamander.

Current Research

- 2000: Researchers begin inventorying reptiles and

amphibians.

- 2004: NPS Greater Yellowstone Network selects amphibian occurrence as a Vital Sign for monitoring ecosystem health.
- 2006: Long-term, Vital Sign amphibian monitoring begins in Yellowstone.

Status

- Spotted and chorus frogs are widely distributed with many

breeding sites in the park.

- Tiger salamanders are common and abundant in some portions of the Yellowstone, such as the northern range and Hayden Valley.
- Boreal toads are abundant in some local areas.
- None of the parks reptiles or amphibians are federally listed as threatened or

endangered.

- Scientists are concerned about the boreal toad, which has declined sharply in other parts of the West.
- In 2008, a scientist reported drastically declined amphibian populations in the northern range, but the study is in question.

Updated January 2011.

Species Descriptions

Valley Garter Snake (*Thamnophis sirtalis fitchi*)

Identification

- Subspecies of the common garter snake.
- Medium sized snake up to 34 inches long.
- Nearly black background color with three bright stripes running the length of the body; underside is pale yellow or bluish gray.
- Most distinguishing characteristics of this subspecies in our region are the irregular red spots along the sides.

Habitat

- Thought to be common in the past, now in decline for no apparent reason.
- Closely associated with permanent surface water.
- In Yellowstone area, observed only in the Falls River drainage in the Bechler region and three miles south of the south entrance along the Snake River.

Behavior

- Generally active during the day.
- In the Yellowstone area it eats mostly toads, chorus frogs, fish remains, and earthworms; can eat relatively poisonous species.
- Predators include fish, birds, and carnivorous mammals.

Wandering Garter Snake (*T. elegans vagrans*)



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.

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.

Rubber Boa (*Charina bottae*)

Identification

- Infrequently encountered in Yellowstone, perhaps due to its nocturnal and burrowing habits.
- One of two species of snakes in the United States related to tropical boa constrictors and pythons.

- Maximum length of 24 inches.
- Back is gray or greenish-brown, belly is lemon yellow; scales are small and smooth, making it almost velvety to the touch.

Habitat and Behavior

- Eats rodents.
- May spend great deal of time partially buried under leaves and soil, and in rodent burrows.
- Usually found in rocky areas near streams or rivers, with shrubs or trees nearby.
- Recent sightings have occurred in the Bechler region and Gibbon Meadows.

Prairie Rattlesnake (*Crotalis viridis viridis*)

Identification

- 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.

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.

Reptiles and Amphibians

Both reptiles and amphibians are ectothermic ("cold-blooded"), meaning they derive body heat from outside sources rather than generate it internally. Reptiles have scaly, dry skin. Some lay eggs; others bear live young. Amphibians have thin, moist glandular skin permeable to water and gases. The young must pass through a larval stage before changing into adults. Amphibious means "double life" and reflects the fact that salamanders, toads, and frogs live in water as larvae and on land for much of the rest of their lives.

In Yellowstone

In the winter in Yellowstone, some amphibians go into water that does not freeze (spotted frogs), others enter underground burrows (salamanders and toads), and others (boreal chorus frog) actually tolerate freezing and go into a heart-stopped dormancy for the winter in leaf litter or under woody debris.

Toad or Frog?

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

- Eaten by bull snakes, wandering garter snakes, rattlesnakes, and some birds.
- May shed tail when threatened or grabbed.

Blotched Tiger Salamander (*Ambystoma tigrinum melanostictum*)



JEFF ARNOLD

Identification

- The only salamander in Yellowstone.
- Adults range up to about 9 inches, including the tail.
- Head is broad, with a wide mouth.
- Color ranges from light olive or brown to nearly black, often with yellow blotches or streaks on back and sides; belly is dull lemon yellow with irregular black spots.
- Larvae, which are aquatic, have a uniform color and large feathery gills behind the head; they can reach sizes comparable to adults but are considerably heavier.

Habitat

- Breeds in ponds and fishless lakes.
- Widespread in Yellowstone in a great variety of habitats, with sizable populations in the Lamar Valley.

Behavior

- Adult salamanders come out from hibernation in late April to June, depending on elevation, and migrate to breeding ponds where they lay their eggs.
- Mass migrations of salamanders crossing roads are sometimes encountered, particularly during or after rain.
- After migration, return to their moist homes under rocks and logs and in burrows.
- Feed on adult insects, insect nymphs and larvae, small aquatic invertebrates, frogs, tadpoles, and even small vertebrates.
- Preyed upon by a wide variety of animals,

including mammals, fish, snakes, and birds such as sandhill cranes and great blue herons.

Boreal Toad (*Bufo boreas boreas*)

Identification

- Yellowstone's only toad.
- Adults range up to about 4 inches, juveniles just metamorphosed from tadpoles are only one inch long.
- Stocky body and blunt nose.
- Brown, gray, or olive green with irregular black spots, lots of "warts," and usually a white or cream colored stripe down the back.
- Tadpoles are usually black and often congregate in large groups.

Habitat

- Once common throughout the park, now appears to be much rarer than spotted frogs and chorus frogs; scientists fear this species has experienced a decline in the 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.



COURTESY JAY FLEMING

Columbia Spotted Frog (*Rana luteiventris*)



COURTESY JAY FLEMING

Identification

- Abundant and best known amphibian in Yellowstone.
- Maximum length is 3.2 inches, newly metamorphosed juveniles less than one inch long.
- Upper surface of the adult is gray-brown to dark olive or even green, with irregular black spots; skin is bumpy; underside is white splashed with brilliant orange on the thighs and arms on many but not all individuals.
- Tadpoles have long tails and may grow to 3 inches long.

Habitat

- Found all summer along or in rivers, streams, smaller lakes, marshes, ponds, and rain pools.
- Lay eggs in stagnant or quiet water, in globular masses surrounded by jelly.

Behavior

- Breeds in May or early June, depending on temperatures.
- Tadpoles mature and change into adults between July and September.
- Tadpoles eat aquatic plants, adults mostly eat insects but are highly opportunistic in their food habits (like many other adult amphibians).

Boreal Chorus Frog (*Pseudacris maculata*)

Identification

- Adults reach 1 to 1.5 inches in length, and females are usually larger than males; newly metamorphosed juveniles are less than one inch long.

- Brown, olive, tan, or green (sometimes bi-colored) with a prominent black stripe on each side from the nostril through the eye and down the sides to the groin; three dark stripes down the back, often incomplete or broken into blotches.

Habitat

- Common, but seldom seen due to its small size and secretive habits.
- Live in moist meadows and forests near wetlands.
- Lays eggs in loose irregular clusters attached to submerged vegetation in quiet water.

Behavior

- Breeds in shallow temporary pools or ponds during the late spring.
- Calls are very conspicuous, resemble the sound of a thumb running along the teeth of a comb.
- Males call and respond, producing a loud and continuous chorus at good breeding sites, from April to early July, depending on elevation and weather.
- Usually call in late afternoon and evening.
- Tadpoles eat aquatic plants; adults mostly eat insects.
- Eaten by fish, predacious aquatic insect larvae, other amphibians, garter snakes, mammals, and birds.



COURTESY JAY FLEMING

Wildlife: Frequently Asked Questions

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 about where wildlife have been seen recently.

Where are the bears?

People who visited Yellowstone prior to the 1970s often remember seeing bears along roadsides and within developed areas of the park. Although observing these bears was very popular with park visitors, it was not good for the people or the bears. 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 viewed occasionally in the wild. Grizzly bears are active primarily at dawn, dusk, and night. In spring, they may be seen around Yellowstone Lake, Fishing Bridge, and the East Entrance due to the trout spawning creeks in these areas. In mid-summer, they are most commonly seen in the meadows between Tower–Roosevelt and Canyon, and in the Lamar Valley. Black bears are most active at dawn and dusk, and sometimes during the middle of the day. Look for black bears in open spaces within or near forested areas. Black bears are most commonly observed between Mammoth, Tower, and the Northeast Entrance.

Are grizzly bears considered threatened or endangered?

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

What is the difference between a bison and a buffalo?

In North America, both terms refer to the American bison; the scientific name is *Bison bison*. Early European explorers called this animal by many names. Historians believe that the term “buffalo” grew from the French word for beef, “boeuf.” Some people insist that the term “buffalo” is incorrect because the “true” buffalo exist on other continents and are only distant relatives. However, “buffalo” is used for less formal, everyday use; “bison” is preferred for scientific use. In this book, we use “bison.”

Where are good birding locations?

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

Hayden Valley is one of the best places to view water birds and birds of prey. Shore birds feed in the mud flats at Alum Creek. Sandhill cranes often nest in the valley. Ducks, geese, and American white pelicans cruise the river. Bald eagles and osprey hunt for fish along the river; northern harriers fly low looking for rodents in the grasses. Great gray owls are sometimes seen searching the meadows for food (these birds are sensitive to human disturbance).

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

Why is fishing lead-free in Yellowstone?

Birds, such as loons, waterfowl, cranes, and shorebirds, are vulnerable to lead poisoning. While we can do little about natural hazards, we can minimize the effects of lead on these species. Yellowstone National Park bans most lead tackle. (Terminal tackle must be lead-free; sinkers used to fish for deep-dwelling lake trout are permissible because they are too large to be ingested.)



Yellowstone National Park is as wondrous as it is complex. Here, Lewis River in winter 2000.

Park Issues

Aquatic Invaders

During the late 1880s when the Army administered Yellowstone National Park, the U.S. Fish Commission (a predecessor of today's U.S. Fish and Wildlife Service) stocked non-native fish in some park waters. These stockings comprise the first known, deliberate introductions of non-native fish to Yellowstone. Four trout species were widely introduced—brook, brown, lake, and rainbow. Rainbow trout hybridize with native cutthroat trout, thus diluting genetic diversity. All four compete with and prey upon native fish.

Other invasive aquatic species, such as the New Zealand mud snail and the microorganism causing whirling disease, probably arrived via unaware boaters and anglers carrying the organisms from other

fishing locations around the country.

Angler and boater introduction of aquatic invasive species remains a serious threat to Yellowstone's aquatic ecosystem because exotic aquatic species



New Zealand mud snails shells resting on a dime.

Aquatic Invaders

The Issue

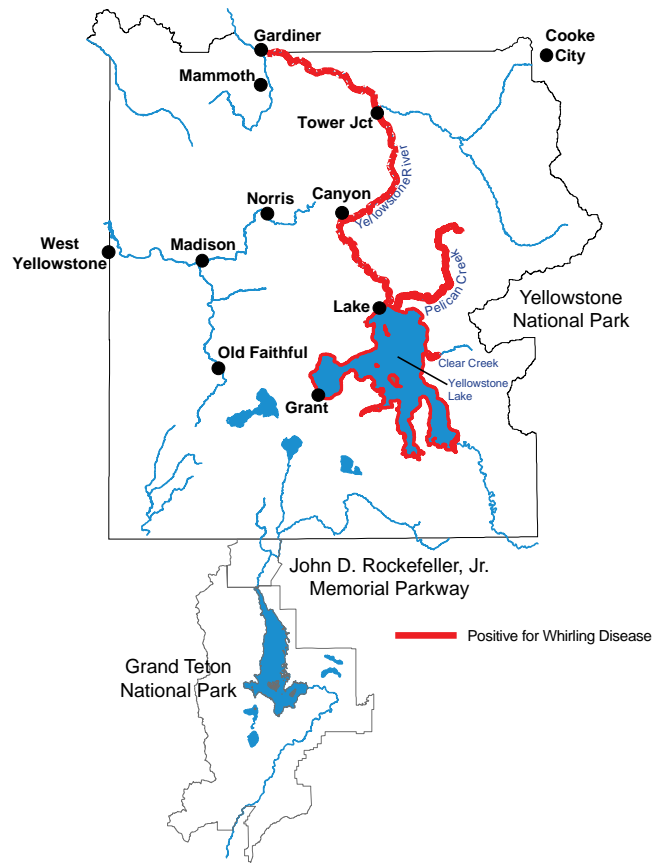
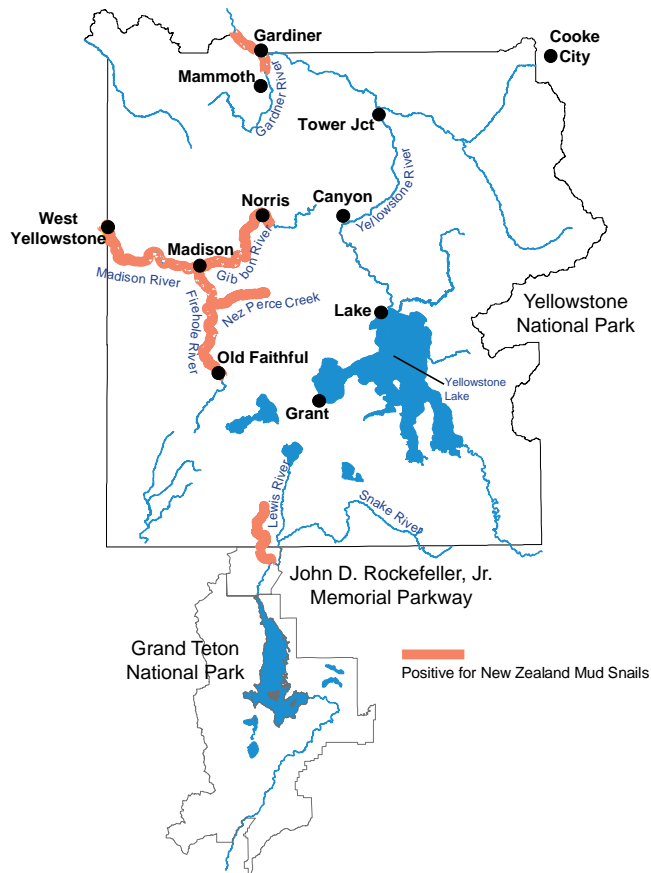
Aquatic invaders can irreversibly damage the park's ecosystems.

Current Status

- In the U.S. currently, more than 250 exotic (from another continent) aquatic species and more than 450 non-native (moved outside their natural range) aquatic species exist.
- At least 7 invasive aquatic species exist in Yellowstone's waters: two mollusks, four fish, one exotic

- disease-causing microorganism (whirling)
- Park staff continues to educate visitors about preventing the spread of aquatic invasive species.
- Read and follow the instructions provided in the fishing regulations, which include:
- Remove all plants, animals, mud, sand, and other debris from your boat and equipment.

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



Locations of New Zealand mud snails (left) and whirling disease (right) in Yellowstone National Park.

occur in waters all across the United States. We may never know exactly how whirling disease or mud snails were introduced to the park's waters, but anglers can help prevent other species from arriving.

For this reason, Yellowstone is publicizing this issue through a brochure and other information available to anglers and boaters in the park. The park's efforts join those of other agencies around the country working to protect the nation's aquatic ecosystems.

Mud Snails

About one-quarter inch long, the New Zealand mud snail forms dense colonies on aquatic vegetation and rocks along streambeds. The snails crowd out native aquatic insect communities, which are a primary food for fish. They also consume a large amount of algae, which is a primary food for native aquatic invertebrates. Strategies for dealing with this invader are being developed.

Lake Trout

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



Nonnative lake trout predate on native Yellowstone cutthroat trout. The smaller fish in photo are native Yellowstone cutthroat trout removed from lake trout stomachs.

could be an ecological disaster.

Hydroacoustic work (using sonar-based fish finders) confirmed lake trout concentrations in the western portion of Yellowstone Lake. These surveys also revealed medium-sized (12–16 inches) lake trout tended to reside in deeper water (greater than 130 feet) than Yellowstone cutthroat. Now biologists can more easily target lake trout without harming cutthroat trout. Hydroacoustic data also provides

Lake Trout

The Issue

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

History/Background

- During the time the park stocked fish, lake trout were introduced to Lewis and Shoshone lakes.
- In 1994, an angler caught the first verified lake trout in Yellowstone Lake.
- Lake trout probably were introduced into Yellowstone Lake several decades ago.
- One mature lake trout can eat approximately 41 cutthroat trout per year.
- The cutthroat trout population in Yellowstone Lake could fall to 10 percent 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.
- In 2009 & 2010, Yellowstone National Park contracted with a commercial gill-netting company to increase the catch of lake trout.

Current Status

- Gill-netting has removed more than 600,000 lake trout since the mid-1990s.
- 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.

minimum abundance estimates of both cutthroat and lake trout, which is invaluable information for long-term evaluation of control efforts.

Controlling Lake Trout

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

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

Cutthroat trout comprise about 80 percent of a

Whirling Disease

The Issue

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

History/Background

- The disease was first described in Europe more than 100 years ago. It was detected in the U.S. in the mid-1950s, and in Yellowstone in 1998.
- It most likely came to the U.S. in frozen fish products.
- Whirling disease has been confirmed in 25

states and appears to be rapidly spreading throughout the western United States.

- Recent laboratory tests suggest cutthroat trout are highly susceptible. Lake trout and grayling appear immune to the disease, and brown trout are resistant, but can be infected and can carry the parasite.
- There is no treatment.

Current Status

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

mature lake trout's diet. Biologists estimate 41 cutthroat trout are saved each year for every mature lake trout caught.

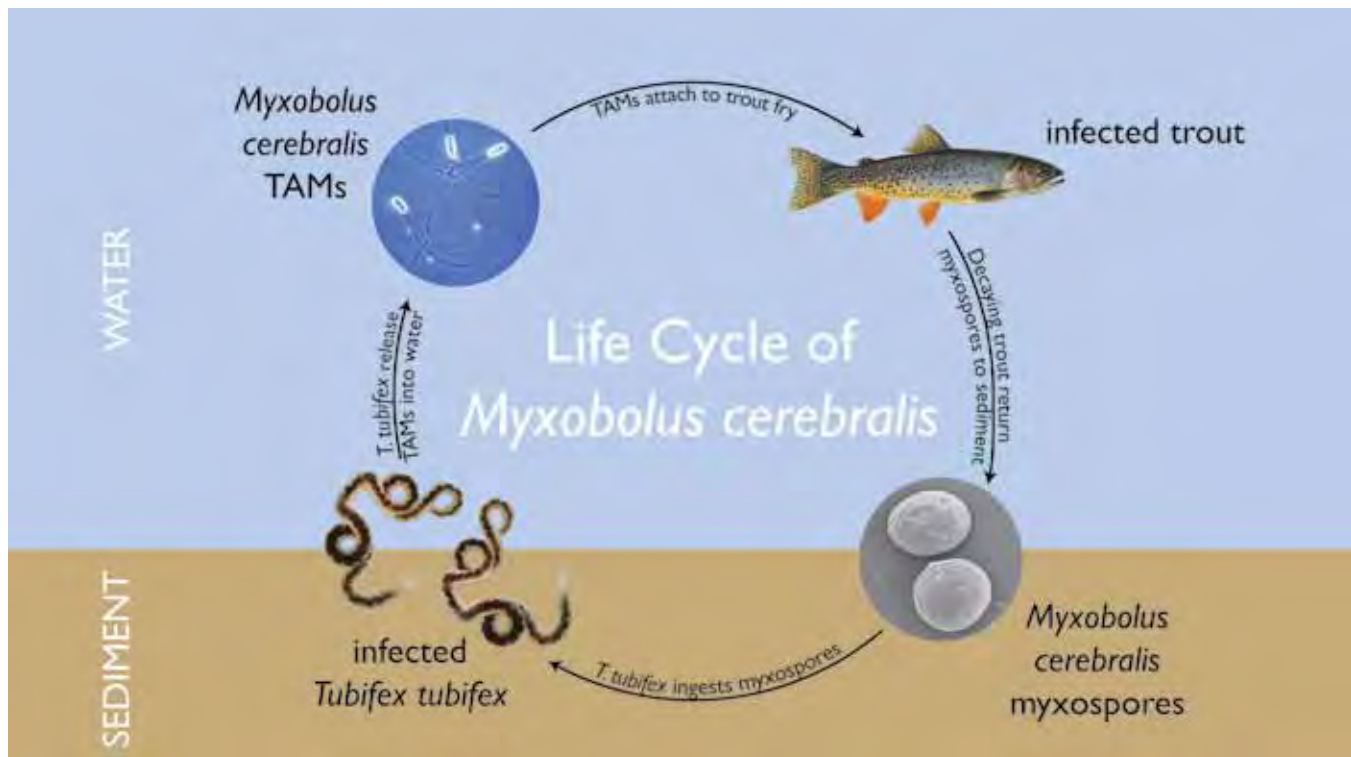
Increasing Suppression

In August 2008, a scientific review panel overwhelmingly agreed that the Yellowstone Lake cutthroat trout population is in serious trouble, but that suppression efforts could restore this population to healthy levels. They believe very little time remains to turn the situation around, and recommended park managers increase lake trout removal. To accomplish this, the park has contracted with a commercial gill-netting company to increase the take of lake trout.

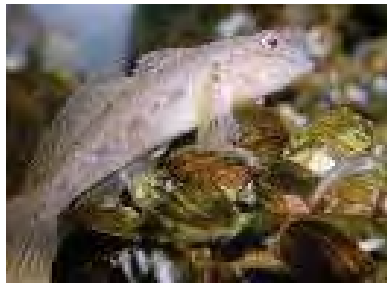
Lake trout probably can't be eliminated from Yellowstone Lake. However, ongoing management of the problem can control lake trout population growth and maintain the cutthroat trout population, which is a critical ecological link between Yellowstone Lake and its surrounding landscape.

Whirling Disease

In 1998, whirling disease was detected in Yellowstone's cutthroat trout. This disease is caused by a non-native microscopic parasite that can infect trout and salmon; it does not infect humans. The parasite attacks the developing cartilage of fish between 1–6 months old and causes deformities of



The life cycle of whirling disease.



These species may spread to Yellowstone National Park, but are not yet present. Clockwise from top left: Round goby; Zebra mussels clog water intakes, crowd out bottom invertebrates, and reduce lake productivity; Bighead carp (middle); Eurasian water-milfoil.

TOP RIGHT: CHARLES RAMCHARAN, WISCONSIN SEA GRANT, CENTER: DAVID RIECK, UNIVERSITY OF ILLINOIS AT URBANA-CHAMPAIGN, BOTTOM: FLORIDA DEPARTMENT OF AGRICULTURE & CONSUMER SERVICES

More Invaders On Their Way?

Several exotic aquatic species are spreading through the United States, among them the species shown here. Fisheries biologists believe they are moving toward Yellowstone. Their arrival might be avoided if anglers remember:

- It is illegal to use any fish as bait in Yellowstone National Park.
- It is illegal to transport fish among any waters in the Yellowstone region.
- It is illegal to introduce any species to Yellowstone waters.

To clean all of their gear properly.

Eurasian water-milfoil

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 exotic aquatic plant lives in calm waters such as lakes, ponds, and calm areas of rivers and streams. It grows especially well in water that experiences sewage spills or abundant motorboat use, such as Bridge Bay.

Eurasian water-milfoil colonizes via stem fragments carried on boating equipment, which is another reason why boats should be thoroughly cleaned, rinsed, and inspected before entering Yellowstone National Park.

Exotic photoplankton

Three zooplankton species may be on their way that can displace native zooplankton that are important food for cutthroat trout. These exotic zooplankton have long spines, which make them difficult for young fish to eat.

the bony structures. An infected fish may have a deformed head and tail, blackened areas of the tail, and whirling swimming behavior. It may be unable to feed normally and is vulnerable to predation.

Studying the Disease

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

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



Grizzly bears (shown here) and black bears inhabit Yellowstone National Park.

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

Bear Management

Feeding Bears

- Late 1880s: Bears begin gathering at night to feed on garbage behind park hotels.
- 1910: First incidents of bears seeking human food along park roads.
- 1916: First confirmed bear-caused human fatality.

Early Management

- 1931: Park begins keeping detailed records of bear-inflicted human injuries, property damage, and bear control actions.
- 1931–1969: average of 48 bear-inflicted human injuries and more than 100 incidents of property damage occur annually in Yellowstone.

Changes in Management

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

Current Status

- Decrease in human injuries from 45 injuries per year in the 1960s to 1 injury per year in the 2000s.

- Decrease in property damage claims from 219 per year in the 1960s to an average of 15 per year in the 2000s.
- Decrease in number of bears that must be killed or removed from the park from 33 black bears and 4 grizzlies per year in the 1960s to an average of 0.34 black bear and 0.2 grizzly bear per year in the 2000s.
- Decrease in bear relocations away from the front country from more than 100 black bears and 50 grizzlies per year in the 1960s to an average of 0.4 black bear and 0.6 grizzly bear per year in the 2000s.

After 10 years of this program, the number of bear-caused human injuries decreased only slightly, to an average of 45 each year. Consequently, in 1970, Yellowstone initiated a more intensive program that included eliminating open-pit garbage dumps inside the park. The long-term goal was to wean bears off human food and back to a natural diet of plant and animal foods.

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

In 1983, the park implemented a new grizzly bear management program that emphasized habitat protection in backcountry areas. The park established “bear management areas” that restricted recreational use where grizzly bears were known to concentrate. The goals were to minimize bear-human interactions that might lead to habituation of bears to people, to prevent human-caused displacement of bears from prime food sources, and to decrease the risk of bear-caused human injury in areas with high levels of bear activity. This program continues today.

Bear Management: Grizzly Bears

On July 28, 1975, under the authority of the Endangered Species Act (ESA), the U.S. Fish and Wildlife Service (USFWS) listed the grizzly bear in the lower 48 states as threatened under the Endangered Species Act, in part, because the species was reduced to only about two percent of its former range south of Canada. Five or six small populations were thought to remain, totaling 800 to 1,000 bears. The southernmost—and most isolated—of those populations was in greater Yellowstone, where 136 grizzly bears were thought to live in the mid-1970s. The goal of ESA listing is to recover a species to self-sustaining, viable populations that no longer need protection.

To achieve this goal, federal and state agencies:

- Stopped the grizzly hunting seasons in the Greater Yellowstone Ecosystem (GYE).
- Established the Yellowstone grizzly bear recovery area (Yellowstone National Park, John D.

Bear Management: 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; total number of comments: 16,794.
- 2002: The Conservation Strategy is approved; will be implemented when the grizzly is removed from threatened species list.
- 2003: The recovery goals are met for the sixth year in a row.
- 2005: The USFWS proposes removing the grizzly bear from threatened species list.
- 2006: The Grizzly Bear Recovery Plan is modified to update methods of estimating population size and sustainable mortality.
- 2007: The grizzly bear population in the Greater Yellowstone Ecosystem is removed from the threatened species list and the Conservation Strategy is implemented.
- 2009: The population is returned to the threatened species list; management continues under the 2006 revision of the recovery plan.

Rockefeller, Jr. Memorial Park-way, portions of Grand Teton National Park and national forests surrounding Yellowstone, Bureau of Land Management lands, and state and private lands in Idaho, Montana, and Wyoming).

- Began the Interagency Grizzly Bear Study Team (IGBST) to coordinate bear management among the federal agencies and state wildlife managers; the team monitors bear populations and studies grizzly bear food habits and behavior.
- Established the Interagency Grizzly Bear Committee (IGBC) to increase communication and cooperation among managers in all recovery areas, and to supervise public education programs, sanitation initiatives, and research studies.
- Developed and implemented a recovery plan and a conservation strategy.

On the List = The Grizzly Bear Recovery Plan

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

Off the List = The Grizzly Conservation Strategy

Bear managers use the conservation strategy when the grizzly is off the threatened species list. It is the long-term guide for managing and monitoring the grizzly bear population and assuring sufficient habitat to maintain recovery. It emphasizes coordination and cooperative working relationships among management agencies, landowners, and the public to ensure public support, continue application of best scientific principles, and maintain effective actions to benefit the coexistence of grizzlies and humans. It incorporates existing laws, regulations, policies, and goals.

Flexibility in the Strategy

- Grizzly/human conflict management and bear habitat management are high priorities in the recovery zone, which is known as the Primary Conservation Area (PCA). Bears are favored when grizzly habitat and other land uses are incompatible; grizzly bears are actively discouraged and controlled in developed areas.
- State wildlife agencies have primary responsibility to manage grizzly bears outside of national parks, including bears on national forests; national parks manage bears and habitat within their jurisdictions.
- The grizzly bear population will be sustained at or above 500 bears in the Greater Yellowstone Ecosystem.
- State and federal wildlife managers will continue to monitor the grizzly population and habitat conditions using the most feasible and accepted techniques.
- Managers will remove nuisance bears conservatively and within mortality limits outlined above, and with minimal removal of females;

Two human fatalities from bear encounters grip Yellowstone during summer 2011

In separate incidents, two park visitors were killed in bear encounters in Yellowstone during the summer of 2011.

In early 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. It 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. Bear 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.

Grizzly Bear Recovery Plan: New Population Monitoring Criteria

Population Objectives	Was the objective achieved?				
	2006	2007	2008	2008	2010
Estimated percent of total mortality of independent aged females not to exceed 9 percent.	•	•		•	•
Estimated percent of total mortality of independent aged males not to exceed 15 percent.	•	•		•	
Estimated percent mortality from human causes for dependent young not to exceed 9 percent.	•	•	•	•	•
Demographic objective of 48 females producing cubs annually.	•	•	•	•	•

• = Objective was achieved.

they will emphasize removing the human cause of conflict rather than removing a bear.

- Outside the PCA, states develop management plans, with input from affected groups and individuals, that define where grizzly bears are acceptable.

Current Status and Outlook

Scientists and managers believe the grizzly population has grown robustly since 1986. Grizzlies are raising cubs in nearly all portions of the recovery area, and cub survival is high. They are also dispersing into new habitat. Of the estimated 603 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 Absarokas onto the plains.

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

In 2009, U.S. District Judge Donald Molloy returned the grizzly to the federal threatened species list, saying the Conservation Strategy was not enforceable and insufficiently considered the impact of climate change on grizzly food sources. The USFWS and the Department of Justice have appealed. A ruling is expected in 2012.

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

Bioprospecting: Innovation through Science

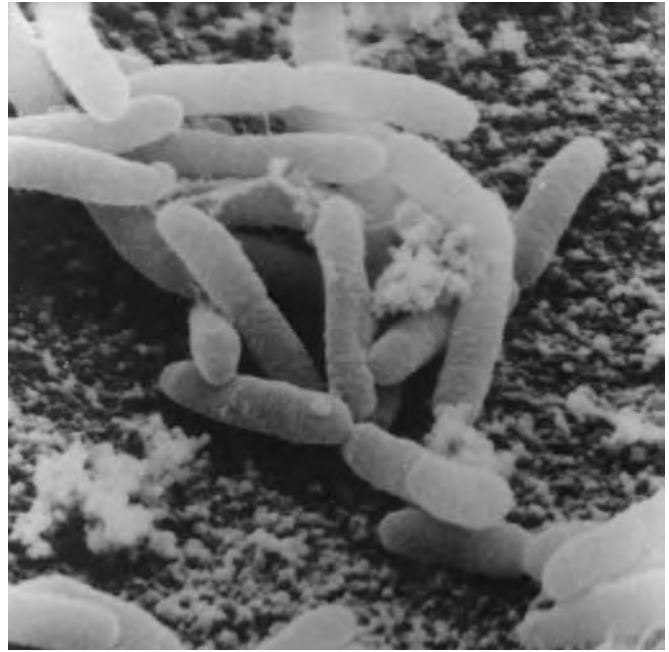
Yellowstone's extremophiles—especially thermophiles—have been the subject of scientific research and discovery for more than 100 years. One of these discoveries in the 1960's—of *Thermus aquaticus* bacteria—led to the invention of a suite of enzymes that have had scientific and economic benefits far beyond what anyone could have imagined. Today, several dozen scientific research projects—sponsored by universities, NASA, and corporations—are underway in the park to investigate extremophiles. 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. As required by law, research is encouraged in Yellowstone if it does not adversely impact park resources and visitor use and enjoyment. Importantly, only research results, i.e. information and know-how gained during research on park specimens, may be commercialized—not the specimens themselves.

How 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.

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



RICHARD WILSON, UNNEBRASKA MEDICAL CENTER (1975)

Thermus aquaticus as seen through a scanning electron microscope.

diagnoses, DNA-based studies of nature, and genetic engineering were unimaginable. But in 1985, the polymerase chain reaction (PCR) was invented. PCR is an artificial way to do something that living things do every day—replicate DNA. PCR is the rocket ship of replication, because it allows scientists to make billions of copies of a piece of DNA in a few hours. Without PCR, scientists could not make enough copies of DNA quickly enough to perform their analyses. They found the solution to this problem in one of the organisms isolated from Yellowstone by Dr. 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.

Bioprospecting and Benefits-sharing

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.

The Issue

Researchers who study material obtained under a Yellowstone National Park research permit will be required to enter into benefits-sharing agreements with the National Park Service before using their research results for any commercial purpose.

Definitions

Bioprospecting is the 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.

A Brief Timeline of Bioprospecting and Benefits Sharing 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 NPS 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 mandates increased 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 NPS decides to adopt benefits-sharing following the completion of the Benefits-Sharing Environmental Impact Statement.



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.

Bison Management

Yellowstone National Park is the one place in the nation where bison are preserved as wildlife with all the features of a naturally functioning system. Genetically, these bison are one of the few populations free of cattle genes. They experience natural competition among themselves and among other species for food. They are preyed upon by the same predators that hunted them two centuries ago. And their herds increase and decrease based on all of these factors—plus annual human intervention through hunting and management.

The story of bison restoration in Yellowstone is told elsewhere. Here, because of the social conflicts regarding how to accept and manage wild bison, we focus on bison management that occurs because of the disease these wild icons can sometimes carry.

About Brucellosis

Brucellosis, caused by the bacterium *Brucella abortus*, can cause pregnant cattle, elk, and bison to abort their calves. It is transmitted primarily when 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 non-native disease to the region when pioneers settled the West. The disease was subsequently transmitted to local wildlife populations.

In Humans

Although rare in the United States, humans can contract brucellosis by consuming unpasteurized, infected milk products or contacting infected birth tissue. It cannot be contracted by eating cooked meat from an infected animal. In humans, the disease is called undulant fever. Since the advent of milk pasteurization, people in developed countries have virtually no risk of contracting the disease. And if they do, they can be treated with a series of antibiotic injections.

In Yellowstone

Brucellosis was discovered in Yellowstone bison in 1917. They probably contracted the disease from

Bison Management Objectives

- Maintain genetic integrity of the bison population.
- Maintain a wild, free-ranging bison population.
- Maintain and preserve the ecological function that bison provide in the Yellowstone area, such as their role as grassland grazers and as a source of food for carnivores.
- Lower brucellosis prevalence because it is not a native organism.
- Reduce risk of brucellosis transmission from bison to cattle.

domestic cattle raised in the park to provide milk and meat for visitors. Now about 50 percent of the park's bison test positive for exposure to the brucella organism. However, testing positive for exposure (seropositive) does not mean the animal is infectious and capable of transmitting brucellosis. (For example, people who received smallpox immunization during their childhood will test positive for smallpox antibodies even though they are not infected with the disease and cannot transmit it.) Research indicates less than half of seropositive female bison are infectious at the time of testing. Male bison do not transmit the disease to other bison. (Transmission between males and females during reproduction is unlikely because of the female's protective chemistry.) Bison have a very low probability of transmitting brucellosis to cattle under natural conditions 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 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. This provision is still enforced by USDA.

However, 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

Bison Management

The Issue

About half of Yellowstone's bison test positive for exposure to brucellosis, a disease that can cause bison and domestic cattle to abort their first calf. Because Yellowstone bison migrate into Montana, their exposure to brucellosis concerns the state's cattle industry.

History/Background

- 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 U.S.
- Bison have not been known to transmit brucellosis to cattle

under natural conditions although transmission has occurred in captivity.

- The state of Montana, like other states, has spent much time, effort, and money attempting to eradicate brucellosis in cattle.
- Elk in the greater Yellowstone area also carry brucellosis.

Current Status

- The bison management plan in effect since December 2000 has been revised.
- 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.
- 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.

Interagency Management Partnership

- National Park Service (NPS)
- Animal Plant Health Inspection Service (APHIS)
- U.S. 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

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.

Nevertheless, the state of Montana remains concerned that bison migrating outside of Yellowstone National Park present a risk to cattle. Therein lies the need for bison management.

The Interagency Bison Management Plan (IBMP)

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 the 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 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 boundaries 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



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.

the end of winter in 2008. More than 3,600 bison were removed from the population for risk management purposes during 2001 to 2011, with more than 1,000 bison and 1,700 bison being culled from the population during the winters 2006 and 2008, respectively. These culls differentially affected breeding herds, altered gender structure, created reduced female cohorts, and dampened productivity of bison. Thus, there was a need to adjust the management plan to better protect migratory bison and facilitate their conservation.

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 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

1917–1995

1917

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.

1985

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

1989

Bison routinely migrate to boundary in years of heavy snowfall. Park begins collaborative planning to develop management plan.

1990

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

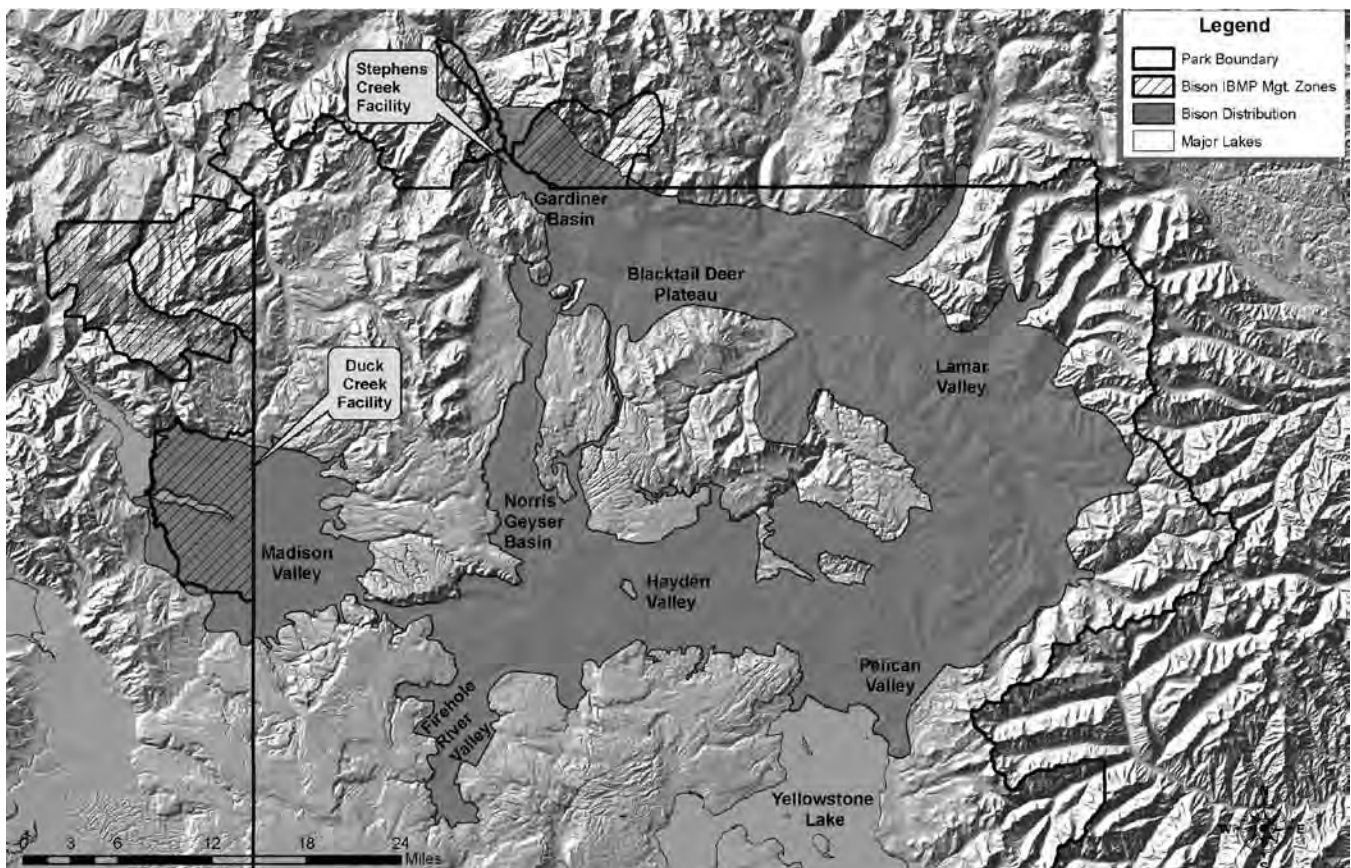
1995

Montana files lawsuit against NPS to keep bison out of the state; settlement requires EIS preparation.

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 U.S. Forest Service and other lands north of the park boundary and south of Yankee Jim Canyon during 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. 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.

Looking Back Over 10 Years

Overall, the NPS 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 longterm 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



The bison conservation area, including capture facilities and management zones outside Yellowstone National Park. Map produced by the Yellowstone National Park Spatial Analysis Lab.

1996

Interim Bison Management Plan begins. Stephens Creek facility is constructed as part of settlement agreement with state of Montana.

1997

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

1998

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

1999

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.

2000

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

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 Recent Developments

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-Kootenai, Shoshone-Bannock, Umatilla— hunt bison on public lands outside the park in accordance with their 1855 treaties with the United States.

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 NPS 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. Because scientists now know more about bison movement patterns, group dynamics, and habitat distribution, they better understand where and when remote field vaccination could

Two Decades of Lawsuits

- 1984: Fund For Animals sues 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 U.S. Forest Service (FS) agree to develop a long-term management plan to cooperatively manage bison.
- 1992: Another MOU between Montana, NPS, Forest Service, & APHIS defines each party's roles and responsibilities in developing a long-term bison management plan.
- 1995: Montana files lawsuit against NPS & 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 & federal agencies into mediation to work out differences. In August, the final EIS is released; federal & 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 it is disrupting nesting bald eagles. (Rejected.)
- 2009: Several groups file a lawsuit against NPS & 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. Case is in appeals court at this time.
- 2010: Several groups sue to stop the state of Montana from moving quarantine bison to private lands.

2001–present

2002–2005

During years 2–5 of the Bison Management Plan, approximately 840 bison are shipped to slaughter or killed.

2005

FWP and APHIS open quarantine facility; 14 bison calves taken from Yellowstone for project. DOL & APHIS begin vaccinating captured bison. FWP begins bison hunt on November 15.

2006

Approximately 1,000 bison removed from the park via management actions, transfer to quarantine, or hunting.

2008

Approximately 1700 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 park boundaries in winter.

2010

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.

succeed. The NPS 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. Eight-seven 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 the state of Montana is transferring 65 additional bison that have successfully completed the quarantine procedures to the Assiniboine and Sioux tribes of the Fort Peck Reservation and the Gros Ventre and Assiniboine tribes of the Fort Belknap Reservations to be managed as wild bison. Thus far the 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 Interagency Bison Management Plan as their primary tool to prevent bison to livestock transmission. Each agency plays a separate role in managing this population that now has approximately 60,000 acres of suitable habitat dispersed throughout 350,000 acres of Montana.



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

Climate Change

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

In the 1700s, scientists began trying to understand how the ice ages had occurred. At the same time, the Industrial Revolution began, powered by fossil fuels. These two events combined to begin understanding global climate change.

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

In 1896, a Swedish scientist connected climate with pollution. Savre Arrhenius wanted to know how carbon dioxide (CO₂) might have affected the ice ages. He calculated the amount of CO₂ emitted by industry, then doubled that amount and calculated it would raise global temperatures 9–11°F.

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

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

In the 1950s, scientific attention began focusing on Earth's systems. Roger Revelle found the oceans could not absorb all the CO₂ humans were emitting. He wanted to know where the CO₂ would go. Revelle hired Charles Keeling to gather baseline data on atmospheric CO₂ from a lab on Mauna Loa, Hawaii, far from industry. Keeling saw the opportunity to begin long-term CO₂ analysis, and so began the first

Words to Know

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

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

Global Climate Models (aka Global Circulation Models): GCMs use established physical laws (such as water expands as it warms) and enormous amounts of data to show how variables (such as increases in carbon dioxide) will affect climate.

Phenology: relationship between periodic biological changes—like the budding of trees or arrival of migratory birds in the spring—and seasonal changes such as temperature.

Climate changes in the past were caused, in part, by changes in the Sun's activity. Scientists have detected no such changes in the Sun during the past few decades.

data set confirming atmospheric CO₂ was rising far beyond that caused by any natural mechanisms.

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

During the ensuing decades, scientists continued to refine instruments and models, and to gather data. To assemble and review this data, the United Nations established the Intergovernmental Panel on Climate Change (IPCC) in 1988, which is comprised of 2000 scientists. Based in part upon the IPCC's work, more than 60 countries convened in 1997 to draft

the Kyoto Protocol, which set mandatory targets for greenhouse gas emissions for most industrialized nations. In 2007, the IPCC shared the Nobel Peace Prize with Al Gore, and published its fourth report, which began: "Warming of the climate system is unequivocal."

Climate-Change Science

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

Climate Change

The Issue

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

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 Arrhenius calculates that increasing atmospheric greenhouse gases will cause global warming.
- 1958: Charles David Keeling begins measuring atmospheric carbon dioxide from Mauna Loa, Hawaii.
- 1957–58: International Geophysical Year
- 1963: Keeling warns of 10.8°F temperature rise in next century.
- 1965: First Global Climate Models (GCM) developed.
- 1969: Weather satellites begin providing 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.
- 2007: IPCC begins its 4th report, "Warming of the climate system is unequivocal."
- 2009: Director's Order 3289 mandates a department-wide strategy to address climate change.
- 2009: Copenhagen Summit held; an accord reached for nonbinding actions to address climate change.
- 2000s: Warmest decade on record.

Predictions for the Western United States

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

What is already happening:

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

Predictions for the Greater Yellowstone Ecosystem

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

What is already happening:

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

18th and 19th Centuries

mid-1700s

Scientists studying Earth's ice ages; Industrial Revolution begins.

1827

Fourier compares Earth's atmosphere to a greenhouse.

1870s

Croll identifies atmospheric feedback loop.

1896

Arrhenius predicts global warming.

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

Evidence

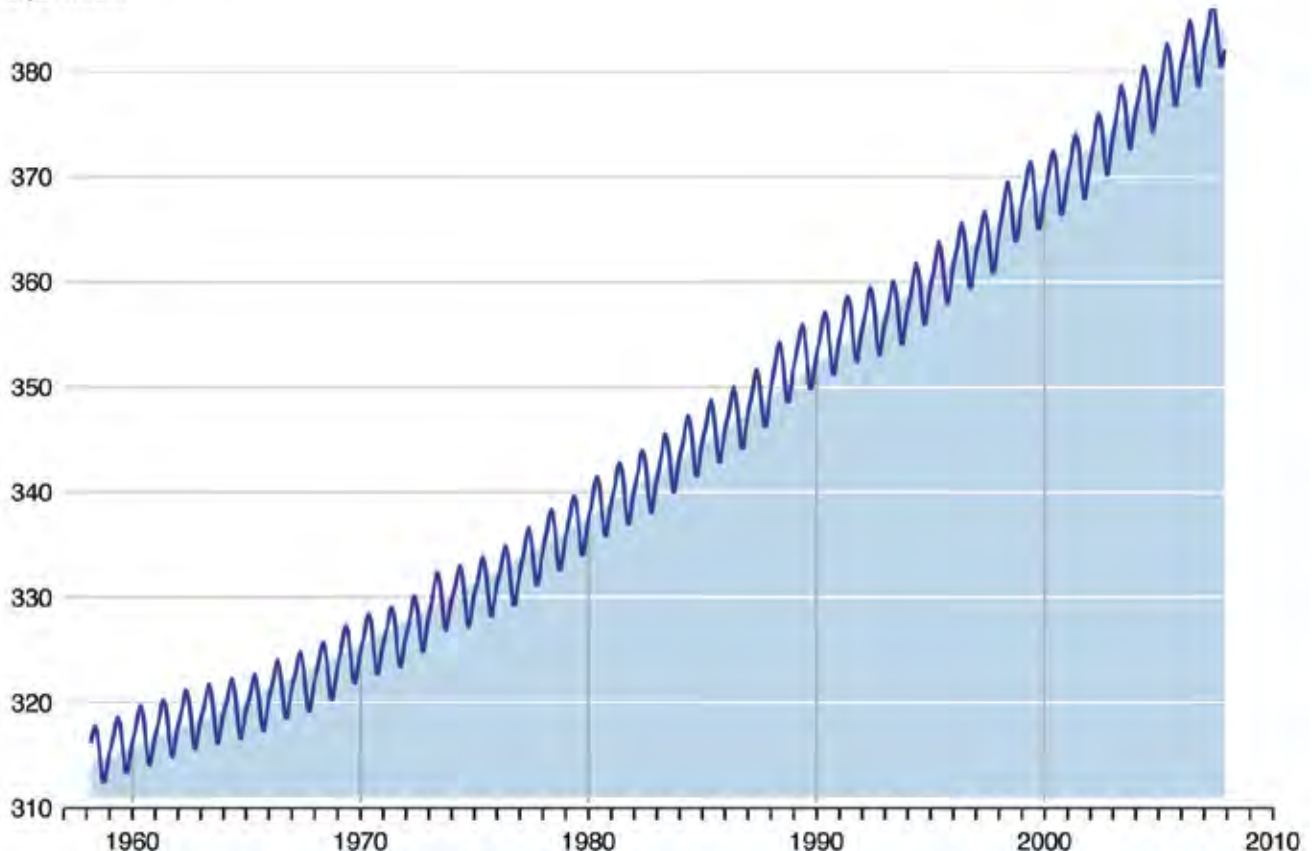
Since the end of the last glaciations, 13,000 to 14,000 years ago, Earth's snow and ice cover has remained relatively consistent. These highly reflective surfaces bounce thermal radiation back into the atmosphere, and as long as this reflection remains steady, so do world temperatures. Satellite and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

the northern hemisphere. As snow and ice coverage decrease, less thermal radiation is reflected, and more heat is absorbed by the increasing amounts of open water and bare land. This increased absorption increases surface and air temperatures.

Ocean temperature is measured every day from thousands of ships; this record combined with air temperature records provide the estimated global average temperature each month. As oceans warm, they expand and their levels rise. Data collected since the 1990s show oceans are rising 0.12 inches per year—50 percent due to water expanding from increased temperatures and 50 percent due to melting ice. Until the 20th century, global sea levels had been stable for thousands of years.

Monthly Carbon Dioxide Concentration

parts per million



The Mauna Loa Record, aka Keeling Curve (begun by Charles Keeling in 1958). This version of the Keeling Curve by the CO2 Program of the Scripps Institute of Oceanography, scrippsco2.ucsd.edu

20th Century

During the 20th century, scientists refine analysis and dating techniques to study Earth's past, ocean & atmospheric chemistry, and climate systems.

1958

Keeling begins long-term recording of CO₂ concentrations in the atmosphere.

1958–1959

International Geophysical Year

1960s

Global Climate Models are developed.

1988

Intergovernmental Panel on Climate Change forms; includes 2000 scientists.

1997

Kyoto Protocol sets goals for reducing CO₂ emissions.

2007

Scientists win Nobel Peace Prize for work on climate change.

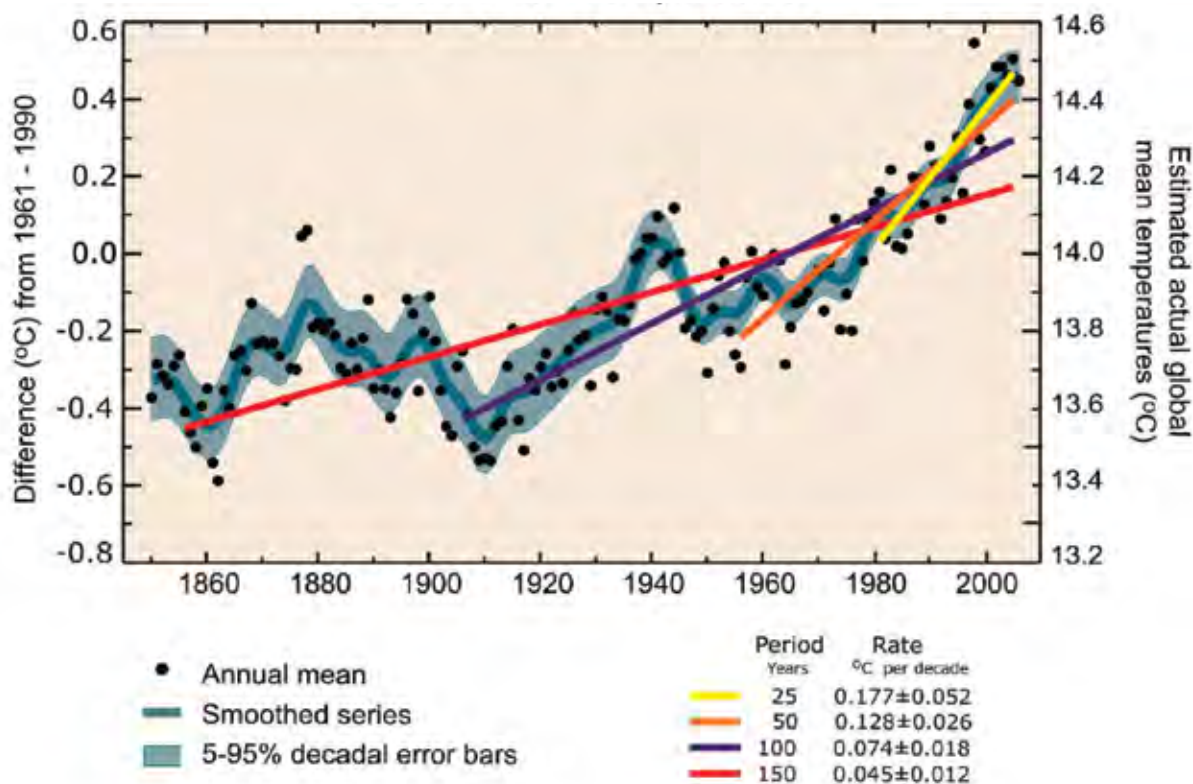
As scientists predicted in the 1800s, carbon dioxide build-up in the atmosphere is causing this extreme and rapid change in Earth's temperature. Ice core records show that after the last glacial period ended, CO₂ concentration gradually rose 80 ppm (parts per million) over 5,000 years. During the past 100 years alone, the concentration has risen 79 ppm—an unprecedented rate.

More than three-fourths of the CO₂ in the atmosphere comes from burning fossil fuels. Scientists know this because carbon atoms released during combustion are chemically distinguished from carbon released by natural causes, and thus can be measured.

Current Effects Around the World

Since the 1950s, in most mid- to high-latitude regions, the number of very cold days and nights has decreased; the extremely hot days and nights have increased; and the length of the frost-free season has increased.

- In 2006, the average mean temperature in the United States was 55°F—2.2°F higher than the 20th century mean.
- The 2000s were the hottest decade on record.
- Temperatures in Alaska are rising almost twice as fast as elsewhere.
- Permafrost is melting across the Arctic regions, reducing habitat for birds, collapsing buildings and roads that used permafrost as a foundation.



Global mean temperature. IPCC published this graph in their 2007 report. An industrialization boom in the northern hemisphere after World War II contributed to cooler temperatures. Carbon dioxide and other greenhouse gases are the main cause of warming after the mid-1970s. The steeper slope in recent decades indicates accelerated warming. This and other graphs available at www.ipcc.ch/graphics/gr-ar4-wg1.htm

- Glaciers have decreased 95 percent.
- The area of melting Arctic sea ice is greater than two Montanas.
- The extent of regions affected by droughts has doubled since the 1970s.
- Since 1970, category 4 & 5 hurricanes have increased by about 75 percent.
- Since 1995, worldwide sea level has risen almost 2 inches—twice the rate of the previous 100 years.

Predictions

If we continue the current rates of CO₂ emissions, scientists predict the following:

Global

- Warming oceans will increase hurricane intensity.
- By 2030, CO₂ emissions will grow 40–110 percent.
- In this century, sea level will rise 15.8–27.6 inches.
- Increased ocean acidity (from increased CO₂) may stop growth of coral reefs.
- By 2100, global surface temperatures will be from 2.5 to 10.4°F higher.
- Heat waves and heavy precipitation will become more frequent.
- Of the species whose sensitivity to climate change has been assessed, 20–30 percent will face greater risk of extinction.

Western United States

Much of the western United States will likely become more arid according to the GCMs. Temperatures could increase 4–13°F, with the increases higher in the mountains and greater during winter. The resulting smaller snowpacks will reduce surface and groundwater supplies, affecting all species in the region. As temperatures increase, evaporation rates increase. So even if precipitation remains the same or increases, less water will be available in the ecosystem.

Less water means wildfires will increase in frequency, intensity, and duration in most western regions. In the last 30 years, the wildfire season has increased more than two months, and individual fires last five times longer. In addition, the increasing levels of CO₂ may change the atmosphere's chemistry so that lightning—a prime cause of natural wildfire—will increase and thus, begin fires more frequently.

Change in Other Western National Parks

North Cascades: 70 to 90 percent of the snowpack could disappear by the end of this century, threatening winter sports and water supplies.

Olympic: Warmer winters and more extreme storms could increase winter flood risk.

Yosemite: Warming and drought have made wildfire season longer and more damaging, and increased insect damage.

Sequoia/Kings Canyon: Warmer temperatures will worsen smog; increasing wildfires will further worsen air quality.

From *Unnatural Disaster: Global Warming and Our National Parks* by the National Parks & Conservation Association.

GCMs generally show changes by latitude—they cannot account for variations in topography that affect regional climate, local weather, and ecosystems. Therefore, the GCMs cannot predict what changes will likely occur at different elevations and within small pockets of habitat.

In general, plants are especially vulnerable to rapid climate changes because they change locations by generations—at best. Even then, they face landscapes already fragmented by humans that will become even more fragmented by climate change.

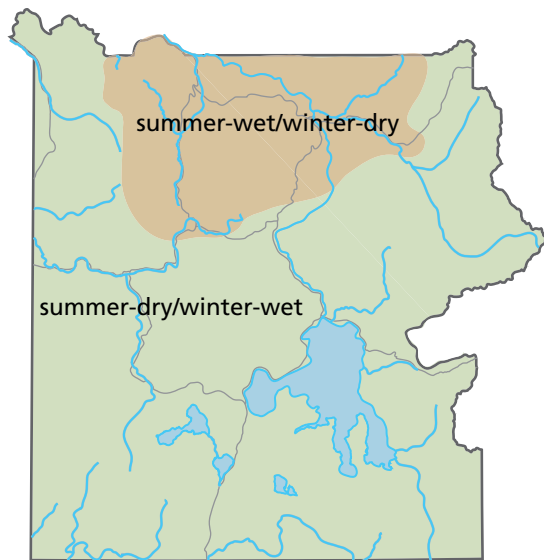
Plants adapted to live in cold environments, such as the Rocky Mountains, often require extremely cold temperatures. For example, young Douglas-fir must be exposed to cold for a certain length of time while they are dormant to promote maximum growth. They will face competition from trees and other plants that don't need chilling.

Throughout the intermountain western United States, spring runoff is 20 days earlier than in the 20th century. Because of this, scientists predict the following:

- By 2050, the Columbia River system—including the Snake River—will lose 35 percent of its snow pack.
- Coldwater fish habitat will be reduced 25–30 percent.
- Aquatic insects and other invertebrates living in streams will be reduced or die out.

Climate Change in Yellowstone

Yellowstone is not considered by many to be a “climate change” park that will have obvious changes in the next few decades. However, higher temperatures and changes in precipitation patterns can greatly



The boundaries of Yellowstone's two climate regimes have remained stable for 14,000 years.

change its ecosystems. The alpine zone, which begins at 9500 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 exotic aquatic species expansion. Changes in precipitation and temperature regimes will likely disrupt vegetation growth that in turn would seriously disrupt wildlife migrations, one of the key resources for which Yellowstone National Park is globally treasured.

Two climate regimes

Yellowstone National Park is bisected by two climate regimes that will influence how and what changes here. These regimes—summer-wet/winter-dry and summer-dry/winter-wet—are remarkably stable, as shown by pollen records extracted from lake sediments throughout the region. By painstakingly examining and identifying pollen from these cores, scientists have determined that Yellowstone's climate regimes have retained approximately the same boundaries since the end of the last glaciation, 13,000 to 14,000 years ago. They remained steady even when temperatures increased 12,000 to 6,000 years ago. This temperature increase equals what we are experiencing now, but over millennia instead of decades.

The northern part of the park, roughly following the southern limit of the northern range, is in a summer-wet/winter-dry climate regime. Moisture comes in the summer via monsoon systems that move north from the gulfs of Mexico and California, wrapping around the Absarokas into the northern range; and winter storms come from the Pacific.

Sagebrush-steppe and grasslands characterize the habitat within this regime. Global climate change may increase summer precipitation within this area, but this may be offset by more rapid evaporation, resulting in a net decrease in moisture available to the ecosystem.

The rest of the park is in a summer-dry/winter-wet regime, influenced by the Pacific sub-tropical high-pressure system in summer and westerly storms in winter. Higher winter moisture used to translate into high snowpack, which provided conditions suitable for forests and their inhabitants. With climate change comes warmer winters and more rain, which will alter the habitat over time.

Although the climate regime boundaries might not change, the vegetation within these regimes will change due to the speed of change and increasing disturbances such as fire and insect infestations.

Fire

The general prediction for wildfire in the western United States calls for more intense fires, similar to those of 1988. However, the charcoal in lake sediment cores is telling a different story in Yellowstone. These records extend back 17,000 years, and were taken from Cygnet Lake on the Central Plateau. Charcoal from 8,000 years ago, when temperature increases equal what we are now experiencing, shows more frequent but smaller fires than today. Fuels, along with fire weather, determine fire size and severity: the stand-replacing fires of today open up the forests where stands have been burned, limiting fuels for the next fire. As a result, areas with frequent fires also tend to have small fires. Whether this holds true for the future remains to be seen.

Insect infestations

In the past, insect infestations were cyclical, following changes in weather. For example, trees defend themselves from pine bark beetles by exuding sap that traps or prevents them from lodging in the tree. During a drought, a tree cannot produce enough sap to defend itself, and so insects infest it. Once the drought ends, the tree successfully defends itself again and the infestation diminishes. In the previous decade, all four pine bark beetles and the spruce budworm attacked trees—a circumstance never seen before. Scientists suspect climate change at work. Currently, all four infestations 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.

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, seem to be thriving. Their growth since 1995 has been three times the average recorded in the 1980s. In part, this is due to the changes in precipitation, snowmelt, and growing season. With a longer growing period to produce energy, willows can meet their essential needs earlier in the season and thus produce more defensive chemicals earlier. They also now have more water earlier in the year because snowmelt occurs sooner, and rain has increased in May and June. This moisture increase occurs at a time most beneficial to their growth.

Wildlife

Climate-change effects on large mammals are hard to determine and predictions are not easy to find. In general, scientists seem to think ungulates depending on grasslands will be able to find suitable habitat. Other species might not be so fortunate.

- Grizzly bear males are tending to den later, which exposes them to risks associated with elk hunting outside park boundaries.
- Canada lynx will have less habitat and food as snow cover decreases in amount and duration.
- Wolverines will have less deep snow for dens where they find shelter and give birth.
- Foxes have to adapt to harder snow surfaces, which decrease access to rodents but increase access to carcasses.

An ironic twist

Yellowstone's thermophilic plants may 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.

Action in Yellowstone

Park employees and residents are reducing their emissions contributions through landmark recycling efforts, using biodiesel and ethanol in vehicles, and

other changes. In 2006 alone, park employees reduced the CO₂ emissions from vehicles by 575.4 tons by using alternative fuels.

At the policy level, park scientists and resource managers have collaborated with other federal agency staff, scientists from the U.S. Geological Survey and from universities, to develop a science agenda that will build a foundation for understanding how the ecological system will change as the climate changes and how management can mitigate these effects.

In addition, the National Park Service, Forest Service, and U.S. Fish & Wildlife Service have inventoried the amount of greenhouse gas (GHG) emissions they produce in the Greater Yellowstone Ecosystem. Yellowstone National Park emissions are higher than others because its operation is the largest. The park inventory revealed:

- More than 60 percent of the GHG emissions come from producing the electricity (coal mines, power plants, etc.) we use
- Heating and cooling park buildings contributes 27 percent to GHG emissions
- Cars, trucks, heavy equipment, and other vehicles directly emit almost 13 percent of Yellowstone's greenhouse gases

In December 2010, the three agencies approved an action plan to reduce GHG emissions in their operations across the entire ecosystem. They also are beginning to coordinate climate change employee education and adaptation efforts.

Other Developments

Scientists are developing new small-scale models that more accurately predict climate change effects at local levels. This kind of new data will help Yellowstone's managers better prepare for the future.

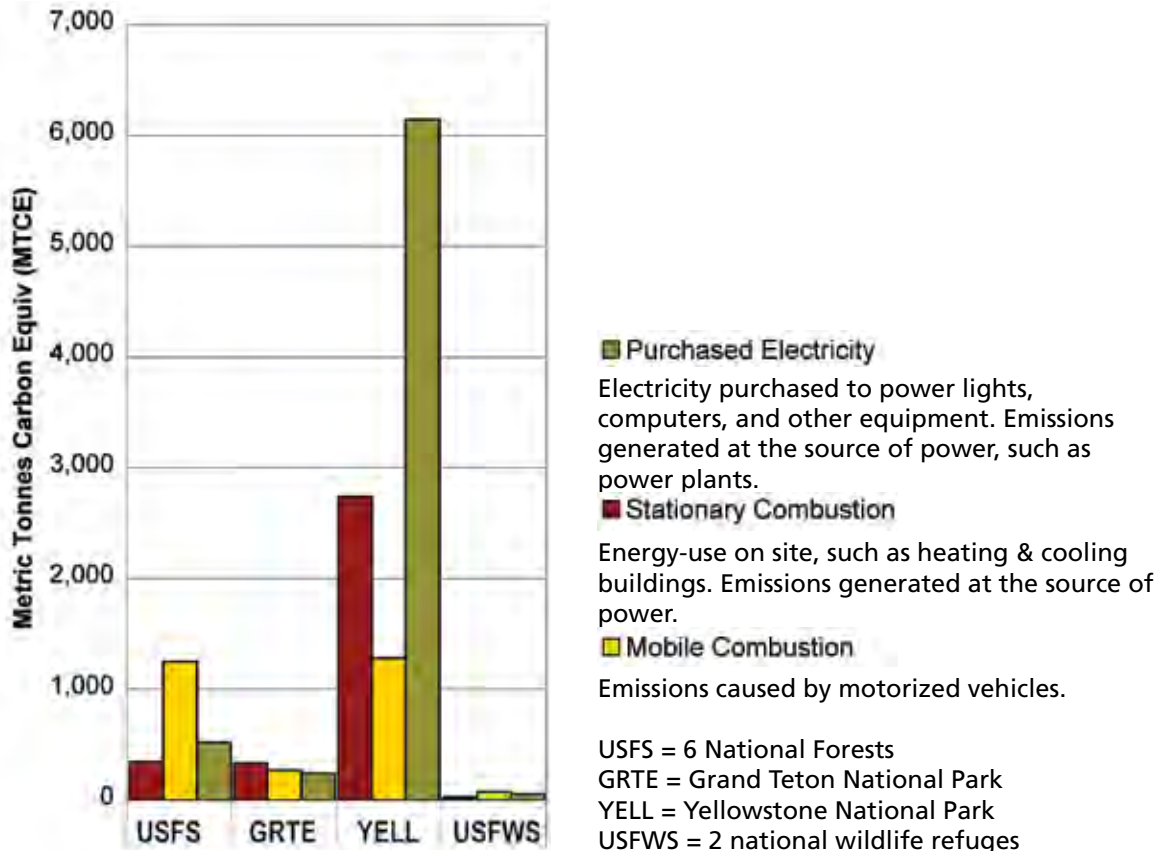
In 2009, the Secretary of the Interior issued Secretary's Order 3289, "Addressing the Impacts of Climate Change on America's Water, Land, and Other Natural and Cultural Resources," which establishes a "department-wide approach for applying scientific tools to increase understanding of climate change and to coordinate an effective response to its impacts."

Also in 2009, more than 100 countries participated in the United Nations Climate Change Conference in Copenhagen, Denmark. They agreed to a long-term goal of limiting global temperature rise to less than 2°C.

Outlook

More than 2000 scientists agree: Earth's climate is warming 40 times faster than any other period in the planet's history. Vegetation cannot keep up with this rapid rate of change. Many animals will not be able to either. And the vast majority of humans, who live within three meters of sea level, will find their homes and livelihoods at risk in the coming decades.

Many scientists believe we have a chance to slow climate change—if we stop increasing CO₂ emissions by 2017. The technology for this change exists, as does the technology to produce climate-safe energy and power.



Greater Yellowstone Ecosystem greenhouse gas emissions. This chart adapted from a report by the National Renewable Energy Laboratory, Department of Energy. Yellowstone National Park is planning to reduce its greenhouse gas emissions approximately 43 percent by 2020.



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

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 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

Northern Range

The Issue

Some scientists believe the park has more ungulates (hoofed mammals) than the northern range can sustain. They blame elk and bison for erosion and declines in willows, aspen, and beaver, ostensibly due to overgrazing. Other scientists have found no evidence that the park's grasslands are overgrazed.

History/Background

- For decades, the park intensively managed elk, bison, and pronghorn.
- The park discontinued wildlife reductions in the late 1960s to restore natural dynamics and minimize human intervention.

- In the 1970s and early 1980s, scientific and public concerns grew about the increasing population of ungulates on the northern range.
- In 1986, Congress mandated a major research initiative to answer these concerns. Results found that the northern range was healthy and that elk did not adversely affect the overall diversity of native animals and plants.

Current Status

- In 1998, Congress called for the National Academy of Sciences to review management of the northern range. Results were released in March 2002.

- Despite scientific conclusions to the contrary, some people continue to claim the northern range is overgrazed.
- In response to recent controversy about the impact of wolves on the elk herds of the northern range, numerous researchers have been studying this elk population and the impact of wolf restoration.
- Some people are now concerned because elk counts have declined approximately 60 percent since 1994 and numbers of bison have doubled.

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 (NPS) conservation philosophy, park managers ended elk removals in the late 1960s and let a combination of weather, predators, range conditions, and outside-the-park hunting and land uses influence elk abundance. Without any direct controls inside the park, elk counts increased to approximately 12,000 elk by the mid-1970s, 16,000 elk by 1982, and 19,000 elk by 1988. This rapid population increase accentuated the debate regarding elk grazing effects on the northern range.

The restoration of wolves into Yellowstone and their rapid increase changed the debate from concerns about “too many” elk to speculation about “too few” elk because of wolf predation. Elk are the most abundant ungulates on the northern range and comprised more than 89 percent of documented wolf kills during winters from 1997 to 2008. These data cause some people to think wolves are killing off elk, despite the fact that elk continue to populate the northern range at relatively high density compared to other areas outside the park.

Another set of statistics also alarm some hunters, outfitters, and state legislators: From 2002 to 2008, elk calf survival (recruitment) and total number of the northern elk herd declined. Many factors (e.g. predators, drought, winterkill, hunting) contributed to the low recruitment and decreased elk numbers.

Research Results

Studies of the northern range began in the 1960s and have continued to the present. These studies reveal some overbrowsing of riparian plants, but no clear evidence of overgrazing. In 1986, continuing concern over the condition of the northern range prompted Congress to mandate more studies. This research initiative, one of the largest in the history of the NPS, encompassed more than 40 projects by NPS biologists, university researchers, and scientists from other federal and state agencies. Results found that the northern range was healthy and elk did not adversely affect the overall diversity of native animals and plants. It was also determined that ungulate grazing actually enhances grass production in all but drought years, and grazing also enhances protein content of grasses, yearly growth of big sagebrush, and establishment of sagebrush seedlings. No reductions in root biomass or increase in dead bunchgrass clumps were observed. However, studies on aspen and

willows and their relationship to ungulates on the northern range are not so clear-cut and are continuing. Despite these results, the belief that elk grazing is damaging northern range vegetation and that grazing accelerates erosion persists among many people, including some scientists.

Continuing Controversy

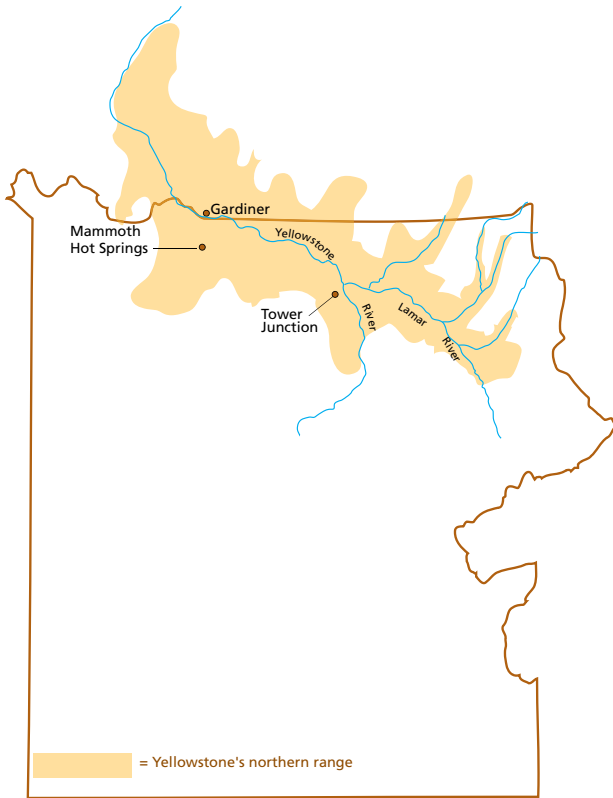
In 1998, Congress again intervened in the controversy, calling for the National Academy of Sciences to review management of the northern range. The results, published in *Ecological Dynamics on Yellowstone's Northern Range* (2002), concluded that “the best available scientific evidence does not indicate ungulate populations are irreversibly damaging the northern range.” Studies investigating the responses of elk populations to wolf restoration continue.

In part, the controversy is likely due to the personal or scientific background of each person. Many urban dwellers live among intensively managed surroundings (community parks and personal gardens and lawns) and are not used to viewing wild, natural ecosystems. Livestock managers and range scientists tend to view the landscape in terms of maximizing the number of animals that a unit of land can sustain. Range science has developed techniques that allow intensive human manipulation of the landscape for this goal, which is often economically based. Many ecologists and wilderness managers, on the other hand, have come to believe that the ecological carrying capacity of a landscape is different from the concept of range or economic carrying capacity. They believe variability and change are the only constants in a naturally functioning wilderness ecosystem. What may look bad, in fact, may not be.

Change on the Northern Range

During the 1990s, the ecological carrying capacity of the northern range increased as elk colonized new winter ranges north of the park that had been set aside for this purpose. Summers were also wet while winters were generally mild. The fires of 1988 also had opened many forest canopies, allowing more grasses to grow.

Many scientists believe that winter is the major factor influencing elk populations. Mild winters allow many more elk to survive until spring, but severe winters result in significant levels of winter kill for many animals, not just elk. In severe winters (like the winter of 1988–89 or 1996–97), up to 25 percent



The northern range of Yellowstone National Park.

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 depredation of crops on private lands. During 1996–2002, approximately 5–19 percent (mean ~11 percent) of the adult female portion of this population was harvested each year during the late hunt. However, 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.



Some sections of the northern range are fenced, as shown above, to study the long-term effects of grazing by fencing out large herbivores. The results were complex: Animals prune shrubs outside the fence but shrubs stay healthy. Apparently the herds are not destroying the unprotected vegetation.

Outlook

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 much differently than elk.



Yellowstone National Park strives to demonstrate and promote sound environmental stewardship through regional and national partnerships. These solar panels in the Lamar Valley are an example of this work.

Sustainable and Greening Practices

In 1997, when Yellowstone National Park celebrated its 125th anniversary, one of the questions asked was what can we do to preserve and protect this national treasure for the next 125 years? The result was “The Greening of Yellowstone” which enabled the park and various partners to address a variety of sustainable and greening issues to increase environmental conservation in the park and surrounding communities.

Meeting to “Green” Yellowstone

Yellowstone National Park, the states of Montana and Wyoming, the U.S. Department of Energy (DOE), and private groups hosted three-day conferences in October 1996 and May 1998. Participants developed a vision for sustaining the park’s values and improving environmental quality. They considered strategies such as developing a regional composting facility, operating alternatively fueled vehicles, replacing toxic solvents, using more environmentally-sound products, and modifying the energy infrastructure to make it more environmentally friendly. In 2003 and 2007, Yellowstone hosted additional greening conferences that highlighted environmental stewardship and successes in the region, and identified future initiatives. In 2011 a “Greening Yellowstone

Symposium” brought together private and corporate partners to develop a vision and strategy for future sustainability in Yellowstone.

Walking on Sustainability

Yellowstone has more than 15 miles of wood boardwalk, most of which are several decades old. As these walkways age, toxic chemicals from wood preservative leach into the ground and water. To reduce this pollutant, the park has replaced some wood walkways with boards made of recycled plastic. This effort began in 1998 when Lever Brothers Company donated plastic lumber for the viewing platform around Old Faithful geyser. The lumber used the equivalent of three million plastic milk jugs. Now visitors receive an educational message about recycling while waiting for the world’s most famous geyser eruption. Yellowstone is also experimenting with permeable pavements for sensitive resource areas and has installed a permeable recycled glass pavement on the west side of the Old Faithful VEC.

Driving Sustainability

Yellowstone National Park offers an opportunity to demonstrate alternative fuels in an environmentally sensitive and extremely cold area. Beginning in 1995, the National Park Service, the Montana Department

of Environmental Quality (DEQ), DOE, and the University of Idaho began testing a biodiesel fuel made from canola oil and ethanol from potato waste. Dodge Truck Inc. donated a new three-quarter ton 4x4 pickup to the project. The truck has been driven more than 200,000 miles on 100 percent biodiesel. It averages about 17 miles per gallon, the same as with petroleum-based diesel fuel. Emissions tests showed reductions in smoke, hydrocarbons, nitrogen oxides, and carbon monoxide. Tests also showed bears were not attracted by the sweet odor of biodiesel exhaust, which had been a concern. In September 1998, the truck's engine was analyzed, revealing very little wear and no carbon build-up.

The park also provides ample opportunity to test and use alternative fuels. All diesel-powered vehicles used by park employees plus many used by concession operations use a 20 percent blend of canola oil and diesel. Gasoline-powered vehicles in the park use an ethanol blend (E-10). This fuel is also available to visitors at park service stations.

In 2004, the park's hybrid fleet began with four models donated by Toyota USA. They operate with electricity generated by the gasoline engine and its braking system. They conserve gas, reduce emissions, and run quietly when using electricity. The park now operates 23 hybrid vehicles.

In 2008, Michelin North America donated \$50,000 worth of tires for the Yellowstone National Park fleet to test. These tires are designed to increase fuel efficiency and to last longer than other tires.

Building Sustainability

Yellowstone's buildings present opportunities for incorporating sustainable building materials and techniques as they are maintained, remodeled, or replaced. The park and its partners have:

- developed standards for outdoor lighting which reduce energy and light pollution.
- planned and constructed the new Old Faithful Visitor Education Center to meet LEED certification requirements.
- retrofitted several maintenance facilities with sustainable heating systems, insulation, and high-efficiency lighting and windows.
- encouraged concessioners to retrofit facilities and ask guests to conserve energy and water in the hotels and lodges.

"Green" Cleaning Products

In August 1998, the U.S. Environmental Protection Agency helped Yellowstone National Park assess its cleaning products. They found some products with slightly toxic ingredients and others with potentially

Sustainable and Greening Practices

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.
- 2006: 70 percent of all garbage in the park is diverted away from a landfill through recycling & composting.
- 2007: Park completes a greenhouse gas inventory, leading to initiatives to reduce greenhouse gas emissions; interns begin gathering data for sustainability efforts.
- 2010: 80 percent of the park's waste stream is diverted from landfills.

- 2010 recycling in the park:

- newspapers, magazines, office paper: 8 tons
- aluminum & steel: 14 tons
- glass: 117 tons
- plastics: 41 tons
- cardboard: 269 tons
- small propane canisters: 25,000
- food waste & other garbage composted: 1395 tons

Fuel Efficiency

- 300 vehicles use more than 156,000 gallons of biodiesel blend fuel
- 350 vehicles use more than 193,000 gallons of ethanol blended fuel

significant health hazards. As a result, the park switched from more than 130 risky products to less than 10 safe products. The assessment expanded to include park concessioners, who also switched to safer products.

Renewable Energy

Yellowstone managers are testing and installing alternative renewable energy sources for various uses in the park. The Lamar Buffalo Ranch meets 80 percent of its electrical energy needs with a solar array. The Lewis Lake Contact Station/Residence also uses solar energy, reducing the use of a polluting propane generator. Bechler Ranger Station receives 95 percent of its electrical energy from a portable solar PV array, which is brought in each summer on

Greening the new Old Faithful Visitor Education Center



The Old Faithful Visitor Education Center, which opened August 2010, achieved Gold level LEED certification. Its features include:

- a design that reduces heated space in winter
- water-conserving fixtures
- displays and programs about sustainable practices
- unobtrusive, down-directed exterior lighting

LEED Certification

The U.S. Green Building Council (USGBC), a building industry group, developed national standards for environmentally-sound buildings. Called LEED (Leadership in Energy and Environmental Design) Green Building Rating System®, these standards have been met in the Yellowstone Park area for an employee housing project completed in 2004. The National Park Service partnered with concessioner Xanterra Parks & Resorts to build two houses following LEED certification standards. The project earned LEED certification—the first in Montana, and the first single-family residence in the NPS. The homes included energy efficiency and passive solar design, state-of-the-art heating & cooling systems, and were landscaped with Yellowstone-produced compost.



Workers spread compost at a park project.

a trailer. In 2007, the park demonstrated a generator that produced electricity using 100 percent vegetable oil. Geothermal energy may seem like an obvious resource in the Yellowstone area—but its use could destroy the geysers and other hydrothermal features protected here. Other geysers in the world have been destroyed by geothermal energy development.

Recycling and Composting

In 1994, a study was done in Yellowstone National Park showing 60–75 percent of solid waste (the waste stream) could be composted. Large-scale composting becomes even more economical when compared to hauling the park's solid waste more than 150 miles to landfills.

The Southwest Montana Composting Project—a partnership among area counties, municipalities, and the National Park Service—built an industrial-grade composting facility near West Yellowstone. It began operating in July 2003 and today transforms 60 percent of park's solid waste into a valuable soil amendment.

The recycling program has expanded in the park and surrounding communities with recycling bins for glass, plastic, paper, aluminum, steel, and cardboard throughout the park and surrounding area.

In 2005, Yellowstone became the first national park to recycle small propane cylinders, such as those used for lanterns and some camp stoves. Now, more than 25,000 cylinders are crushed and redeemed as steel. In 2011, Yellowstone and its partners started recycling bear spray containers.

Employee Ride-Share Program

In January 1998, Yellowstone National Park initiated a Ride-Share Program at the suggestion of

park employees living north of the park—some more than 50 miles away. They were willing to help finance the program. Benefits of the program include:

- reducing fuel consumption and air pollution
- improving safety by decreasing traffic
- easing parking constraints in the park
- saving employees money
- improving employee morale, recruitment, and retention

Approximately 45 employees participate in the Ride-Share Program, a significant demonstration of the National Park Service commitment to public transportation.

Clean Energy Coalition

The Greater Yellowstone/Teton Clean Energy Coalition, which is part of the federal Clean Cities Coalition, promotes alternative, cleaner fuels. Its goals include:

- substantially reducing particulate matter entering the atmosphere
- educating and promoting the advancement of renewable fuels
- reducing dependency on fossil fuels
- setting an example of environmental stewardship

Projects include:

- expanding the use of renewable fuels
- developing partnerships to foster sustainable efforts
- converting all stationary applications (heating boilers, generators, etc.) to renewable fuels
- creating a tour district to promote a shuttle service within the Yellowstone region
- no-idling program.

Greening of Concessions

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

Ecologix: Xanterra Parks & Resorts

Xanterra, which provides lodging, food and beverage, and other guest services in the park, calls its EMS "Ecologix." Xanterra's environmental commitment



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

includes the development and implementation of sustainable practice such as:

- Replacing tens of thousands of incandescent bulbs with energy efficient compact fluorescent and LED (light-emitting diode) lamps.
- 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 wildlife and bird habitats, 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, and in 2011, set the bar high with a 73 percent diversion rate. Through innovative composting and recycling programs, Xanterra was able to keep over 4.2 million pounds of material from entering our 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 in linens to non-profits and businesses. All told, all of these recycled items added up to over 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 3-Star rating, it's the FIRST 3-Star certified restaurant in Wyoming, and one of only 71 in the country. To achieve its 3-Star Green Restaurant certification, the Mammoth Hotel Dining Room 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 EMS “GreenPath.®” This EMS 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 DNC 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 NPS, other concessioners, not for profit organizations, and others to improve environmental efforts in the Greater Yellowstone Area.
- Training nearly 600 seasonal associates on GreenPath® and how they can help to educate others on a great program.



XANTERRA PARKS & RESORTS

In 2010, Xanterra transformed the gift shop in the Mammoth Hot Springs Hotel into a retail store focused on environmental education and environmentally friendly products.

- 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.

The YES! Initiative

In 2008, in concert with the Yellowstone Park Foundation, the park launched the “Yellowstone Environmental Stewardship (YES!) Initiative.” YES! is a multi-year plan to elevate the park as a world-wide leader in advancing environmental stewardship practices. This program enables Yellowstone to build upon its sustainability successes to further minimize the environmental impacts of its operations and decrease consumption of natural resources.

YES! intends to reach these milestones by 2016, using 2003 figures as the baseline:

- reduce greenhouse gas emissions by 30 percent
- reduce electricity consumption by 15 percent
- reduce fossil fuel consumption by 18 percent
- reduce water consumption by 15 percent
- divert 100 percent of solid waste from landfills

The park is also working to develop a strategic plan for sustainability in Yellowstone in cooperation with the Yellowstone Foundation, corporate, and private partners.



In 1972, 90 percent of Yellowstone National Park was recommended for federal wilderness designation.

Wilderness

Yellowstone National Park has always managed its backcountry to protect natural and cultural resources and to provide visitors the opportunity to enjoy a pristine environment within a setting of solitude. Yet none of the park is designated as federal wilderness under the Wilderness Act of 1964.

In 1972, in accordance with that law, the Secretary of the Interior recommended 2,016,181 acres of Yellowstone's backcountry be designated as wilderness. Although Congress has not acted on this recommendation, these lands are managed so as not to preclude wilderness designation in the future. The last Yellowstone wilderness recommendation sent to Congress was for 2,032,721 acres.

Wilderness in the National Park System

Congress specifically included the National Park Service in the Wilderness Act and directed the NPS to evaluate all its lands for suitability as wilderness. Lands evaluated and categorized as "designated," "recommended," "proposed," "suitable," or "study area" in the Wilderness Preservation System must be managed in such a way as to 1) not diminish their suitability as wilderness, and 2) apply the concepts of "minimum requirements" to all management decisions affecting those lands, regardless of the wilderness category.

Wilderness

The Issue

In 1972, 90 percent of Yellowstone National Park was recommended for federal wilderness designation. Congress has not acted on this recommendation.

History

- 1964: Wilderness Act becomes law.
- 1972: National Park Service recommends 2,016,181 acres in Yellowstone as wilderness.
- 1994: YNP writes a draft Backcountry Management Plan (BCMP) and environmental assessment, which is never signed. The BCMP begins to provide management guidance even though not official document.
- 1999: Director's Order 41 (DO 41) issued to guide NPS efforts to

meet the letter and spirit of the 1964 Wilderness Act. It states that recommended wilderness must be administered to protect wilderness resources and values.

- 2003: NPS Intermountain Region implements a Minimum Requirement Policy to evaluate proposed management actions within proposed wilderness areas.

Backcountry Statistics

- Approximately 1,000 miles of trail.
- 72 trailheads within the park; 20 trailheads on the boundary.
- 301 designated backcountry campsites.
- Approximately 13 percent of backcountry users travel with boats and 17 percent travel with stock.

- In 2010, approximately 40,000 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 & implementing Limits of Acceptable Change (LAC).
- Educating users in Leave No Trace practices.

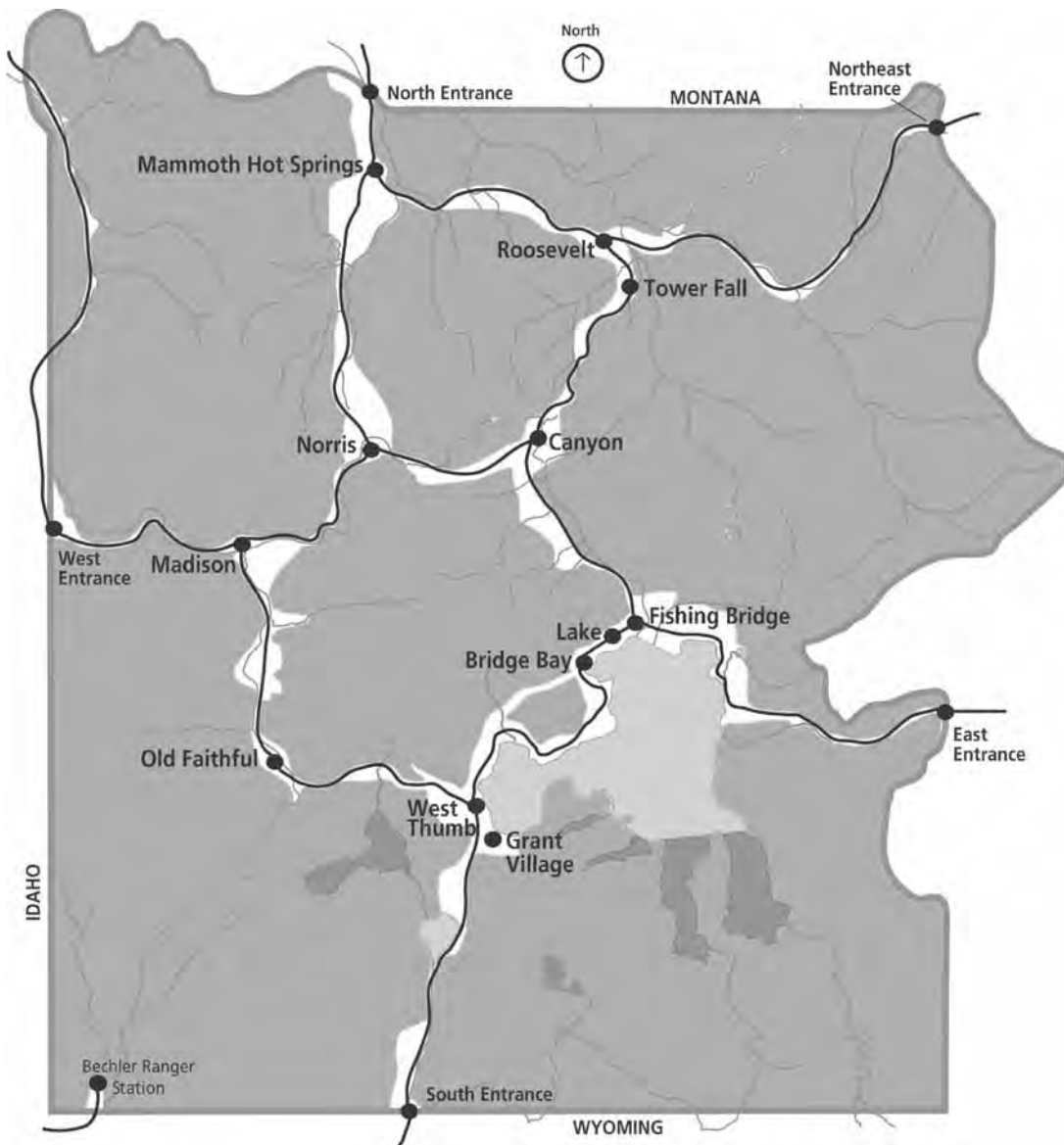
Current Status

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

Director's Order 41

Director's Order 41, issued in 1999, provides accountability, consistency, and continuity to the National Park Service's wilderness management program, and guides the NPS efforts to meet the letter and spirit of the 1964 Wilderness Act. Instructions include:

- "... all categories of wilderness (designated, recommended, proposed, etc.) must be administered by the NPS to protect wilderness resources and values, i.e., all areas must be managed as wilderness."
- "Park superintendents with wilderness resources will prepare and implement a wilderness management plan or equivalent integrated into an appropriate planning document. An environmental compliance document, in keeping with NEPA requirements, which provides the public with the opportunity to review and comment on the park's wilderness management program, will accompany the plan."



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 untrammelled by man, where man himself is a visitor who does not remain ... an area of undeveloped federal land retaining its primeval character and influence, without permanent improvements or human habitation, which is protected and managed so as to preserve its natural condition....

—The Wilderness Act of 1964

Minimum Requirement Analysis

The Intermountain Regional Director said “all management decisions affecting wilderness must be consistent with the minimum requirement concept.”

This concept allows managers to assess:

- if the proposed management action is appropriate or necessary for administering the area as wilderness and does not impact wilderness significantly
- what techniques and type of equipment are needed to minimize wilderness impact.

Superintendents apply the minimum requirement concept to all administrative practices, proposed special uses, scientific activities, and equipment use in wilderness. They must consider potential disruption of wilderness character and resources before, and give significantly more weight than, economic efficiency and convenience. If wilderness resource or character impact is unavoidable, the only acceptable actions are those preserving wilderness character or having localized, short-term adverse impacts.

Wilderness Designation and Current Practices in Yellowstone

As managers develop a wilderness plan for Yellowstone, they must determine how current practices in the park will be handled within the proposed wilderness areas:

- Protecting natural and cultural resources while also maintaining the wilderness character of the park’s backcountry.
- Managing administrative and scientific use to provide the greatest contribution with the minimum amount of intrusion in the wilderness.
- Monitoring Limits of Acceptable Change (LAC) to develop and enact long-range strategies to better protect wilderness resources and enhance visitor experiences.
- Minimizing visitor wilderness recreation impact by educating users in Leave No Trace outdoor skills and ethics that promotes responsible outdoor recreation.

Outlook

Yellowstone will continue to manage its backcountry to protect park resources and provide a wilderness experience to park visitors. Park managers are developing a wilderness plan to best manage and preserve the wilderness character that Yellowstone’s backcountry has to offer. Yellowstone will then wait for the time when Congress will act upon the recommendation to officially designate Yellowstone’s wilderness.



Winter use in Yellowstone National Park has been the subject of debate for more than 75 years.

Winter Use

Background

Winter use in Yellowstone has been the subject of debate for more than 75 years. At least twelve times since 1930, the National Park Service (NPS), its interested observers, and park users have formally debated what winter in Yellowstone should be.

Beginning in the early 1930s, communities around the park began asking the NPS to plow Yellowstone's roads year-round so tourist travel and associated spending in their communities would be stimulated. Each time, the NPS resisted, citing non-winterized buildings, harsh weather conditions, and roads too narrow for snow storage. Meanwhile, snowbound entrepreneurs in West Yellowstone began experimenting with motorized vehicles capable of traveling over snow-covered roads. In 1949, they drove the first motorized winter visitors into Yellowstone in snowplanes, which consisted of passenger cabs set on skis and blown about (without becoming airborne) with a rear-mounted airplane propeller and engine. In 1955, they began touring the park on snowcoaches (then called snowmobiles), enclosed oversnow vehicles capable of carrying about ten people. Finally, in 1963 the first visitors on modern snowmobiles entered Yellowstone. Not long after, snowmobiling became the dominant way to tour the park in winter.

Still, pressure to plow park roads persisted, and Yellowstone authorities knew that they could not accommodate both snowmobiles and automobiles.

The matter culminated in a congressional hearing in Jackson, Wyoming, in 1967.

By this time, park managers felt plowing would dramatically alter the look and feel of the park's winter wilderness. They thought snowmobiles offered

Visitor Survey Results

The University of Montana conducted a survey of winter visitors in 2007–2008:

- Almost 90 percent of those surveyed agreed that Yellowstone is a place for natural quiet and to hear natural sounds.
- 83 percent were somewhat or very satisfied with their experience of natural sounds.
- 71 percent indicated that they found the level of natural sound they desired for half or more of the time they desired it.
- 87 percent were "very satisfied" with their overall experience. The remaining 13 percent were "satisfied."
- 71 percent considered the opportunity to view bison to be extremely important.
- 87 percent reported that this aspect of their Yellowstone winter experience was very satisfying.
- 99 percent who saw bison in winter were able to see them behaving naturally.
- 21 percent witnessed an encounter where the bison were hurried, took flight, or acted defensively.
- More than 72 percent largely considered the bison-human interactions they witnessed and the park setting as a whole as "very" appropriate and/or acceptable.

a way to accommodate visitors while preserving a park-like atmosphere. Thus, an oversnow vehicle program was formalized. In 1971, park managers began grooming snowmobile routes to provide smoother, more comfortable touring, and also opened Old Faithful Snowlodge so visitors could stay overnight at the famous geyser.

Throughout the 1970s, 80s, and early 90s, visitation by snowmobile grew consistently. This brought unanticipated problems such as air and noise pollution, conflicts with other users, and wildlife harassment.

In 1990, recognizing that in solving one problem, others were developing, park managers completed the Winter Use Plan Environmental Assessment for Yellowstone and Grand Teton national parks and the John D. Rockefeller, Jr. Memorial Parkway. This plan formalized the park's existing winter use program

and included a commitment to examine the issue further if winter visitation exceeded certain thresholds. The threshold of 143,000 visitors was exceeded in the winter of 1992–1993, eight years earlier than the plan predicted.

According to the 1990 plan, then, the NPS began an analysis of all types of winter recreation on all NPS and Forest Service (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

Winter Use

The Issue

Debate of appropriate winter use in the park has waged 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 over-snow use instead of plowing.
- 1971: Managers begin grooming roads and Yellowstone Park Co. opens Old Faithful Snowlodge.

- 1990: NPS issues first winter-use environmental assessment (EA) for Yellowstone and Grand Teton.
- 1997: NPS is sued by groups who believe bison used groomed roads to leave the park, which led to their slaughter. NPS must develop a new winter-use environmental impact statement (EIS).
- 1999: Draft EIS released; ±46,000 public comments received.
- 2000: Final EIS released, banning snowmobiles and converting to snowcoach-only transportation.
- 2000, December: Snowmobile group files suit challenging the ban.
- 2001: NPS settles with snowmobilers' group by agreeing to prepare a supplemental EIS (SEIS).
- 2002: Draft SEIS released; ±357,000 comments received.
- 2003, December 11: Final rule published in Federal Register to allow 950 Best Available Technology (BAT), guided snowmobiles daily.
- 2003–2004: Federal court decisions void previous decisions. NPS writes a new EA, allowing 750 BAT, guided snowmobiles daily; 95,000 comments received.

- 2004–2007: Winter use proceeds per 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, NPS begins preparing a next long-term plan. In 2011, the process is extended for another year to consider factors raised by public input. A Supplemental EIS (SEIS) is expected in spring 2012, with a Record of Decision and long-term regulation in place for the mid-December start of the 2012–2013 winter season.

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

1992

Winter visitation exceeds threshold of 140,000 people per year, 8 years earlier than expected.

1993

NPS begins to evaluate winter recreation in the greater Yellowstone area.

1997

Fund for Animals files lawsuit; results in NPS agreeing to develop a new winter use plan and EIS.

1999

Draft EIS released. Bluewater Network and other organizations petition to prohibit trail grooming and snowmobile use in all national parks.

2000

Final EIS released and Record of Decision signed. Snowmobile group sues to stop this winter plan.

2001

Snowmobilers lawsuit settled, which requires NPS to prepare SEIS.

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.

A Decade of Planning and Litigation

The winter of 1996–1997 was one of the three harshest winters of the 20th century, with abundant snow, cold temperatures, and a thick ice layer in the snowpack. Unable to access the forage under the ice, more than 1,000 bison left the park and were shot or shipped to slaughter amid concerns they could transmit brucellosis to cattle in Montana. Concerned that groomed roads increased the number of bison leaving the park and being killed, the Fund for Animals and other groups filed suit in the U.S. District Court for the District of Columbia against the NPS in May 1997. The groups alleged that the NPS had failed to examine the environmental impacts of winter use. In 1999, Bluewater Network filed a legal petition with the NPS to ban snowmobiles from all national park units nationwide. These two actions inaugurated more than 15 years of winter use planning and associated lawsuits, and catapulted the issue into one of

the NPS'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 were commercially available. These machines used new technologies to dramatically reduce emissions and somewhat reduce noise. Requiring visitors to tour with snowmobile guides or in commercially guided snowcoaches reduced the conflicts with wildlife. Resource monitoring allowed the NPS to gauge the effects of these actions and take further protective actions. These changes largely eliminated the problems of the past.

Each of the winter use plans was litigated. The Fund for Animals, the Greater Yellowstone Coalition, and other environmental groups consistently sue in the U.S. District Court for the District of Columbia. The International Snowmobile Manufacturer's Association, the State of Wyoming, the BlueRibbon Coalition, and others consistently file their lawsuits in the U.S. District Court for the District of Wyoming. Litigants have found some traction in each of their courts, with varying degrees of success on any given environmental document. Certainly, the litigation is one of the factors accounting for the ongoing nature of the winter use debate. In each



Snowcoaches entered the park in 1955.

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

decision against it, the NPS has responded by addressing the concerns of the courts.

Improving Conditions in the Parks

With the conversion to BAT snowmobiles, mandatory 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

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 NPS 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.

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 2010/11 monitoring report, down from 67 and 54 percent, respectively. (NPS vehicles account for approximately one-fourth of this noise.) In a new long-term plan, the NPS 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 percent of time oversnow vehicles are heard.

Making all visitors use a commercial guide has nearly eliminated wildlife harassment. Guides enforce proper touring behaviors, such as passing wildlife on or near roads without harassment and ensuring that wildlife do not obtain human food. Monitoring indicates that snowcoaches have a slightly higher probability of disturbing wildlife than do snowmobiles.

With commercial guiding has come a 50 percent reduction of law enforcement incidents, even when accounting for the drop in visitation. Arrests have virtually disappeared. Calls for medical assistance are the only statistic that has increased since the conversion to mandatory guiding.

The recent science on winter use indicates park resources are in very good condition. For each topic monitored, the NPS now understands that both snowmobiles and snowcoaches are contributing similarly to the measured impacts of winter use. The perception that snowmobiles are contributing to the vast majority of observed effects, and that those effects would greatly diminish with snowcoaches only, is not supported by the research. When managed, as they have been for the past five winters, both modes of transportation provide opportunities for visitors to enjoy the park. Each can offer different experiences for visitors, just as cross-country skiing, snowshoeing, and walking offer different opportunities for visitors to enjoy the park in the winter.

Current Situation and Outlook

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 a day in the park. It also continued to provide for motorized oversnow travel over Sylvan Pass and the East Entrance Road.

In May 2011, the NPS 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 NPS decided additional study was needed before putting a long-term plan in place. While the final plan is being developed, the NPS 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 a.m. 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.

The Supplemental EIS is expected to be released for public review and comment in spring 2012. The NPS intends to have a final Supplemental EIS/Winter Use Plan, Record of Decision, and a long-term regulation for winter use in Yellowstone in place before the mid-December start of the 2012–2013 winter season.

To stay current on winter-use planning, go to www.nps.gov/yell/planyourvisit/winteruse.htm

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



Wolves arrived in Yellowstone National Park via truck on January 12, 1995.

Wolf Restoration

The gray wolf (*Canis lupus*) was present in Yellowstone when the park was established in 1872. Predator control, including poisoning, was practiced here in the late 1800s and early 1900s. Between 1914 and 1926, at least 136 wolves were killed in the park; by the 1940s, wolf packs were rarely reported. An intensive survey in the 1970s found no evidence of a wolf population in Yellowstone, although an occasional wolf probably wandered into the area. A wolf-like canid was filmed in Hayden Valley in August 1992, and a wolf was shot just outside the park's southern boundary in September 1992. However, no verifiable evidence of a breeding pair of wolves existed. During the 1980s, wolves began to reestablish breeding packs in northwestern Montana; 50–60 wolves inhabited Montana in 1994.

Restoration Proposed

NPS policy calls for restoring native species when: a) sufficient habitat exists to support a self-perpetuating population, b) management can prevent serious threats to outside interests, c) the restored subspecies most nearly resembles the extirpated subspecies, and d) extirpation resulted from human activities.

The U.S. Fish & Wildlife Service (USFWS) 1987 Northern Rocky Mountain Wolf Recovery Plan proposed reintroduction of an “experimental population” of wolves into Yellowstone. (An experimental population, under section 10(j) of the Endangered Species Act, is considered nonessential and allows more management flexibility.) Most scientists believed that wolves would not greatly reduce populations of mule deer, pronghorns, bighorn sheep, white-tailed deer, or bison; they might have minor

effects on grizzly bears and cougars; and their presence might cause the decline of coyotes and increase of red foxes.

In 1991, Congress provided funds to the USFWS to prepare, in consultation with the NPS and the U.S. Forest Service, an environmental impact statement (EIS) on restoration of wolves. In June 1994, after several years and a near-record number of public comments, the Secretary of the Interior signed the Record of Decision for the final EIS for reintroduction of gray wolves to Yellowstone National Park and central Idaho.

Staff from Yellowstone, the USFWS, and participating states prepared for wolf restoration to the park and central Idaho. The USFWS prepared special regulations outlining how wolves would be managed as an experimental population.

Park staff completed site planning and archeological and sensitive plant surveys for the release sites. Each site was approximately one acre enclosed with 9-gauge chain-link fence in 10 x 10 foot panels. The fences had a two-foot overhang and a four-foot skirt at the bottom to discourage climbing over or digging under the enclosure. Each pen had a small holding area attached to allow a wolf to be separated from the group if necessary (i.e., for medical treatment). Plywood boxes provided shelter if the wolves wanted isolation from each other.

Relocation and Release

In late 1994 and early 1995, and again in 1996, USFWS and Canadian wildlife biologists captured wolves in Canada and relocated and released them in both Yellowstone and central Idaho. In mid-January 1995, 14 wolves were temporarily penned

in Yellowstone; the first 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.

Lawsuits

Several lawsuits were filed to stop the restoration on a variety of grounds. These suits were consolidated, and in December 1997, the judge found that the wolf reintroduction program in Yellowstone and central Idaho violated the intent of section 10(j) of the Endangered Species Act because there was a lack of geographic separation between fully protected wolves already existing in Montana and the reintroduction areas in which special rules for wolf management apply. The judge wrote that he had reached his decision “with utmost reluctance.” He ordered the removal (and specifically not the killing) of reintroduced wolves and their offspring from the Yellowstone and central Idaho experimental population areas, but immediately stayed his order pending appeal. The Justice Department appealed the case, and in January 2000 the decision was reversed.

Wolf Restoration

The Issue

The wolf is a major predator that had been missing from the Greater Yellowstone Ecosystem for decades until its restoration in 1995.

History

- Late 1800s–early 1900s: predators, including wolves, 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; U.S. 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.

Current Status

- As of December 2011, 98 wolves live in Yellowstone—38 in the northern range and 60 in the interior. Ten packs and eight breeding pairs were noted.
- The leading natural cause of mortality in Yellowstone National Park is wolves killing other wolves.
- Researchers are studying the impact of wolf restoration on cougars, coyotes, bears, and elk.
- The USFW and state legislators are considering a compromise that would allow wolves to be delisted in Wyoming, with significant, ongoing conditions.



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.

Results of the Restoration

Preliminary data from studies indicate that wolf recovery will likely lead to greater biodiversity throughout the Greater Yellowstone Ecosystem (GYE). Wolves have preyed primarily on elk and these carcasses have provided food to a wide variety of other animals, especially scavenging species. They are increasingly preying on bison, especially in late winter. Grizzly bears have usurped wolf kills almost at will, contrary to predictions and observations from other areas where the two species occur. Wolf kills, then, provide an important resource for bears in low food years. Aggression toward coyotes initially decreased the number of coyotes inside wolf territories, which may have benefited other smaller predators, rodents, and birds of prey.

So far, data suggests wolves are contributing to decreased numbers of elk calves surviving to adulthood and decreased survival of adult elk. Wolves may also be affecting where and how elk use the habitat. Some of these effects were predictable, but were based on research in relatively simple systems of one to two predator and prey species. Such is not the case in Yellowstone, where four other large predators (black and grizzly bears, coyotes, cougars) prey on elk—and people hunt the elk outside the park. Thus, interactions of wolves with elk and other ungulates has created a new degree of complexity that makes it difficult to project long-term population trends. The effect of wolf recovery on the dynamics of northern Yellowstone elk cannot be generalized to other elk populations in the GYE. The effects depend on a complex of factors including elk densities, abundance of other predators, presence of alternative

ungulate prey, winter severity, and—outside the park—land ownership, human harvest, livestock depredations, and human-caused wolf deaths. A coalition of natural resource professionals and scientists representing federal and state agencies, conservation organizations and foundations, academia, and land owners are collaborating on a comparative research program involving three additional wolf-ungulate systems in the western portion of the GYE. Results to date indicate the effects of wolf predation on elk population dynamics range from substantial to quite modest.

On and Off the Endangered Species List

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 USFWS 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 GYE and the other recovery areas. A court decision required the wolf to be listed again as an endangered species. In 2009, the USFWS again delisted wolf populations in Montana and Idaho, but not in Wyoming. A legal challenge resulted in the NRM wolf population being returned to the federal endangered species list.

As of May 2011, wolf populations had again been delisted in Montana and Idaho by action of Congress within the previous year, and an October 2011 proposal by the USFW to delist wolves in Wyoming was still pending. A bill under consideration in the state legislature calls for state management in the northwest portion of Wyoming and acknowledges federal authority of wildlife within Yellowstone and Grand Teton National Parks, the Wind River Indian Reservation, and the National Elk Refuge. The state would maintain a breeding population of at least 100 wolves and 10 breeding packs outside of Yellowstone and the Wind River Indian Reservation. Wolves would be protected as trophy animals subject to hunting in a trophy game area in northwestern Wyoming. But elsewhere in the state, wolves would be classified as predators that could be shot on sight.

Outlook

The future for wolves seems secure. The USFW in 2011 estimated about 1,650 wolves, 244 packs, and 110 breeding pairs in the Northern Rocky Mountain Distinct Population Segment (DPS)—well above minimum delisting requirements.

In December 2011, there were 98 wolves counted within Yellowstone, 38 in the northern range, and 60 in the interior. Ten packs and eight breeding pairs were noted.

For More Information

General

Yellowstone National Park has a long history of study and public interest. In addition to the references listed for each topic covered in this handbook, here are some interdisciplinary sources.

- 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.
- *Yellowstone Today*, distributed at entrance gates and visitor centers.
- Site Bulletins, published as needed, provide more detailed information on park topics such as trailside museums and the grand hotels. Free; available upon request from visitor centers.
- Trail guides, available at all visitor centers and most viewpoints. A 50-cent donation is requested.

History of the Park

- Bartlett, Richard. 1974. *Nature's Yellowstone*. Tucson: UArizona Press.
- Bartlett, Richard. 1985. *Yellowstone: A Wilderness Besieged*. Tucson: UArizona Press.
- Carr, Ethan. 2007. *Mission 66: modernism and the National Park dilemma*. Amherst: UMass Press.
- Clary, David. 1993. *The Place Where Hell Bubbled Up: A History of Yellowstone National Park*. Moose, WY: Homestead Publishing.
- Cook, Charles W., David E. Folsom, and William Peterson. 1965. *The Valley of the Upper Yellowstone: An Exploration of the Headwaters of the Yellowstone River in the Year 1869*. Norman: UOklahoma Press.
- Culpin, Mary S. 2003. *For the Benefit and Enjoyment of the People: A History of Concession Development in Yellowstone National Park, 1872–1966*. YCR-CR-2003-01. NPS, Mammoth, WY.
- Davis, L. B. et al. 1995. *The Obsidian Cliff plateau prehistoric lithic source, Yellowstone National Park, Wyoming*. U. S. Dept. of the Interior, NPS Rocky Mtn. Region, Div. of Cultural Resources, Selections Series. No. 6, Denver, CO.
- Everhart, William. 1983. *The National Park Service*. Boulder: Westview Press.
- Frison, George. 1978. *Prehistoric Hunters of the High Plains*. New York: Academic Press.
- Haines, Aubrey. 1996. *The Yellowstone Story: A History of Our First National Park*. 2 vols. Niwot: U. Press Colorado.
- Haines, Aubrey. 1974. *Yellowstone National Park: Its Exploration and Establishment*. National Park Service.
- Janetski, Joel C. 2002. *Indians of Yellowstone Park*. Revised edition. Salt Lake City: U Utah Press.
- Keller, Robert and Michael Turek. 1998. *American Indians and National Parks*. Tucson: UArizona Press.
- Langford, Nathaniel P. 1972. *The Discovery of Yellowstone Park*. Lincoln: U Nebraska Press.
- Leopold, A.S. et al. 1963. *Wildlife Management in the National Parks*. www.nps.gov
- Merrill, M. 1999. *Yellowstone and the Great West: Journals, Letters, and Images from the 1871 Hayden Expedition*. Lincoln: U Nebraska Press.
- Milstein, Michael. 1996. *Yellowstone: 125 Years of America's Best Idea*. Billings MT: Billings Gazette.
- Nabokov, Peter and Larry Loendorf. 2004. *Restoring a Presence: American Indians in Yellowstone National Park*. Norman: UOklahoma.
- National Park Service. *Management Policies 2006*. www.nps.gov/policy/mp/policies.html
- National Park Service. *Director's Order 28: Cultural Resource Management*. (1998; being revised) www.nps.gov/refdesk
- National Park System Advisory Board. 2001. *Rethinking the National Parks for the 21st Century*. www.nps.gov/policy
- Quinn, Ruth. 2004. *Weaver of Dreams: The Life and Architecture of Robert C. Reamer*. Bozeman, MT: Ruth & Leslie Quinn.
- Reinhart, Karen and Jeff Henry. 2004. *Old Faithful Inn: Crown Jewel of National Park Lodges*. Emigrant, MT: Roche Jaune Pictures, Inc.
- Russell, Osborne. 1997. *Journal of a Trapper*. New York: MJF Books.
- Santucci, Vincent. 1998. *Paleontological resources of Yellowstone National Park*. Mammoth, WY. YCR-NR-98-1. www2.nature.nps.gov/grd/geology/paleo/yell_survey/index.htm.
- Schullery, Paul, editor. 1979. *Old Yellowstone Days*. Boulder: Colorado Associated U Press.
- Schullery, Paul. 1997. *Searching for Yellowstone*. Houghton Mifflin.
- Schullery, Paul. 1965. *Yellowstone's Ski Pioneers*. High Plains Publishing Company.
- Strong, W.E. 1968. *A Trip to Yellowstone National Park in July, August, and September of 1875*. Norman: UOklahoma Press.
- Weixelman, Joseph. 2001. *Fear or reverence? Yellowstone Science*. Fall.

Whittlesey, Lee H. 2006. *Yellowstone Place Names*. Wonderland Publishing Co.

Whittlesey, Lee H. and National Park Service Staff. *A Yellowstone Album*. Boulder: Roberts Rinehart.

Whittlesey, Lee H. and Paul Schullery. 2003. *Myth and History in the Creation of Yellowstone National Park*. Lincoln/UNebraska.

Internet Links

www.nps.gov/history/
www.nps.gov/legacy/organic-act.htm
www.nps.gov/legacy/legacy.html

Reviewers

Tobin Roop, Chief of Cultural Resources
 Lee Whittlesey, Historian

Greater Yellowstone Ecosystem

Ashton, I. W., et al. 2010. Observed and projected ecological response to climate change in the Rocky Mountains and Upper Columbia Basin: A synthesis of current scientific literature. *Natural Resource Report NPS/ROMN/NRR—2010/220*. www.fedgycc.org/documents/NRR_Ecological_Synthesis_FINAL_high.pdf

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

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

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

Greater Yellowstone Coordinating Committee: www.fedgycc.org

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

Kauffman, Mathew et al. 2007. Landscape heterogeneity shapes predation in restored predator-prey system. *Ecology Letters* 10: 690–700.

Marchand, Peter J. 1996. *Life in the Cold*. UNew England.

McWethy D. B., et al. 2010. Climate and terrestrial ecosystem change in the U.S. Rocky Mountains and Upper Columbia Basin: Historical and future perspectives for natural resource management. *Natural Resource Report NPS/GRYN/NRR—2010/260*. www.fedgycc.org/documents/McWethy_et_al_2010_NPS_NRR260_Climate_Terrestrial_Change_RockyMtns_UprColBasin.pdf

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

Olliff, Tom et al. 2010. A Science Agenda for the Greater Yellowstone Area. *Yellowstone Science* 18(2):14–21.

Schullery, Paul. 2010. Greater Yellowstone Science: Past, Present, and Future. *Yellowstone Science* 18(2):7–13.

Tercek, Michael et al.; 2010. Bottom-up factors influencing riparian willow recovery in YNP. *Western North American Naturalist*. In press.

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

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

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

Wolf, Evan C. et al. 2007 Hydrologic regime and herbivory stabilize an alternative state in YNP. *Ecol. App.* 17(6): 1572–1587.

Yellowstone to Yukon: www.Y2Y.net

Geology

General

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

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

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

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

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

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

Raymo, Chet. 1983. *The Crust of Our Earth*. Englewood Cliffs, NJ: Prentice-Hall.

Smith, Robert B. and Lee J. Siegel. 2000. [New edition is in press.] *Windows Into the Earth: The Geologic Story of Yellowstone and Grand Teton National Parks*. New York: Oxford University Press.

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

Volcanic

Christiansen, Robert L. 2001. The Quaternary + Pliocene, Yellowstone Plateau Volcanic Field of Wyoming, Idaho, and Montana. *USGS Professional Paper* 729–6.

Christiansen, Robert L. et al. 2007. Preliminary assessment of volcanic and hydrothermal hazards in Yellowstone National Park and vicinity. *USGS Open-file Report* 2007-1071; v. 1.1. pubs.usgs.gov/of/2007/1071/.

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

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

- Cottrell, Dr. William H. 1987. *Born of Fire: The Volcanic Origin of Yellowstone National Park*. Boulder: Roberts Rinehart.
- Denasquo, K.R. & R.B. Smith, A.R. Lowry. 2009. Density and lithospheric strength models of the Yellowstone-Snake River Plain volcanic system. *J Volcanology & Geo.Res.* 188:108–127.
- Morgan, Lisa A. et al (editors). 2009. The track of the Yellowstone hot spot: multi-disciplinary perspectives on the origin of the Yellowstone-Snake River Plain Volcanic Province. *J Volcanology & Geo.Res.* 188(1–3): 1–304.
- Puskas, C. M. 2000. Deformation of the Yellowstone Caldera, Hebgen Lake fault zone, and eastern Snake River plain from GPS, seismicity, and moment release. Masters thesis. U Utah.
- Smith, R.B. et al. 2009. Geodynamics of the Yellowstone hot spot and mantle plume. *J Volcanology & Geo.Res.* 188:108–127.

Hydrothermal

- Bryan, T. Scott. 2008. *The Geysers of Yellowstone*. Boulder: Colorado Associated University Press. Fourth Edition.
- Fouke, B. W. et al. 2000. Depositional facies and aqueous-solid geochemistry of travertine-depositing hot springs (Angel Terrace, Mammoth Hot Springs, Yellowstone National Park, U.S.A.) *J. Sedimentary Res.* 70(3): 565–585.
- Fournier, R. O. 1989. Geochemistry and dynamics of the Yellowstone National Park hydrothermal system. *Ann. Rev. Earth Planet. Sci.* 17:13–53.
- Gallant, Roy A. 1997. *Geysers: When Earth Roared*. Franklin Watts.
- Ingebritsen, S. E. and S. A. Rojstaczer. 1993. Controls on geyser periodicity. *Science*. 262: 889–892.
- Ingebritsen, S. E. and S. A. Rojstaczer. 1996. Geyser periodicity and the response of geysers to deformation. *J. Geophys. Res.* 101(B10): 21,891–21,905.
- Marler, George D. 1973. Inventory of thermal features of the Firehole River geyser basins and other selected areas of Yellowstone National Park. U.S. Department of Commerce, National Technical Information Service, Publication PB221 289.

- Marler, George D. 1969. *The Story of Old Faithful*. Mammoth, WY: Yellowstone Library and Museum Association.
- Rinehart, John S. 1976. *Guide to Geyser Gazing*. Santa Fe: Hyper Dynamics.
- Yellowstone Lake
- Cuhel, Russell et al. 2005. The Bridge Bay spires. *Yellowstone Science*. 12(4): 25–40.
- Morgan, Lisa et al. 2003. The floor of Yellowstone Lake Is anything but quiet. *Yellowstone Science*. 11(2): 15–30.
- Morgan, Lisa, ed. 2007. Integrated geoscience studies in the greater Yellowstone area—Volcanic, tectonic, and hydrothermal processes in the Yellowstone geosystem. USGS Professional Paper 1717. pubs.usgs.gov/pp/1717/

Earthquakes

- Christopherson, Edmund. 1960, 1962. *The Night the Mountain Fell*. West Yellowstone, MT/Yellowstone Publications.

Glaciers

- Liccardi, J.M., and Pierce, K.L. 2008. Cosmogenic exposure-age chronologies of Pinedale and Bull Lake glaciations in greater Yellowstone and the Teton Range, USA. *Quaternary Science Reviews* 27: 817–831.
- Pierce, Kenneth L. 1979. History and dynamics of glaciation in the Northern Yellowstone National Park Area. U.S. Geological Survey Professional Paper 729–F.
- Pierce, Kenneth L. 2004. Pleistocene glaciations of the Rocky Mountains in *Developments in Quaternary Science*, J. Rose (ed). 1: 63–76. Elsevier Press.

Sedimentation/Erosion

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

Fossils

- Cannon, K.P. et al. 1997. Results of Archeological and Paleoenvironmental Investigations Along the North Shore of Yellowstone Lake, Yellowstone National Park, Wyoming: 1990–1994. Lincoln: NPS Midwest Archeological Center.
- Hadly, Elizabeth. 1995. Evolution, ecology, and taphonomy of late-Holocene mammals from Lamar Cave, Yellowstone National Park, Wyoming. Ph.D. dissertation. UCalifornia, Berkeley.
- Hadly, E. A. 1999. Fidelity of terrestrial vertebrate fossils to a modern ecosystem. *Palaeogeography, Palaeoclimatology, Palaeoecology* 149(1999): 389–409.
- Hadly, E.A. 1990. Late holocene mammalian fauna of Lamar Cave and its implications for ecosystem dynamics in Yellowstone National Park, Wyoming. Master's thesis. Northern Arizona University.

Internet Links

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

Videos

- The Complete Yellowstone
 Yellowstone: Imprints of Time
 Yellowstone: A Symphony of Fire and Ice

Staff reviewers

- Henry Heasler, Geologist; Cheryl Jaworowski, Geologist

Life in Extreme Heat

- Andrews, Mark. 2005. Could It Be? Life on Mars? Podcast: Terra Videos, episode 105. terravideos.blogspot.com
- Barns, Susan et al. 1996. Perspectives on archaeal diversity, thermophily, and monophyly from environmental rRNA sequences. *Proceedings Natl Acad. Sci.* 93: 9188–9193.
- Boomer, Sarah et al. 2002. Molecular characterization of novel red green nonsulfur bacteria from five distinct hot spring communities in Yellowstone National Park. *Applied and Environmental Microbiology*. January: 346–355.

- Brock, Thomas D. 1978. Thermophilic microorganisms and life at high temperatures. Springer-Verlag, New York.
- 1998. Early days in Yellowstone Microbiology. ASM News. 64:137–140.
- T. D. 1994. Life at High Temperatures. Yellowstone Association/Mammoth, WY.
- Dyer, Betsey Dexter 2003. A Field Guide to Bacteria. Cornell/Ithaca.
- Carsten, Laura. 2001. Life in extreme environments. Northwest Science and Technology. Spring: 14–21.
- Farmer, Jack D. 2000. Hydrothermal Systems: Doorways to Early Biosphere Evolution. GSA Today 10(7): 1–9.
- Farmer, J. D., and D. J. Des Marais. 1999. Exploring for a record of ancient Martian life. J. Geophys. Res. 104.
- Fouke, Bruce et al. 2000. Depositional facies and aqueous-solid geochemistry of travertine-depositing hot springs. J Sedimentary Research. 70(3): 565–585.
- Gihring, Thomas et al. 2001. Rapid arsenite oxidation by *T. aquaticus* and *T. thermophilus*: Field and laboratory investigations. Environ. Sci. Technol. 35: 3857–3862.
- Madigan, Michael and Aharon Oren. 1999. Thermophilic and halophilic extremophiles. Current Opinion in Microbiology. 2: 265–269.
- Marquez, Luis et al. 2007. A virus in a fungus in a plant: 3-way symbiosis required for thermal tolerance. Science 315 (5811): 513–515.
- Pierson, Beverly and Mary Parenteau. 2000. Phototrophs in high iron microbial mats: microstructure of mats in iron-depositing hot springs. Microbiology Ecology. 32: 181–196.
- Reysenbach, A-L. et al, eds. 2001. Thermophiles: Biodiversity, Ecology, and Evolution. Kluwer Academic Press/Plenum, New York.
- Reysenbach, A-L and Sherry Cady. 2001. Microbiology of ancient and modern hydrothermal systems. Trends in Microbiology 9(2): 80–86.
- Reysenbach, A-L, et al. 2000. Microbial diversity at 83°C in Calcite Springs, Yellowstone National Park. Extremophiles. 4: 61–67.
- Sheehan, K.B. et al. 2005. Seen and Unseen: Discovering the Microbes of Yellowstone. Falcon/Helena.
- Sheehan, K.B. et al. 2004. Yellowstone Under the Microscope. The Globe Pequot Press/Gilford, CT.
- Walter, M. R. and D. J. Des Marais. 1993. Preservation of biological information in thermal spring deposits: developing a strategy for the search for fossil life on Mars. Icarus 101: 129–143.
- Ward, D.M. 1998. Microbiology in Yellowstone National Park. ASM News. 64:141–146.
- Ward, D.M. et al. 1992. Modern phototrophic microbial mats: anoxygenic, intermittently oxygenic/anoxygenic, thermal, eucaryotic and terrestrial. In The Proterozoic Biosphere: a Multidisciplinary Study, J.W. Schopf and C. Klein, eds. Cambridge U Press/Cambridge.
- Ward, D.M. and R.W. Castenholz. 2000. Cyanobacteria in geothermal habitats. In Ecology of Cyanobacteria. Kluwer Academic Publishers.
- Ward, D.M. et al. 2002. Natural history of microorganisms inhabiting hot spring microbial mat communities: clues to the origin of microbial diversity and implications for micro- and macro-biology. In Biodiversity of Microbial Life: Foundation of Earth's Biosphere, J.T. Staley and A-L. Reysenbach, eds. John Wiley and Sons/New York.
- Internet Links**
- www.windowsintowonderland.org, "Hot Colors: Windows into Hidden Worlds" (electronic field trip)
- www.microbeworld.org, the public website of the American Society for Microbiology
- www.tbi.montana.edu, website of the Thermal Biology Institute of Montana State University
- Additional information available on numerous websites. Search topics include thermophiles, extreme life, and astrobiology.
- Vegetation**
- Craighead, John J. et al. 1963. A Field Guide to Rocky Mountain Wildflowers from Northern Arizona and New Mexico to British Columbia. Boston: Houghton Mifflin.
- Cronquist et al. (ongoing, currently 6 volumes) Intermountain Flora. New York Botanical Garden.
- Despain, Don. 1990. Yellowstone Vegetation: Consequences of Environment and History in a Natural Setting. Boulder: Roberts Rinehart.
- Dorn, Bob. 2001. Vascular Plants of Wyoming. 3rd edition.
- Elliot, C.R. and M.M. Hektner. 2000. Wetland Resources of Yellowstone National Park. YNP: Wyoming. Out of print, available at www.nps.gov/yell
- Hagle, Susan K. et al. 2003. A Field Guide to Diseases & Insects of Northern & Central Rocky Mountain Conifers. U.S. Forest Service Report R1-03-08. http://www.fs.fed.us/r1-r4/spf/fhp/field_guide/index.htm
- Hicke, J.A. et al. 2006. Changing temperatures influence suitability for modeled mountain pine beetle outbreaks in the western United States. J Geophysical Research 111:G02019.
- Hitchcock & Cronquist. 1974. Flora of the Pacific Northwest. Seattle: UWashingon Press.
- Hitchcock et al. Vascular Plants of the Northwest (5 volumes). Seattle: UWashington Press.
- Kershaw et al. 1998. Plants of the Rocky Mountains. Lone Pine Publishing.
- Logan, J.A. et al. 2003. Assessing the impacts of global warming on forest pest dynamics. Frontiers in Ecology and the Environment 1:130–137.
- Pauchard, A. and Alaback, P. 2006. Edge types defines alien species invasions along *P. contorta* burned, highway and clearcut forest edges. Forest Eco. & Mgt. 223: 327–335.
- Preston, Richard J. 1968. Rocky Mountain Trees: A Handbook of the Native Species with Plates and Distribution Maps. New York: Dover.
- Romme, William H. and Dennis Knight. 1982. Landscape diversity: The concept applied to Yellowstone National Park. Bioscience. 32:8.
- Shaw, Richard J. 1964. Trees and Flowering Shrubs of Yellowstone and Grand Teton National Parks. Salt Lake City: Wheelwright Press.

- Shaw, Richard J. 1992. *Wildflowers of Yellowstone and Grand Teton National Parks*. Salt Lake City: Wheelwright Press.
- Sheley, Roger L. and Janet K. Petroff. 1999. *Biology and Management of Noxious Rangeland Weeds*. Corvallis: OSU Press.
- Whitson, Tom L. et al. 2002. *Weeds of the West*. Western Society of Weed Science. Jackson, WY/Grand Teton Lithography.

Staff reviewers

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

Fire

- Barbee, Robert and Paul Schullery. 1989. Yellowstone: The smoke clears. *National Parks* 62:18–19.
- Barker, Rocky. 2005. *Scorched Earth: How the fires of Yellowstone changed America*. Island Press/Washington.
- Blanchard, B.M. and R.R. Knight. 1996. Effects of wildfire on grizzly bear movements and foraging strategies in Proc. Second Biennial Conf. on the Greater Yellowstone Ecosystem. Fairfield, WA: Int. Assoc. Wildl. Fire.
- Despain, Don, editor. 1993. *Plants & Their Environments: Proceedings of the First Biennial Scientific Conference on the Greater Yellowstone Ecosystem*. NPS, Mammoth, WY.
- Franke, Mary Ann. 2000. *Yellowstone in the Afterglow: Lessons from the Fires*. YCR-NR-2000-3. NPS, Mammoth, WY.
- Greenlee, J., ed. *The Ecological Implications of Fire in Greater Yellowstone: Proceedings of the Second Biennial Conference on the Greater Yellowstone Ecosystem*. Fairfield, WA: Int. Assoc. Wildl. Fire.
- Knight, D.H. and L.L. Wallace. 1989. The Yellowstone fires: issues in landscape ecology. *BioScience* 39:707–715.
- Littell, J.S. 2002. Determinants of fire regime variability in lower elevation forest of the northern Yellowstone ecosystem. M.S. thesis. MSU/Bozeman.
- Masters, Ronald et al, eds. 2009. *The '88 Fires: Yellowstone & Beyond*. Tall Timbers/Tallahassee, FL.
- Millsbaugh, S.H. et al. 2000. Variations in fire frequency and climate over the last 17,000 years in Yellowstone National Park. *Geology* 28(3): 211–214.
- Morrison, M. 1993. *Fire in Paradise: The Yellowstone Fires and the Politics of Environmentalism*. New York: Harper Collins.
- Nyland, R. D. 1998. Patterns of lodgepole pine regeneration following the 1988 Yellowstone fires. *Elsevier Forest Ecology and Management*. 111:23–33.
- Pyne, S.J. 1989. Letting wildfire loose: the fires of '88. *Montana the Magazine of Western Living*. 39(3):76–79.
- Renkin, R.A. and D.G. Despain. 1992. Fuel moisture, forest type, and lightning-caused fire in Yellowstone National Park. *Canadian J. Forestry Research* 22(1):37–45.
- Romme, W. H. et al. 1997. A rare episode of sexual reproduction in aspen (*Populus tremuloides* Michx.) following the 1988 Yellowstone fires. *Natural Areas Journal* 17:17–25.
- Romme, W.H. 1982. Fire and landscape diversity in subalpine forest of Yellowstone National Park. *Ecological Monographs* 52(2):199–221.
- Romme, W.H. et al. 1995. Aspen, elk, and fire in northern Yellowstone National Park. *Ecology* 76(7):2097–2106.
- Turner, M.G., et al. 2003. Surprises and Lessons from the 1988 Yellowstone Fires. *Frontiers in Ecology and the Environment*. 1(7):351–358.
- Varley, John D. and Paul Schullery. 1991. Reality and opportunity in the Yellowstone Fires of 1988. In *The Greater Yellowstone Ecosystem: Redefining American Heritage*, R. Keiter and M. Boyce, eds. New Haven: Yale U Press.
- Wallace, Linda L., editor. 2004. *After the Fires: The Ecology of Change in YNP*. New Haven: Yale U Press.
- Wuerthner, George. 1988. *Yellowstone and the Fires of Change*. Salt Lake City: Haggis House Publications.

Internet Links

www.fire.nps.gov
www.iawfonline.org
www.nifc.gov

Staff Reviewer

Joe Krish, Fire Management Officer

Mammals

General

- Burt, W.H. 1964. *A Field Guide to the Mammals*. Boston: Houghton Mifflin.
- Clark, T. W. et al, editors. 1999. *Carnivores in Ecosystems: the Yellowstone Experience*. New Haven: Yale University Press.
- Clark, T.W. and M.R. Stromberg. 1987. *Mammals in Wyoming*. Lawrence: UKansas.
- Curlee, A. P. et al, eds. 2000. *Greater Yellowstone Predators: Ecology and Conservation in a Changing Landscape*. Proc., Third Biennial Conference on the Greater Yellowstone Ecosystem. Jackson, WY: Northern Rockies Conservation Coop.
- Garrott, R. et al, editors. 2009. *The Ecology of Large Mammals in Central Yellowstone*. San Diego: Academic Press.
- Reading, Richard and Brian Miller, eds. 2000. *Endangered Animals: A Reference Guide to Conflicting Issues*. Westport, CT: Greenwood Press.
- Ruth, Toni et al. 2003. Large carnivore response to recreational big-game hunting along the YNP and Absaroka-Beartooth Wilderness boundary. *Wildlife Society Bulletin*. 31(4):1–12.
- Schullery, Paul and Lee Whittlesey. 2001. Mountain goats in the Greater Yellowstone Ecosystem: a prehistoric and historical context. Great Basin Naturalist.
- Schullery, Paul and Lee Whittlesey. 1999. Early wildlife history of the GYE. Report, available in YNP Research Library.

Schullery, Paul and Lee Whittlesey. 1995. Summary of the documentary record of wolves and other wildlife species in YNP prior to 1882. In *Ecology and Conservation of Wolves in a Changing World*. Canadian Circumpolar Institute, Occasional Publication 35.

Streubel, Don. 2002. *Small Mammals of the Yellowstone Ecosystem*. Juneau: Windy Ridge Publishing

White, P.J. 2010. Yellowstone's wildlife in transition: an assessment of ecological process management. YCR-2010-08. Yellowstone National Park, Mammoth, Wyoming..

Yellowstone National Park. 1997. *Yellowstone's Northern Range: Complexity and Change in a Wildland Ecosystem*.

Bats

Keinath, Douglas A. 2005. Bat Inventory of the Greater Yellowstone Network. Report. uwadmnweb.uwyo.edu/wyndd/

Bears

Blanchard, B.M. and R.R. Knight. 1991. Movements of Yellowstone grizzly bears, 1975–87. *Biol. Conserv.* 58:41–67.

Craighead, John C., Jay S. Sumner, and John A. Mitchell. 1995. *Grizzly Bears of Yellowstone, Their Ecology in the Yellowstone Ecosystem 1959–1992*. Washington: Island Press.

French, S. P., M. G. French, and R. R. Knight. 1994. Grizzly bear use of army cutworm moths in the Yellowstone ecosystem. *Intl. Conf. Bear Res. and Mgt.* 9: 389–399.

Gunther, Kerry and Roy Renkin. 1990. Grizzly bear predation on elk calves and other fauna of Yellowstone National Park. *Intl. Conf. Bear Res. and Mgt.* 8:329–334.

Gunther, K.A. and D. W. Smith. 2004. Interactions between wolves and female grizzly bears with cubs in Yellowstone National Park. *Ursus.* 15(2): 232–238.

Gunther, K.A. et al. 2002. Probable grizzly bear predation on an American black bear in Yellowstone National Park. *Ursus.* 12: 372–374.

Halfpenny, James C. 2007. *Yellowstone Bears: In the Wild*. Helena, MT: Riverbend Publishing.

Haroldson, M.A. et al. 2005. Changing numbers of spawning cutthroat trout in tributary streams of Yellowstone Lake & estimates of grizzly bears visiting streams from DNA. *Ursus.* 16 (2): 167–180.

Haroldson, M.A. et al. 2002. Grizzly bear denning chronology and movements in the GYE. *Ursus.* 13: 29–37.

Mattson, D. J., and D. P. Reinhart. 1997. Excavation of red squirrel middens by Yellowstone grizzly bears in the whitebark pine zone. *J. Applied Ecol.* 34: 926–940.

Peacock, Doug. 1990. *Grizzly Years*. New York: Holt.

Schullery, Paul. 1992. *The Bears of Yellowstone*. Worland: High Plains Publishing Co.

Schullery, Paul. 1991. *Yellowstone Bear Tales*. Boulder: Roberts Rinehart.

Schwartz, C.C. et al. 2003. *Grizzly bear in Wild Mammals of North America: Biology, Management, and Conservation*. 2nd edition. Baltimore: Johns Hopkins U Press.

Varley, N. and K.A. Gunther. 2002. Grizzly bear predation on a bison calf in Yellowstone National Park. *Ursus.* 13: 377–381.

Wyman, T. 2002. Grizzly bear predation on a bull bison in Yellowstone National Park. *Ursus.* 13: 375–377.

Staff reviewer:

Kerry Gunther, Bear Management Biologist

Beaver

Murphy, S.L. Consolo and D.D. Hanson. 1991. Current distribution of beaver in Yellowstone National Park. *Wolves for Yellowstone. A Report to the United States Congress*. Washington: National Park Service.

Smith, D.W. 2001. *Beaver Survey in Yellowstone National Park*. Yellowstone Center for Resources.

Smith, D.W. & Daniel B. Tyers. 2008. *The Beavers of Yellowstone*. *Yellowstone Science.* 16(3): 4–15.

Staff reviewer

Douglas W. Smith, Senior Wildlife Biologist

Bighorn Sheep

Barmore, W.J. Jr. 2003. Ecology of ungulates and their winter range in Northern Yellowstone National Park, Research and Synthesis 1962–1970. Yellowstone Center for Resources.

Heiner, Michael G. 1999. *Habitat use by Rocky Mountain sheep on the Yellowstone Northern Range*. Thesis, Yellowstone Research Library

Ostovar, K. 1998. Impacts of human activity on bighorn sheep in Yellowstone National Park. Master's thesis, Montana State Univ., Bozeman.

White, P.J. et al. 2008. Initial effects of reintroduced wolves on bighorn sheep dynamics in Yellowstone National Park. *Wildlife Biology.* 14: 138.

Staff reviewer:

P.J. White, Supervisory Wildlife Biologist

Bison

Cross, P.C., E.K. Cole, A.P. Dobson, W.H. Edwards, K.L. Hamlin, G. Luikart, A.D. Middleton, B.M. Scurlock, and P.J. White. 2010. Probable causes of increasing brucellosis in free-ranging elk of the Greater Yellowstone Ecosystem. *Ecological Applications* 20:278–288.

Dary, David. 1974. *The Buffalo Book: The Full Saga of an American Animal*. Chicago: Sage Books.

Dawes, S. R. and L. R. Irby. 2000. Bison forage utilization in the upper Madison drainage, Yellowstone National Park. *Intermountain J Science* 6(1):18–32.

Franke, Mary Ann. 2005. *To Save the Wild Bison*. UOklahoma Press.

Gates, C. C., et al. 2005. *The Ecology of Bison Movements and Distribution in and Beyond Yellowstone National Park, A Critical Review with Implications for Winter Use and Transboundary Population Management*. UCalgary, Alberta.

- Geist, Valerius. 1996. Buffalo Nation: History and Legend of the North American Bison. Voyageur Press.
- Geremia, C., P.J. White, R.L. Wallen, F.G.R. Watson, J.J. Treanor, J. Borkowski, C.S. Potter, and R.L. Crabtree. 2011. Predicting bison migration out of Yellowstone National Park using Bayesian models. *PLoS ONE* 6:el 6848.
- Irby, L. and J. Knight, eds. 1998. International Symposium on Bison Ecology and Management in North America. Bozeman: Montana State Univ.
- Jones, J.D., J.J. Treanor, R.L. Wallen, and P.J. White. 2010. Timing of parturition events in Yellowstone bison—implications for bison conservation and brucellosis transmission risk to cattle. *Wildlife Biology* 16:333-339.
- Meagher, Mary. 1973. The bison of Yellowstone National Park. National Park Service, Scientific Monograph Series No. 1.
- Plumb, G.E., P.J. White, M.B. Coughenour, and R.L. Wallen. 2009. Carrying capacity, migration, and dispersal in Yellowstone bison. *Biological Conservation* 142:2377-2387.
- Price, David and Paul Schullery. 1993. The bison of Yellowstone and the challenge of conservation. *Bison World*, Nov/Dec.
- Proffitt, K.M., P.J. White, and R.A. Garrott. 2010. Spatio-temporal overlap between Yellowstone bison and elk - implications of wolf restoration and other factors for brucellosis transmission risk. *Journal of Applied Ecology* 47:281-289.
- Rudner, Ruth. 2000. A Chorus of Buffalo. Burford Books.
- Treanor, J.J., J.S. Johnson, R.L. Wallen, S. Cilles, P.H. Crowley, J.J. Cox, D.S. Maehr, P.J. White, and G.E. Plumb. 2010. Vaccination strategies for managing brucellosis in Yellowstone bison. *Vaccine* 28S:F64-F72.
- White, P.J., G.E. Plumb, M.B. Coughenour, and R.L. Wallen. 2010. Carrying capacity and movements of Yellowstone bison. *Yellowstone Science* 19:8-14.
- White, P.J., J.J. Treanor, and R.L. Wallen. 2011. Balancing brucellosis risk management and wildlife conservation. *Yellowstone Science* 19:15-21.
- White, P.J., R.L. Wallen, C. Geremia, J.J. Treanor, and D.W. Blanton. 2011. Management of Yellowstone bison and brucellosis transmission risk - implications for conservation and restoration. *Biological Conservation* 144:1322-1334.
- Staff reviewer:**
Rick Wallen, Bison Ecology & Management
- Cougar**
Biek, R. et al. 2006. Examining effects of persistent retrovirus infection on fitness and pathogen susceptibility in a natural feline host. *Can. J. Zoology*. 84:365-373.
- Biek, R., et al. 2006. Factors associated with microparasite seroprevalence and infection risk in Rocky Mountain cougars. *J. Wildlife Diseases* 42(3):606-615.
- Biek, R. et al. 2006. Long term genetic effects of sex-biased dispersal in a solitary carnivore: Yellowstone cougars. *Biology Letters*.
- Frostic, Maria. 2005. Dr. Toni Ruth: Cougar Biologist. Podcast: Terra Videos, episode 214. terravideos.blogspot.com
- Hansen, K. 1992. Cougar: The American Lion. Flagstaff: Northland Publishing Co.
- Kobalenko, Jerry. 2005. Forest Cats of North America. Richmond Hill, Ontario: Firefly.
- Murphy, Kerry. 1998. The ecology of the cougar (*Puma concolor*) in the northern Yellowstone ecosystem: interactions with prey, bears, and humans. Ph.D. dissertation. Uldaho, Moscow.
- Murphy, Kerry et al. 1998. Encounter competition between bears and cougars: some ecological implications. *Ursus* 10:55-60.
- Ruth, Toni. 2004. Ghost of the Rockies. *Yellowstone Science* 12:1, Winter: 13-27.
- Ruth, T.K. et al. 2003. Large carnivore response to recreational big game hunting along the Yellowstone National Park and Absaroka-Beartooth Wilderness boundary. *Wildlife Society Bulletin* 31(4):1150-1161.
- Ruth, T. K. et al. 1999. Cougar-wolf interactions in Yellowstone National Park: competition, demographics, and spatial relationships. Annual technical report, Hornocker Wildlife Institute, Yellowstone cougars, Phase II.
- Staff reviewer**
Kerry Gunther, Bear Management Biologist
- Coyote**
Allen, J. J., M. Bekoff, and R. L. Crabtree. 1999. An observational study of coyote (*Canis latrans*) scent-marking and territoriality in Yellowstone National Park. *Ethology*. 105:289-302.
- Bekoff, Marc, editor. 2001. Coyotes: Biology, Behavior, and Management. Caldwell, NJ: Blackburn Press.
- Crabtree, R. L., and J. W. Sheldon. 2006. Introduction in *The Voice of the Coyote* by J. Frank Dobie. Lincoln: U Nebraska Press.
- Crabtree, R. L., and J. W. Sheldon. 1999. The ecological role of coyotes on Yellowstone's northern range. *Yellowstone Science* 7:15-23.
- Crabtree, R. L., and J. W. Sheldon. 1999. Coyotes and canid coexistence in Yellowstone. Pages 126-163 in T. W. Clark, et al, editors. *Carnivores in Ecosystems: the Yellowstone Experience*. New Haven: Yale University Press.
- Gese, E. M. 1999. Threat of predation: do ungulates behave aggressively towards different members of a coyote pack? *Can. J. Zool.* 77:499-503.
- Gese, E. M. 1998. Response of neighboring coyotes to social disruption in an adjacent pack. *Can. J. Zool.* 76:1960-1963.
- Gese, E. M., and S. Grothe. 1995. Analysis of coyote predation on deer and elk during winter in Yellowstone National Park, Wyoming. *Am. Midl. Nat.* 133: 36-43.
- Gese, E. M. and R. L. Ruff. 1998. Howling by coyotes: variation among social classes, seasons, and pack sizes. *Can. J. Zool.* 76: 1037-1043.

- Gese, E. M. and R. L. Ruff. 1997. Scent-marking by coyotes: the influence of social and ecological factors. *Anim. Behav.* 54:1155–1166.
- Gese, E. M. et al. 1996. Foraging ecology of coyotes: the influence of extrinsic factors and a dominance hierarchy. *Can. J. Zool.* 74:769–783.
- Gese, E. M. et al. 1996. Intrinsic and extrinsic factors influencing coyote predation of small mammals in Yellowstone National Park. *Can. J. Zool.* 74:784–797.
- Gese, E. M. et al. 1996. Social and nutritional factors influencing dispersal of resident coyotes. *Anim. Behav.* 52:1025–1043.
- Gese, E. M. et al. 1996. Interactions between coyotes and red foxes in Yellowstone National Park, Wyoming. *J. of Mamm.* 77(2):377–382.
- Moorcroft, P., M. A. Lewis, and R. L. Crabtree. 1999. Home range analysis using a mechanistic home range model. *Ecology.* 80:1656–1665.
- Moorcroft, P. M., and M. A. Lewis. 2006. *Mechanistic Home Range Analysis*. Princeton, NJ: Princeton U Press.
- Moorcroft, P. R., M. A. Lewis, and R. L. Crabtree. 2006. Mechanistic home range models capture spatial patterns and dynamics of coyote territories in Yellowstone. *Proceedings of the Royal Society Biological Sciences.* 273:1651–1659.
- Coughenour, M.B. and F. J. Singer. 1996. Elk population processes in YNP under the policy of natural regulation. *Ecological Applications.* 6: 573–593.
- Eberhardt, L.L., et al. 2003. Assessing the impact of wolves on ungulate prey. *Ecological Applications* 13:776–783.
- Evans, S.B., et al. 2006. Survival of adult female elk in Yellowstone following wolf restoration. *J Wildlife Mgt* 70:1372–1378.
- Evanoff, R. and F.J. Singer, eds. 1996. *Effects of grazing by wild ungulates in Yellowstone National Park*. Denver: National Park Service, Natural Resource Program Center.
- Garrott, R.A. et al. 2002. A geochemical trophic cascade in Yellowstone's geothermal environments. *Ecosystems.* 5: 659–666.
- Garrott, R.A., et al. 2005. Generalizing wolf effects across the greater Yellowstone area: a cautionary note. *Wildlife Society Bulletin* 33:1245–1255.
- Garrott, R. A. et al, editors. 2009. *Large mammal ecology in central Yellowstone: A synthesis of 16 years of integrated field studies*. Elsevier, San Diego, California, USA.
- Houston, D.B. 1982. *The Northern Yellowstone Elk: Ecology and Management*. New York: Macmillan Publishing Co.
- Mao, J. 2003. *Habitat selection by elk before and after wolf reintroduction in YNP*. Unpublished M.S. thesis. University of Alberta, Edmonton, Alberta.
- Murie, Olaus J. 1957. *The Elk of North America*. Harrisburg, PA: Stackpole Co.
- Singer, F.J. et al. 1997. Density dependence, compensation, and environmental effects on elk calf mortality in YNP. *J Wildlife Management.* 61: 12–25.
- Taper, M.L. and P.J.P. Gogan. 2002. The northern Yellowstone elk: density dependence and climatic conditions. *J Wildlife Management.* 66: 106–122.
- Thomas, Jack Ward, and Dale E. Towell, eds. 1982. *Elk of North America*. Harrisburg, PA: Stackpole Co.
- White, P.J., and R.A. Garrott. 2005. Northern Yellowstone elk after wolf restoration. *Wildlife Society Bulletin.* 33:942–955.
- White, P.J., and R.A. Garrott. 2005. Yellowstone's ungulates after wolves – expectations, realizations, and predictions. *Biological Conservation.* 125:141–152.
- White, P.J. et al. 2003. Evaluating the consequences of wolf recovery on northern Yellowstone elk. *Yellowstone Center for Resources.*
- White, P.J., et al. 2005. Yellowstone after wolves – EIS predictions and ten-year appraisals. *Yellowstone Science.* 13:34–41.
- White, P. J., K. M. Proffitt, and T. O. Lemke. 2012. Changes in elk distribution and group sizes after wolf restoration. *American Midland Naturalist* 167:174–187.
- White, P.J., R.A. Garrott, K.L. Hamlin, R.C. Cook, J.G. Cook, and J.A. Cunningham. 2011. Body condition and pregnancy in northern Yellowstone elk - evidence for predation risk effects? *Ecological Applications* 21:3–8.
- White, P.J., K.M. Proffitt, L.D. Mech, S.B. Evans, J.A. Cunningham, and K.L. Hamlin. 2010. Migration of northern Yellowstone elk - implications of spatial structuring. *Journal of Mammalogy* 91:827–837.

Staff reviewer

Douglas W. Smith, Senior Wildlife Biologist

Elk

- Barber-Meyer, S. M. et al. 2008. Survival and cause-specific elk calf mortality following wolf restoration to Yellowstone National Park. *Wildlife Monographs* 169.
- Barmore, W.J. Jr. 2003. Ecology of ungulates and their winter range in Northern Yellowstone National Park, Research and Synthesis 1962–1970. *Yellowstone Center for Resources.*

Staff reviewer

P.J. White, Supervisory Wildlife Biologist

Felids: Bobcat & Lynx

- Anderson, E. M. and M. J. Lovallo. 2003. Bobcat and lynx in Wild Mammals of North America: Biology, Management, and Conservation. Baltimore: Johns Hopkins University Press.
- Anderson, E. M. 1987. Critical review and annotated bibliography of the literature on the bobcat (Special Report No. 62). Colorado Division of Wildlife, Denver, CO.
- Hansen, Kevin. 2006. *Bobcat: Master of Survival*. New York: Oxford.
- Kobalenko, Jerry. 2005. *Forest Cats of North America*. Richmond Hill, Ontario: Firefly.
- Murphy, K. M., et al. 2006. Distribution of Canada lynx in Yellowstone National Park. *Northwest Science.* 80:199–206.

Ruggiero, L. F. et al. ed. 2000. Ecology and Conservation of Canada Lynx in the U. S. Boulder: UColorado.

Squires, J. R., and R. Oakleaf. 2005. Movements of a male Canada lynx crossing the Greater Yellowstone area, including highways. *Northwest Science*. 79:196–201.

Staff reviewer

Kerry Gunther, Bear Management Biologist

Fox

Crabtree, R. L. 1998. On the trail of a gray ghost. *National Wildlife*. 36(3):48.

Crabtree, R. L. 1997. A new forest carnivore: Yellowstone's mountain fox. *National Wildlife*. 35.

Crabtree, R. L. 1993. Gray ghost of the Beartooth: on the taxonomic trail of the mountain fox. *Yellowstone Science*. 1:13–16.

Crabtree, R. L., and J. W. Sheldon. 1999. Coyotes and canid coexistence in Yellowstone. Pages 127–163 in Clark, T. W., et al, editors. *Carnivores in ecosystems: the Yellowstone experience*. New Haven: Yale U Press.

Fuhrmann, R.T. 2002. Tracking down Yellowstone's red fox: Skis, satellites and historical sightings. *Yellowstone Science*. 10:1.

Fuhrmann, R. T. 1998. Distribution, morphology, and habitat use of the red fox in the northern Yellowstone ecosystem. M.S. Thesis. Bozeman: Montana State University.

Gehrt, Stanley D. and William R. Clark. 2003. Raccoons, coyotes, and reflections on the mesopredator release hypothesis. *Wildlife Society Bulletin*. 31(3): 836–842.

Gese, E.M. et al. 1996. Interactions between coyotes and red foxes in Yellowstone National Park, Wyoming. *JMammology*. 77(2): 377–382.

Henry, J. D. 1986. *Red Fox: The Catlike Canine*. Washington: Smithsonian Institution Press.

Kamler, Jan F. and Warren B. Ballard. 2002. A review of native and non-native red foxes in North America. *Wildlife Society Bulletin*. 30(2): 370–379.

Swanson, B. J., R. T. Fuhrmann, and R. L. Crabtree. 2005. Elevational isolation of red fox populations in the Greater Yellowstone Ecosystem. *Conservation Genetics*. 6:123–131.

Van Etten, K. W. 2006. Habitat selection by red fox in Yellowstone National Park and mechanisms of coexistence with coyotes. M.S. Thesis. Fort Collins: Colorado State U.

Van Etten, K. W., K. R. Wilson, and R. L. Crabtree. 2007. Habitat use of red foxes in Yellowstone National Park based on snow tracking and telemetry. *J Mammalogy*. 88:1498–1507.

Staff reviewer

Douglas W. Smith, Senior Wildlife Biologist

Moose

Barmore, W.J. Jr. 2003. Ecology of ungulates and their winter range in Northern Yellowstone National Park, Research and Synthesis 1962–1970. Yellowstone Center for Resources.

Houston, Douglas B. Aspects of the social organizations of moose. National Park Service Paper No. 37.

Houston, Douglas B. 1968. The Shiras moose in Jackson Hole, Wyoming. Technical Bulletin No. 1. Moose, WY: Grand Teton Natural History Association.

Tyers, Dan. 2003. Winter ecology of moose on the Northern Yellowstone Winter Range. Doctoral dissertation. Montana State University: Bozeman.

Staff reviewer

P.J. White, Supervisory Wildlife Biologist

Otter

Crait, J. R. et al. 2006. Late seasonal breeding of river otters in Yellowstone National Park. *Am. Midland Naturalist* 156: 189–192.

Crait, J. R. and M. Ben-David. 2003. The impact of introduced lake trout on river otters in Yellowstone National Park. Progress report. National Park Service.

Crait, J. R. and M. Ben-David. 2006. River otters in Yellowstone Lake depend on a declining cutthroat trout population. *J. Mammalogy*. 87: 485–494.

Pronghorn

Barmore, W.J. Jr. 2003. Ecology of ungulates and their winter range in Northern Yellowstone National Park, Research and Synthesis 1962–1970. Yellowstone Center for Resources.

Barnowe-Meyer, K. K. 2009. The behavioral ecology and population genetics of pronghorn in Yellowstone National Park. University of Idaho, Moscow, Idaho.

Barnowe-Meyer, K. K. et al. 2009. Predator-specific mortality of pronghorn on Yellowstone's northern range. *Western North American Naturalist*. In press.

Barnowe-Meyer, K.K., P.J. White, and J.A. Byers. 2011. Maternal investment by Yellowstone pronghorn following winter habitat deterioration. *Western North American Naturalist* 71:222–233.

Barnowe-Meyer, K.K., P.J. White, T.L. Davis, D.W. Smith, R.L. Crabtree, and J.A. Byers. 2010. Influences of wolves and high-elevation dispersion on reproductive success of pronghorn (*Antilocapra americana*). *Journal of Mammalogy* 91:712–721.

Barnowe-Meyer, K.K., P.J. White, T.L. Davis, and J.A. Byers. 2009. Predator-specific mortality of pronghorn on Yellowstone's northern range. *Western North American Naturalist* 69:186–194.

Boccardi, S.J. 2002. Effects of winter range on a pronghorn population in YNP. MS thesis. Montana State University, Bozeman.

Boccardi, S. J. et al. 2008. Yellowstone pronghorn alter resource selection after sagebrush decline. *J Mammalogy* 89:1031–1040.

Byers, J.A. 2002. Fecundity and fawn mortality of northern Yellowstone pronghorn. Yellowstone Center for Resources.

- Caslick, J., and E. Caslick. 1999. Pronghorn distribution in winter 1998–1999. Mammoth, WY: National Park Service. YCR–NR–99–2.
- Goodman, D. 1996. Viability analysis of the antelope population wintering near Gardiner, Mont. Final report to NPS.
- Houston, D.B. 1973. Letter to Superintendent regarding status of pronghorn in YNP. January 24. Park archives box 119, Yellowstone National Park, WY.
- Keating, K. 2002. History of pronghorn population monitoring, research, and management in Yellowstone National Park. Report to the NPS by USGS Northern Rocky Mountain Science Center, Bozeman, MT.
- White, P. J. et al. 2007. Irruptive population dynamics in Yellowstone pronghorn. *Ecological App.* 17:1598–1606.
- White, P.J., et al. 2007. Partial migration and philopatry of Yellowstone pronghorn. *Bio. Conservation* 135:518–526.
- Staff reviewer**
P.J. White, Supervisory Wildlife Biologist
- Wolf**
- Bangs, E.E. and D.W. Smith. In press. Re-introduction of the gray wolf into Yellowstone National Park and central Idaho. IUCN Reintroduction Specialist Group.
- Brainard, S.M. et al. 2008. The effects of breeder loss on wolves. *J Wildlife Management.* 72:89–98.
- Ferguson, Gary. 1996. *The Yellowstone Wolves: The First Year.* Helena, MT: Falcon Press.
- Fischer, Hank. 1995. *Wolf Wars.* Helena, MT: Falcon Press.
- Halfpenny, James C. 2003. *Yellowstone Wolves: In the Wild.* Helena, MT: Riverbend Publishing.
- Hebblewhite, M. and D.W. Smith. In press. Wolf community ecology: Ecosystem effects of recovering wolves in Banff and Yellowstone National Parks in M. Musiani, L. Boitani, and P. Paquet, editors, *The world of wolves: new perspectives on ecology, behavior and policy.* Calgary: U Calgary Press
- Kauffman, M.J. et al. 2007. Landscape heterogeneity shapes predation in a newly restored predator-prey system. *Ecology Letters.* 10:1–11.
- Lopez, Barry. 1978. *Of Wolves and Men.* New York: Scribners.
- MacNulty, D.R. and L.D. Mech, D.W. Smith. 2007. A proposed ethogram of large-carnivore predatory behavior, exemplified by the wolf. *J Mammalogy.* 88:595–605.
- McIntyre, Rick, ed. 1995. *War against the Wolf: America's Campaign to Exterminate the Wolf.* Stillwater, MN: Voyageur Press.
- McIntyre, Rick. 1993. *A Society of Wolves: National Parks and the Battle over the Wolf.* Stillwater, MN: Voyageur Press.
- McNamee, Thomas. 1997. *The Return of the Wolf to Yellowstone.* New York: Henry Holt.
- Mech, L. David. 1981. *The Wolf: The Ecology and Behavior of an Endangered Species.* Minneapolis: U. Minnesota Press.
- Mech, L. David and L. Boitani. 2003. *Wolves: Behavior, Ecology, & Conservation.* U. Chicago Press.
- Peterson, Rolf et al. 2002. Leadership behavior in relation to dominance and reproductive status in gray wolves. *Can. J. Zool.* 80: 1405–1412.
- Phillips, Michael K. and Douglas W. Smith. 1996. *The Wolves of Yellowstone.* Stillwater, MN: Voyageur Press.
- Schullery, Paul, ed. 1996. *The Yellowstone Wolf: A Guide and Sourcebook.* Worland: High Plains Publishing Co.
- Shoemaker, Jennifer. 2005. *The New Wolf Hunters.* Podcast: Terra Videos, episode 208. terravideos.blogspot.com
- Smith, D.W. 2005. Ten years of Yellowstone Wolves. *Yellowstone Science,* 13(1):7–33.
- Smith, D.W. 2007. Wolf and human conflicts: A long, bad history. Pages 402–409 in M. Bekoff, editor, *Encyclopedia of human–animal relationships.* Westport, CT: Greenwood Press.
- Smith, D.W. and Gary Ferguson. 2005. *Decade of the Wolf: Returning the Wild to Yellowstone.* Guilford, CT: Lyons.
- Smith, D.W. and D.R. Stahler, M.S. Becker. In press. Wolf recolonization of the Madison headwaters area in Yellowstone in R.A. Garrott & P.J. White, editors, *Large Mammal Ecology in Central Yellowstone.* Elsevier Academic Press–Terrestrial Ecology Series.
- Smith, D.W. and E.E. Bangs. In press. Reintroduction of wolves to Yellowstone National Park: History, values and ecosystem restoration in M. Hayward and M. Somers, editors, *Reintroduction of Top-order Predators.* Blackwell Scientific.
- Smith, D.W. et al. 2006. Wolf restoration in Yellowstone National Park. Pgs. 242–254 in D.R. McCullough, K. Kaji, and M. Yamanaka, editors, *Wildlife in Shiretoko and Yellowstone National Parks: Lessons in Wildlife Conservation from Two World Heritage Sites.* Hokkaido, Japan: Shiretoko Nature Foundation.
- Smith, D.W. et al. 2000. Wolf–bison interactions in Yellowstone National Park. *J Mammalogy.* 81(4):1128–1135.
- Stahler, D. R. 2000. Interspecific interactions between the common raven and the gray wolf in Yellowstone National Park, Wyoming: investigations of a predator and scavenger relationship. Master's thesis. Univ. of Vermont.
- VonHoldt, B.M. et al. 2008. The genealogy and genetic viability of reintroduced Yellowstone grey wolves. *Molecular Ecology.* 17:252–274.
- Wright, G.J. et al. 2006. Selection of northern Yellowstone elk by gray wolves and hunters. *J Wildlife Management.* 70:1070–1078.
- Staff reviewer**
Douglas W. Smith, Senior Wildlife Biologist

Wolverine

- Consolo-Murphy, S. L., and M. Meagher. 1995. The status of wolverine, Canada lynx, and fisher in Yellowstone National Park in Proc. 3rd Biennial Conference on the GYE. Jackson, WY: Northern Rockies Conservation Cooperative.
- Copeland, J. P., and J. S. Whitman. 2003. Wolverine in Wild Mammals of North America: Biology, Management, and Conservation. Baltimore: Johns Hopkins University Press.

Staff reviewer

Kerry Gunther, Bear Management Biologist

Birds

- Baril, Lisa M. and Leslie Henry, Douglas W. Smith. 2009. Annual Bird Program Report. (Yellowstone National Park). unpublished.
- Crick, H. 2004. The impact of climate change on birds. *Ibis*. 146: 48–56.
- Follett, Dick. 1986. Birds of Yellowstone and Grand Teton National Parks. Boulder: Roberts Rinehart.
- Groshong, L.C. 2004. Mapping riparian vegetation change in Yellowstone's Northern Range using high spatial resolution imagery. Dissertation. University of Oregon, Eugene.
- Hansen, Skylar. 1984. The Trumpeter Swan—A White Perfection. Flagstaff: Northland Press.
- Harmata, Al. 1994. Yellowstone's bald eagles. *Yellowstone Science*. 2(3).
- Law, R.J. et al. 2009. Trumpeter swan abundance and growth rates in Yellowstone National Park. *J Wildlife Management*. 73: 728–736.
- McEneaney, Terry et al. 1998. Greater Yellowstone peregrine falcons: their trials, tribulations, and triumphs. *Yellowstone Science*. 6(2).
- McEneaney, Terry. Yellowstone Bird Report. Yellowstone National Park. Annual, 1999–2006. www.nps.gov/yell/naturescience/birdreports.htm
- McEneaney, Terry. 1988. Birds of Yellowstone: A Practical Habitat Guide to the Birds of Yellowstone National Park, and Where to Find Them. Boulder: Roberts Rinehart Publishers.
- McEneaney, Terry. 1997. Harlequin ducks: noble ducks of turbulent waters. *Yellowstone Science* 5(2): 2–7.
- McEneaney, Terry. 2000. The common raven: Field notes on an important Yellowstone predator in Greater Yellowstone Predators: Ecology and Conservation in a Changing Landscape. Proc., third biennial conference on the Greater Yellowstone Ecosystem. Jackson, WY: Northern Rockies Conservation Cooperative.
- Proffitt, K.M., T.P. McEneaney, P.J. White, and R.A. Garrott. 2010. Productivity and fledging success of trumpeter swans in Yellowstone National Park, 1987–2007. *Waterbirds* 33:341–348.
- Proffitt, K.M., T.P. McEneaney, P.J. White, and R.A. Garrott. 2009. Trumpeter swan abundance and growth rates in Yellowstone National Park. *Journal of Wildlife Management* 73:728–736.
- Sheffield, L. M. et al. 2001. Response of American kestrels and gray-tailed voles to vegetation height and supplemental perches. *Can. J. Zoology* 79: 380–385.
- Skinner, M.P. 1925. The Birds of Yellowstone National Park. *Roosevelt Wildlife Bulletin*. 3(1).
- Saab, V. et al. 2007. Birds and burns of the interior West: descriptions, habitats, and management in western forests. Gen. Tech. Rep. PNW-GTR-712. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station.
- Smucker, K.M., and R.L. Hutto, B.M. Steele. 2005. Changes in bird abundance after wildfire: importance of fire severity and time since fire. *Ecological Applications*. 15: 1535–1549.
- U.S. Fish and Wildlife Service. 2003. Monitoring plan for the American Peregrine Falcon, a species recovered under the Endangered Species Act. U.S. Fish and Wildlife Service, Pacific Region, Portland, OR.
- White, P.J., K.M. Proffitt, T.P. McEneaney, R.A. Garrott, and D.W. Smith. Yellowstone's trumpeter swans in peril? Drastic decrease in resident swans over the past 40 years. *Yellowstone Science* 19:12–16.

Staff reviewer

Douglas W. Smith, Senior Wildlife Biologist

Fish

- Koel, Todd et al. Annual. Yellowstone Fisheries and Aquatic Sciences Report. National Park Service: Yellowstone.
- Lilly, Bud and Paul Schullery. 2000. Bud Lilly's Guide to Fly Fishing the New West. Portland, OR: Frank Amato Publications.
- Mathews, Craig and Clayton Molinero. 1970. The Yellowstone Fly Fishing Guide. New York: Lyons.
- Parks, Richard. 1998. Fishing Yellowstone National Park. Helena, MT: Falcon.
- Schullery, Paul. 2008. Vaguely disquieting scenes: Fishing bridge & the evolution of American sport fishing. *Yellowstone Science*. 16(3): 24–33.
- Varley, John and Paul Schullery. 1998. Yellowstone Fishes. Harrisburg, PA: Stackpole.
- Yellowstone National Park. Fishing Regulations. Annual.

Reptiles and Amphibians

- Koch, Edward D. and Charles R. Peterson. 1995. Amphibians and Reptiles of Yellowstone and Grand Teton National Parks. Salt Lake City: U Utah Press
- McMenamin, Sarah et al. 2008. Climatic change and wetland desiccation cause amphibian decline in Yellowstone National Park. *PNAS*. 105: 16988–16993.
- Patla, D.A. 2000. Amphibians in native fish restoration areas, Yellowstone National Park. Part II, Greater Yellowstone Amphibian Monitoring and Survey Project. Mammoth Hot Springs, WY. Herpetology Laboratory, Dept. of Biological Sciences, Idaho State Univ., Pocatello.
- Patla, D. A. 1997. Changes in a population of spotted frogs in YNP between 1935 and 1995: the effects of habitat modification. Master's thesis. Idaho State Univ., Pocatello.
- Patla, D.A. and Charles R. Peterson. 2004. Amphibian and reptile inventorying and monitoring: Grand Teton and Yellowstone National Parks 2000–2003. Report.

Staff reviewer

Jeff Arnold, Ecologist

Park Issues

Aquatic Invaders

www.100thmeridian.org

nas.er.usgs.gov

www.sgnis.org

- Benhke, R.J. 1992. Native Trout of Western North America. Monograph 6. Bethesda, MD: American Fisheries Society.
- Crait, J. R. and M. Ben-David. 2006. River otters in Yellowstone Lake depend on a declining cutthroat trout population. *J Mammalogy*. 87: 485–494.
- Crait, J. R. et al. 2004. Influence of bio-pollution on ecosystem processes: the impact of introduced lake trout on streams, predators, and forests in Yellowstone National Park. Progress report. Environmental Protection Agency.
- Crait, J. R. and M. Ben-David. 2003. The impact of introduced lake trout on river otters in Yellowstone National Park. Progress report. National Park Service.
- Elle, Steven. 1997. Comparative infection rates of cutthroat and rainbow trout exposed to *Myxobolus cerebralis* in Big Lost River, Idaho during June, July, and August. Whirling Disease Symposium, Logan, UT.
- Gunther, Kerry. Grizzly bears and cutthroat trout: Potential impact of the introduction of non-native trout to Yellowstone Lake. Bear Management Office Information Paper. Number BMO-9.
- Koel, Todd et al. Yellowstone Fisheries & Aquatic Sciences. Yellowstone National Park. Annual.
- MacConnell, E. et al. 1997. Susceptibility of grayling, rainbow, and cutthroat trout to whirling disease by natural exposure to *Myxobolus cerebralis*. Whirling Disease Symposium, Logan, UT.
- Mahony, D.L. and C.J. Hudson. 2000. Distribution of *Myxobolus cerebralis* in Yellowstone cutthroat trout *Oncorhynchus clarki bouvieri* in Yellowstone Lake and its tributaries. Whirling Disease Symposium, Coeur d'Alene, Idaho.

- Martinez, P.A. et al. 2009. Western lake trout woes. *Fisheries*. 34(9): 424–442.
- Mattson, D. J., and D. P. Reinhart. 1995. Influences of cutthroat trout on behavior and reproduction of Yellowstone grizzly bears 1975–1989. *Can. J. Zool.* 73:2072–2079.
- Nickum, D. 1999. Whirling disease in the United States: a summary of progress in research and management. Arlington, VA: Trout Unlimited.
- Reinhart, D.P. and D.J. Mattson. 1990. Bear use of cutthroat trout spawning streams in YNP. *Int. Conf. Bear Res. and Manage.* 8:343–350.
- Varley, J. D. and P. Schullery. 1996. Yellowstone Lake and its cutthroat trout in Science and Ecosystem Management in the National Parks. Halvorson, W. L., and G. E. Davis, eds. Tucson: U Arizona Press.
- Varley, J. D., and P. Schullery, eds. 1995. The Yellowstone Lake crisis: confronting a lake trout invasion. A report to the director of the NPS. Mammoth, WY: NPS.
- Vincent, E.R. 1996. Whirling disease and wild trout: the Montana experience. *Fisheries* 21(6): 32–33.
- Felicetti, L.A. et al. 2004. Use of naturally occurring mercury to determine the importance of cutthroat trout to Yellowstone grizzly bears. *Can. J. Zool.* 82(3):493–501.
- Gunther, K.A. et al. 2004. Grizzly bear–human conflicts in the GYE, 1992–2000. *Ursus*. 15(1):10–22.
- Gunther, K.A., and D.L. Smith. 2004. Interactions between wolves and female grizzly bears with cubs in YNP. *Ursus*. 15(2):232–238.
- Gunther, K.A. et al. 2004. Management of habituated grizzly bears in North America in: J. Rahm ed., *Trans. of the 69th North American Wildlife and Natural Resources Conference*. Washington: Wildlife Management Institute.
- Gunther, K.A. et al. 2002. Probable grizzly bear predation on an American black bear in Yellowstone National Park. *Ursus*. 13:372–374.
- Haroldson, M.A. et al. 2005. Changing numbers of spawning cutthroat trout in tributary streams of Yellowstone Lake and estimates of grizzly bears visiting streams from DNA. *Ursus*. 16(2):167–180.
- Haroldson, M.A. et al. 2002. Grizzly bear denning chronology and movements in the GYE. *Ursus*. 13:29–37.
- Herrero, S. et al. 2005. Brown bear habituation to people—safety, risks, and benefits. *Wildlife Society Bulletin*. 33(1):362–373.
- Kieter, Robert B. 1991. Observations on the future debate over 'delisting' the grizzly bear in the GYE. *The Environmental Professional*. 13.
- Mattson, D.J. et al. 1996. Designing and managing protected areas for grizzly bears: how much is enough? In R. G. Wright, ed. *National Parks and Protected Areas: Their Role in Environmental Protection*. Cambridge: Blackwell Science.
- Podruzny, S.R. et al. 2002. Grizzly bear denning and potential conflict areas in the GYE. *Ursus*. 13:19–28.
- Schwartz, C.C. et al. 2002. Distribution of grizzly bears in the GYE, 1990–2000. *Ursus*. 13:203–212.
- Servheen, C., M. et al. 2004. Yellowstone mortality and conflicts reduction. Report. Missoula, MT: U.S. Fish and Wildlife Service.

Staff reviewer

Todd M. Koel, Supervisory Fishery Biologist

Bear Management

- Anderson, C. et al. 2005. Reassessing methods to estimate population size and sustainable mortality limits for the Yellowstone grizzly bear. Report. Interagency Grizzly Bear Study Team. Bozeman, MT: MT State U.
- Blanchard, B.M. and R.R. Knight. 1995. Biological consequences of relocating grizzly bears in the Yellowstone ecosystem. *J. Wildl. Manage.* 59:560–565.
- Cole, G. F. 1974. Management involving grizzly bears and humans in Yellowstone National Park, 1970–1973. *BioScience* 24:6.
- Felicetti, L.A. et al. 2003. Use of sulfur and nitrogen stable isotopes to determine the importance of whitebark pine nuts to Yellowstone grizzly bears. *Can. J. Zool.* 81:763–770.

- Varley, N., and K.A. Gunther. 2002. Grizzly bear predation on a bison calf in YNP. *Ursus*. 13:377–381.
- Wyman, T. 2002. Grizzly bear predation on a bull bison in YNP. *Ursus*. 13:375–377.

Staff reviewer

Kerry Gunther, Bear Management Biologist

Bioprospecting

- www.nature.nps.gov/benefitsssharing
Bison Management
Staff reviewer: Rick Wallen, Bison Ecology & Management
www.ibmp.info
www.nps.gov/yell
Cheville, N.F. et al. 1998. Brucellosis in the Greater Yellowstone Area. Washington, DC: National Academy Press.
- Gates, C. Cormack et al. editors. 2010. American Bison Status Survey & Conservation Guidelines. IUCN.
- Geremia, et al [citation needed]
- Irby, L. and J. Knight, eds. 1998. International Symposium on Bison Ecology and Management in North America. Bozeman, MT: MT State U.
- Meagher, M. and M. E. Meyer. 1995. Brucellosis in captive bison. *J Wildl. Dis.* 31(1):106–110.
- Meagher, M. and M. E. Meyer. 1994. On the origin of brucellosis in bison of Yellowstone National Park: A review. *Conserv. Biol.* 8(3):645–653.
- Meyer, M. E. and M. Meagher. 1995. Brucellosis in free-ranging bison (Bison bison) in Yellowstone, Grand Teton, and Wood Buffalo National Parks: A Review. Letter to the Editor in *J. Wildl. Dis.* 32(4):579–598.
- Nishi, John. 2010. Review of Best Practices & Principles for Bison Disease Issues. ABS Working Paper #3. Wildlife Conservation Society.

Staff reviewers

Ann Deutch, Enviro. Protection Assistant; Sue Mills, Enviro. Protection Specialist

Climate Change

- www.climatescience.gov
www.ecoclim.org
www.epa.gov/climatechange

- www.ipcc.ch
www.nps.gov/climatechange/

- Arndt, D. S., M. O. Baringer, and M. R. Johnson, eds. 2010: State of the Climate in 2009. *Bull. Amer. Meteor. Soc.* 91:7 (S1–S224) www.ncdc.noaa.gov/bams-state-of-the-climate/NOAA
- Bartlein, Patrick and Cathy Whitlock, Sarah Shafer. 1997. Future climate in the Yellowstone National Park Region and its potential impact on vegetation. *Conservation Biology*. 11:5 (782–792).
- Burns, Catherine and Kevin Johnston, Oswald Schmitz. 2007. Global Climate change and Mammalian Species Diversity in US National Parks. *Proceedings of the National Academy of Sciences of the United States of America*. 100:20 (11474–11477).
- Cicerone, Ralph. 2005. Climate Change Science & Research: Recent & Upcoming Studies from the National Academies. Report to Congress. July 20 & 21.
- Climate Change Action Committee. 2007. Report. State of Montana.
- EPA. 1999. Climate Change and Public Lands: National Parks at Risk.
- Evanoff, Jim. 2006. YNP Environmental Management System Review. Report, draft.
- Gonzalez, Patrick et al. 2007. Potential impacts of climate change on habitat and conservation of priority areas for Lynx Canadensis. Report to The Nature Conservancy.
- Hoffman, Jennie and Eric Mielbrecht. 2007. Unnatural Disaster: Global Warming and Our National Parks. National Parks & Conservation Association.
- IPCC. 2007. Climate Change 2007: The Physical Science Basis (FAQ). —Summary for Policymakers of the Synthesis Report of the IPCC Fourth Assessment Report. November 16. www.ipcc.ch/index.htm
—Summary for Policymakers. Working Group 1. October.
—Summary for Policymakers. Working Group III.
- Kilham, Susan et al. 1996. Linking planktonic diatoms and climate change in the large lakes of the Yellowstone Ecosystem using resource theory. *Limnology and Oceanography*. 41:5 (1052–1062).
- Lynch, Heather et al. 2006. Influence of Previous Pine Beetle Activity on the 1988 Yellowstone Fires. *Ecosystems*. 9: 1318–1327.
- Mattson, David and Matthew Reid. 1991. Conservation of the Yellowstone Grizzly Bear. *Conservation Biology*. 5:3(364+).
- McMenamin, Sarah et al. 2008. Climatic change and wetland desiccation cause amphibian decline in Yellowstone National Park. *PNAS*. 105: 16988–16993.
- Meyer, Grant and Jennifer Pierce. 2003. Climatic controls on fire-induced sediment pulses in Yellowstone National Park and central Idaho: a long-term perspective. *Forest Ecology and Management*. 178:89–104.
- Millsbaugh, Sarah and Cathy Whitlock, Patrick Bartlein. 2000. Variations in fire frequency and climate over the past 17,000 yr in central YNP. *Geology*. 28(3):211–214.
- Murphy, Sue Consolo and Kevin Schneider. 2002. Reading History through Crevice Lake sediment records. *Yellowstone Science*. 10(1):2–7.
- National Academy of Sciences. 2000. Ecological Indicators for the Nation: Executive Summary.
- National Park Service. Climate Friendly Program. www.nps.gov/climatefriendlyparks
- North American Bird Conservation Initiative, U.S. Committee, 2010. The State of the Birds 2010 Report on Climate Change. Washington, DC: USDOL. www.stateofthebirds.org
- Rennicke, Jeff. 2007. A Climate of Change. National Parks & Conservation Association.
- Romme, William and Monica Turner. 1991. Implications of global climate change for biogeographic patterns in the greater Yellowstone ecosystem. *Conservation Biology*. 5:3(373–386).
- Saunders, Stephen and Maureen Maxwell. 2005. Less Snow, Less Water: Climate Disruption in the West. Rocky Mountain Climate Organization. September.
- Saunders, Stephen et al. 2006. Losing Ground: Western National Parks Endangered by Climate Disruption. Rocky Mountain Climate Organization and NRDC. July.

- Schweiger, Larry. 2009. Last Chance: Preserving Life on Earth. Golden, Co: Fulcrum.
- Shafer, S. L., P. J. Bartlein, and C. Whitlock. 2005. Understanding the spatial heterogeneity of global environmental change in mountain regions. Pages 21–30. In: U. M. Huber, H. K. M. Bugmann, and M. A. Reasoner (eds.), Global Change and Mountain Regions: An Overview of Current Knowledge. Springer, Dordrecht.
- Shafer, Sarah, and Patrick Bartlein, Robert Thompson. 2001. Potential Changes in the Distributions of Western North America Tree and Shrub Taxa under Future Climate Scenarios. *Ecosystems*. 4:200–215.
- Singer, Frances. 1999. Is there a connection between El Nino and global temperatures? The Science & Environmental Policy Project.
- Stott, Peter et al. 2000. External control of 20th century temperature by natural and anthropogenic forcings. *Science*. 290(5499): 2133–2137.
- Tercek, Michael et al. 2010. Bottom-up factors influencing riparian willow recovery in YNP. *Western North American Naturalist*. In press.
- U.S. Climate Change Science Program. 2008. The Effects of Climate Change on Agriculture, Land Resources, Water Resources, & Biodiversity in the United States. www.sap43.ucar.edu
- Weart, Spencer. 2003. The Discovery of Global Warming. Harvard University Press/Cambridge, MA.
- Westerling, A. L. et al. 2006. Warming and earlier spring increase western U.S. forest wildfire activity. *Science*. 313(5789): 940–943.
- Whitlock, Cathy et al. 2007. A 2650-year-long record of environmental change from northern Yellowstone National Park based on a comparison of multiple proxy data. *Quaternary International* (author's proof).
- et al. 1995. Stability of Holocene Climate Regimes in the Yellowstone Region Quaternary Research. 43: 433–436.
- 1993. Postglacial vegetation and climate of Grand Teton and Southern Yellowstone national parks *Ecological Monographs*. 63(2):173–198.
- and Patrick Bartlein. 1993. Spatial Variations of Holocene Climatic Change in the Yellowstone Region. *Quaternary Research*. 39:231–238.
- Northern Range
Staff reviewer: P.J. White, Supervisory Wildlife Biologist
- Houston, D.B. 1982. The Northern Yellowstone Elk: Ecology and Management. New York: Macmillan Publishing Co.
- Huff, D. E. and J.D. Varley. 1999. Natural regulation in Yellowstone National Park's Northern Range. *Ecol. Appl.* 9(1):17–29.
- Krauseman, P. R. 1998. Conflicting views of ungulate management in North America's western national parks. *Wildlife Soc. Bull.* 26(3): 369–371.
- National Research Council. 2002. Ecological Dynamics on Yellowstone's Northern Range. Washington: National Academy Press.
- Yellowstone National Park 1997. Yellowstone's Northern Range: Complexity and Change in a Wildland Ecosystem. NPS: Mammoth, WY.
- Staff reviewers**
Kevin Schneider, Acting Chief, Yellowstone Center for Resources;
Roy Renkin, Vegetation Management Specialist; P.J. White, Supervisory Wildlife Biologist
- Sustainability**
www.nps.gov/yell
www.ypf.org
- Staff reviewers**
Jim Evanoff, Mary Murphy
- Wilderness**
www.wilderness.nps.gov
www.wilderness.net
www.LNT.org
National Park Service. 1972. Wilderness Recommendation: Yellowstone National Park.
National Park Service. 2003. NPS Annual Wilderness Report 2002–2003.
Wilderness Act of 1964. U.S. Code, 16: 1131–1136.
Wilderness Preservation and Management: NPS Reference Manual 41.
- www.nps.gov/policy/DOrders/RM41.doc
- Winter Use**
Staff reviewer:
Wade Vagias, Management Assistant
- Bishop, Gary A., et al. August, 2009. Portable Emission Measurements of Yellowstone Park Snowcoaches and Snowmobiles. *J Air & Waste Management Association* 59: 936–942.
- Bisseger, Jeffrey. 2005. Snowmobiles in Yellowstone: Conflicting Priorities in Setting National Parks Policy and the Paradox of Judicial Activism for Recreational Business. *J Land, Resources, & Enviro. Law*. 25:109–118.
- Borkowski, J.J. et al. 2006. Wildlife responses to motorized winter recreation in Yellowstone National Park. *Ecol. App.* 16:1911–1925.
- Bruggerman, J.E. et al. 2006. Temporal variability in winter travel patterns of Yellowstone bison: the effects of road grooming. *Ecol. App.* 16:1539–1554.
- Burson, Shan. 2009. Natural Soundscape Monitoring in Yellowstone National Park December 2008–March 2009. www.nps.gov/yell/parkmgmt/upload/10_2009_winter_sound-scape_monitoring.pdf
- Dustin, Daniel L. and Ingrid E. Schneider. 2005. The Science of Politics/The Politics of Science: Examining the Snowmobile Controversy in Yellowstone National Park. *Environmental Mgt.* 34:761–767.
- Freimund, Wayne, et al. 2009. Winter Experiences of Old Faithful Visitors in Yellowstone National Park. www.nps.gov/yell/parkmgmt/upload/8_2009final_winter_experiences.pdf
- Layzer, Judith. 2006. The Environmental Case: Translating Values into Policy. Washington: CQ Press.
- Yochim, Michael J. 2009. Yellowstone and the Snowmobile: Locking Horns over National Park Use. Lawrence: UPress Kansas.

Staff reviewers

Ivan Kowski, Backcountry
Program Manager; Dan Reinhart,
Supervisory Resource Mgt.
Specialist

Wolf Restoration

- Bangs, E. E., and S. H. Fritts. 1996. Reintroducing the gray wolf to central Idaho and YNP. *Wildlife Soc. Bull.* 24(3):402–413.
- Bangs, Edward et al. 2001. Gray wolf restoration in the northwestern U.S. *Endangered Species Update.* 18(4):147–152.
- Carbyn, Ludwig et al. 1995. Ecology and Conservation of Wolves in a Changing World. Edmonton: U. Alberta.
- Creel, S. et al. 2002. Snowmobile activity and glucocorticoid stress responses in wolves and elk. *Cons. Biology.* 16(3): 809–814.
- Eberhardt, L.L. et al. 2003. Assessing the impact of wolves on ungulate prey. *Ecol. App.* 13(3): 776–783.
- Ferguson, Gary. 1996. *The Yellowstone Wolves: The First Year.* Helena, MT: Falcon Press.
- Fischer, Hank. 1995. *Wolf Wars.* Helena, MT: Falcon Press.
- Fritts, S.H. 2000. Review of Carnivores in Ecosystems: the Yellowstone Experience. *Ecology.* 81(8): 2351–2352.
- Gunther, K. A. and D.W. Smith. 2004. Interactions between wolves and female grizzly bears with cubs in YNP. *Ursus.* 15(2):232–238.
- Halfpenny, James C. 2003. *Yellowstone Wolves: In the Wild.* Helena, MT: Riverbend Press.
- Kauffman, M.J. et al. 2007. Landscape heterogeneity shapes predation in a newly restored predator-prey system. *Ecology Letters.* 10:1–11.
- Lopez, Barry. 1978, 2004. *Of Wolves and Men.* New York: Scribners.
- MacNulty, D.R. and L.D. Mech, D.W. Smith. 2007. A proposed ethogram of large-carnivore predatory behavior, exemplified by the wolf. *J Mammalogy.* 88:595–605.
- MacNulty, D.R. et al. 2001. Grizzly bear usurps bison calf captured by wolves in YNP. *Can. Field Nat.* 115:495–498.
- McIntyre, Rick, ed. 1995. *War against the Wolf: America's Campaign to Exterminate the Wolf.* Stillwater, MN: Voyageur Press.
- McIntyre, Rick. 1993. *A Society of Wolves: National Parks and the Battle over the Wolf.* Stillwater, MN: Voyageur.
- Mech, L. David et al. 2001. Winter severity and wolf predation on a formerly wolf-free elk herd. *J. Wildlife Mgt.* 65(4):998–1003.
- Peterson, R.O. et al. 2002. Leadership behavior in relation to dominance and reproductive status in gray wolves, *Canis lupus.* *Can. J. Zool.* 80:1405–1412.
- Phillips, Michael K. and Douglas W. Smith. 1998. Gray wolves and private landowners in the GYA. *Trans. 63rd North American Wildlife and Natural Resources Conference.*
- Phillips, Michael K. and Douglas W. Smith. 1996. *The Wolves of Yellowstone.* Stillwater, MN: Voyageur Press.
- Ruth, T.K. 2000. Cougar–wolf interactions in Yellowstone National Park: Competition, demographics, and spatial relationships. *Wildlife Conservation Society.* August:1–28.
- Smith, D. W. 2005. Meet five, nine, and fourteen: Yellowstone's heroine wolves. *Wildlife Conservation.* 108(1):28–33.
- Smith, D.W. 2005. Ten years of Yellowstone Wolves. *Yellowstone Science.* 13(1):7–33.
- Smith, D.W. and Gary Ferguson. 2005. *Decade of the Wolf: Returning the Wild to Yellowstone.* Guilford, CT: Lyons.
- Smith, Douglas and Michael K. Phillips. 2000. *Northern Rocky Mountain wolf in Endangered Animals.* Greenwood Press.
- Smith, Douglas et al. *Yellowstone Wolf Project Annual Report.* Annual.
- Smith, Douglas et al. 2004. Winter prey selection and estimation of wolf kill rates in YNP. *J Wildlife Mgt.* 68(1): 153–166.
- Smith, Douglas et al. 2003. *Yellowstone after wolves.* BioScience. April, 53(4): 330–340.
- Smith, Douglas et al. 2001. Killing of a bison calf by a wolf and four coyotes in YNP. *Can. Field Nat.* 115(2): 343–345.
- Smith, Douglas et al. 2000. Wolf–bison interactions in YNP. *J Mammalogy.* 81(4): 1128–1135.
- Smith, Douglas et al. 1999. Wolves in the GYE: Restoration of a top carnivore in a complex management environment in Carnivores in Ecosystems. New Haven: Yale U. Press.
- Stahler, Daniel R. et al. 2002. The acceptance of a new breeding male into a wild wolf pack. *Can. J. Zool.* 80:360–365.
- U.S. Fish and Wildlife Service. 1994. *Final EIS: The Reintroduction of Gray Wolves to YNP and Central Idaho.*
- Varley, John D. and Paul Schullery. 1992. *Wolves for Yellowstone? A Report to the United States Congress.*
- VonHoldt, B.M. et al. 2008. The genealogy and genetic viability of reintroduced Yellowstone grey wolves. *Molecular Ecology.* 17:252–274.
- Wright, G.J. et al. 2006. Selection of northern Yellowstone elk by gray wolves and hunters. *J Wildlife Management.* 70:1070–1078.

Staff reviewer

Douglas W. Smith, Senior Wildlife
Biologist

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.



U.S. Department of the Interior
National Park Service

Yellowstone National Park



YELLOWSTONE
ASSOCIATION



000902

\$14.95